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Impact of Land Use Change on Flood Vulnerability of Agricultural Land and Livelihoods to Support Sustainable Development Goals (SDGs)

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ABSTRACT

Flooding remains one of the most recurrent natural hazards, posing serious threats to agricultural land, food production systems, and rural livelihoods, particularly in rapidly urbanizing regions of developing countries. Understanding land use and land cover dynamics is therefore essential for assessing flood vulnerability and supporting sustainable agricultural land management. This study examines the impact of land use change on flood vulnerability of agricultural land and livelihoods in Suleja Local Government Area, Niger State, Nigeria. Multi-temporal satellite imagery was analyzed using Geographic Information Systems and remote sensing techniques to identify major land use categories and their changes over time. Supervised classification was applied to assess spatial patterns of land transformation. The findings indicate a significant expansion of built-up areas accompanied by a decline in agricultural and natural land covers, which has increased surface runoff and flood exposure on agricultural landscapes. These changes have heightened the vulnerability of livelihood systems dependent on land-based activities. The study underscores the importance of land use zoning and flood-sensitive agricultural planning to enhance resilience and promote sustainable food production in flood-prone environments. This study supports Sustainable Development Goals (SDGs).

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1. INTRODUCTION

The frequency and severity of weather-related events such as floods are undoubtedly rising (Meresa *et al*., 2021), driven largely by rapid urbanization and the increasing impacts of climate change on hydrological systems (Li *et al*., 2022). Projections indicate that climate change will continue to exert adverse effects on rainfall patterns, runoff processes, and flood risks, particularly in regions with fragile environmental and land management systems (Meresa *et al*., 2021). Floods remain among the most destructive natural hazards worldwide, affecting human lives, agricultural land, and food production systems while causing substantial economic losses. These impacts are often more pronounced in developing countries due to limited technical capacity, weak land use planning, insufficient awareness of flood hazards, and inadequate preparedness and coping mechanisms (Nkwunonwo, 2020).

Flood disasters are widely recognized as the most recurrent and destructive hazards globally. Consequently, understanding historical flood patterns and land use dynamics has become increasingly important for improving adaptation strategies and mitigating future risks, especially in agriculturally dependent regions (Smith *et al*., 2019; Feliciano *et al*., 2022). Recent extreme flood events, such as those triggered by cyclones Idai and Kenneth, have resulted in severe human and economic losses and have further highlighted the vulnerability of land-based livelihood systems in regions with limited adaptive capacity. In such contexts, floods not only threaten settlements but also disrupt agricultural production through crop loss, soil erosion, and degradation of arable land, thereby undermining food security and rural livelihoods.

In Nigeria, flood events have become increasingly recurrent, with significant impacts on agricultural land and livelihood systems, particularly in the Suleja Local Government Area of Niger State. Located in the central region of Nigeria and characterized by several inland rivers, the area is highly susceptible to flooding. Despite the frequency of flood events, the availability of hydrological records such as river discharge and long-term precipitation data remains limited. Previous studies in the region have largely relied on terrain-based analyses using coarse-resolution datasets, including Shuttle Radar Topography Mission and NigeriaSat imagery, to delineate flood-prone zones (Lamine *et al*., 2021). However, the magnitude and intensity of recent flood events, particularly those recorded in 2017, exceeded earlier occurrences and exposed growing vulnerabilities associated with land use change and expanding built-up areas (Adeleye *et al*., 2019). With a rapidly increasing population and intensified land conversion, a greater proportion of agricultural land and livelihood systems are likely to be exposed to flood risk (Malgwi *et al*., 2021).

Reliable techniques for collecting and analyzing spatial information are essential for identifying flood-prone areas and understanding the relationship between land use dynamics and flood vulnerability. In this regard, the integrated application of Remote Sensing and Geographic Information Systems has proven to be an effective approach for flood hazard assessment, land use monitoring, and agricultural land management. These geospatial tools enable the generation of flood hazard maps that support land use planning, agricultural zoning, and disaster risk reduction strategies in flood-prone environments. Such information is critical for protecting agricultural landscapes, sustaining food production, and enhancing the resilience of communities dependent on land-based livelihoods.

Therefore, this study seeks to address existing gaps by examining the impact of land use change on flood vulnerability and its implications for agricultural land and livelihood systems in Suleja Local Government Area of Niger State, Nigeria. Specifically, the study aims to assess the land use pattern of the study area using geospatial techniques in order to provide

evidence-based insights that can support sustainable land management, flood-sensitive agricultural planning, and improved resilience of food production systems in flood-prone regions. This study supports Sustainable Development Goals (SDGs).

2. METHODS

This study was conducted in Suleja Local Government Area, Niger State, Nigeria, which lies between latitudes 9°6′00″–9°15′00″ N and longitudes 7°5′00″–7°15′00″ E. The geographical location and extent of the study area are illustrated in **Figure 1**. The area is characterized by gently undulating terrain, sandstone-derived soils, and a tropical climate with a pronounced wet season, conditions that contribute to its susceptibility to flooding and land use change. Multi-temporal Landsat satellite imagery for 1993, 2013, and 2023 was obtained from the United States Geological Survey Earth Explorer platform. Details of the satellite data used in the study are presented in **Table 1**. Geographic Information Systems and remote sensing techniques were employed for data processing and analysis using Idrisi TerrSet and ArcMap 10.8. Image preprocessing involved layer stacking, resampling, and enhancement to improve visual interpretation and classification accuracy. Land use and land cover classification was carried out using a supervised maximum likelihood approach based on Anderson Level I classification, with land use categories defined as built-up areas, forest cover, grassland, cropland, bare surface, and water bodies, as summarized in **Table 2**. The classified outputs were analyzed to assess spatial and temporal changes in land use patterns and their implications for flood vulnerability and agricultural land dynamics in the study area.

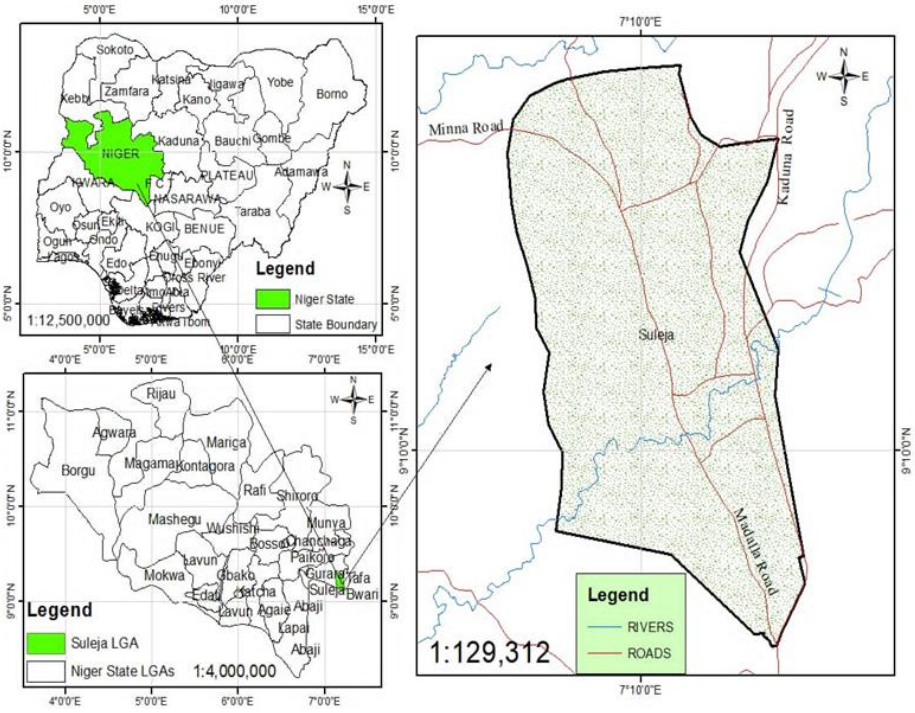

Figure 1. Location of the study area (Suleja Local Government Area, Niger State, Nigeria).

Table 1. Details of Satellite Data Used.

S/N	Sensor	Path/Row	Source	Year of Acquisition	Spatial Resolution (m)
1	TM	189/054	Earth Explorer (USGS)	1993	30
2	ETM+	189/054	Earth Explorer (USGS)	2013	30
3	OLI	189/054	Earth Explorer (USGS)	2023	30

Table 2. Land Use and Land Cover Classes.

S/N	Land Use Class	Description
1	Built-up areas	Settlements and infrastructure consisting of buildings and road networks
2	Forest cover	Areas dominated by tree vegetation
3	Grassland	Areas predominantly covered by grasses
4	Cropland	Land used for agricultural crop production
5	Bare surface	Exposed rock, soil, and sandy surfaces
6	Water bodies	Rivers, streams, and other surface water features

3. RESULTS AND DISCUSSION

The results of the land use and land cover (LULC) analysis for Suleja Local Government Area are presented for three epochs (1993, 2013, and 2023) in order to examine spatial and temporal changes and their implications for flood vulnerability and agricultural land dynamics. The classified LULC maps for the respective years are illustrated in **Figures 2, 3, and 4**, while the quantitative distribution of land use categories is summarized in **Table 3**. These results provide a basis for understanding how land transformation processes have influenced surface characteristics, runoff behavior, and exposure of agricultural land and livelihood systems to flooding.

The 1993 LULC classification shows that cropland was the dominant land use type in the study area, covering a substantial proportion of the total land area (**Figure 2**). This indicates that, during this period, land use was largely oriented toward agricultural production and open land systems. The extensive presence of cropland and grassland suggests relatively higher infiltration capacity and lower surface runoff compared to impervious surfaces. Such land cover conditions generally reduce flood intensity by allowing rainfall to percolate into the soil, thereby moderating overland flow. However, a considerable extent of bare surface was also observed, which may have contributed to localized runoff generation, particularly during intense rainfall events. Built-up areas occupied a smaller portion of the landscape in 1993, reflecting a lower level of urban development and reduced anthropogenic pressure on agricultural land resources.

From an agricultural and flood management perspective, the dominance of cropland in 1993 implies that livelihood systems were closely tied to land-based activities. Flood events occurring during this period would likely have directly affected crop production through inundation of farmlands, soil erosion, and loss of planting materials. These impacts are consistent with observations in flood-prone agricultural regions of developing countries, where land use patterns strongly mediate flood vulnerability and livelihood outcomes (Smith *et al*., 2019; Nkwunonwo *et al*., 2020). The relatively limited extent of built-up areas during this period suggests that natural drainage systems were less obstructed, allowing floodwaters to disperse across open land rather than being concentrated within confined urban channels.

By 2013, noticeable changes in land use patterns had occurred, as shown in **Figure 3**. Grassland emerged as the dominant land cover, while cropland experienced a reduction in spatial extent compared to 1993. At the same time, built-up areas expanded significantly, indicating accelerated urban growth within the study area. This transition reflects increasing population pressure, infrastructure development, and the conversion of agricultural land to residential and commercial uses. The reduction in cropland and forest cover suggests a gradual loss of land that traditionally served as natural buffers against flooding. As vegetation cover declines, soil compaction and reduced infiltration capacity become more pronounced, leading to increased surface runoff during rainfall events.

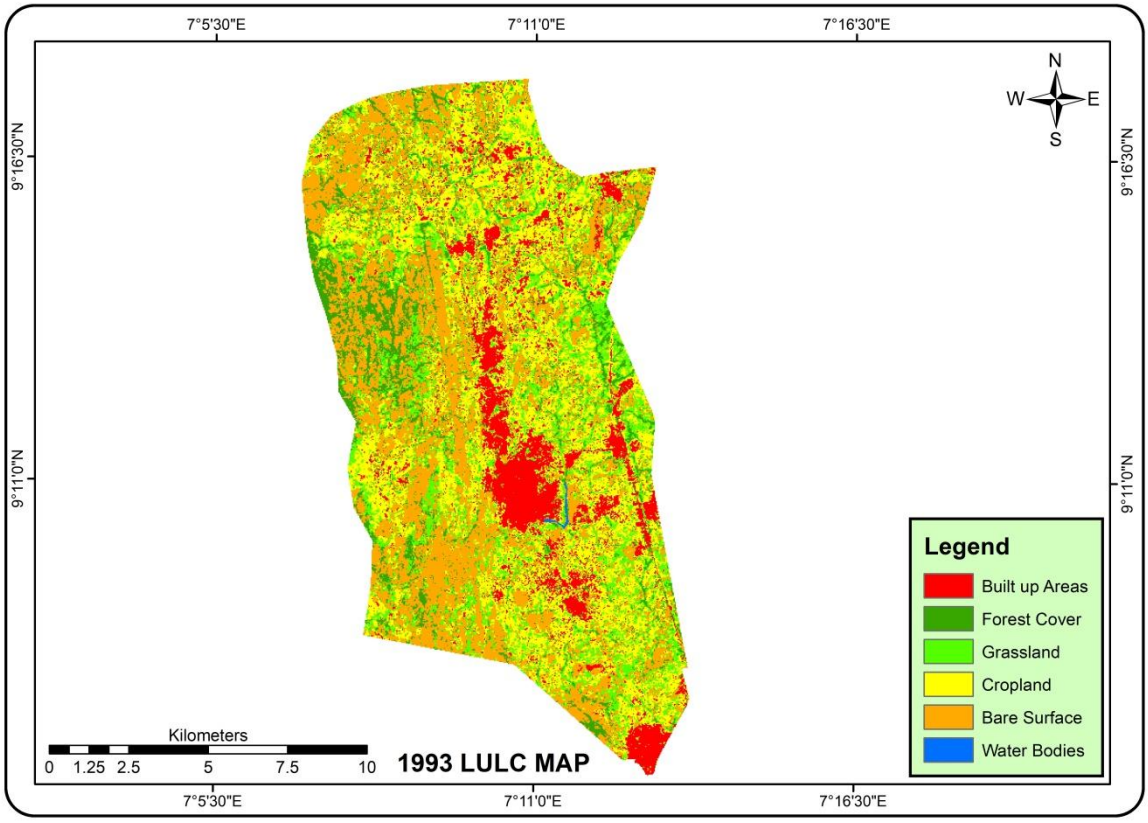

Figure 2. Land use and land cover classification of Suleja Local Government Area in 1993.

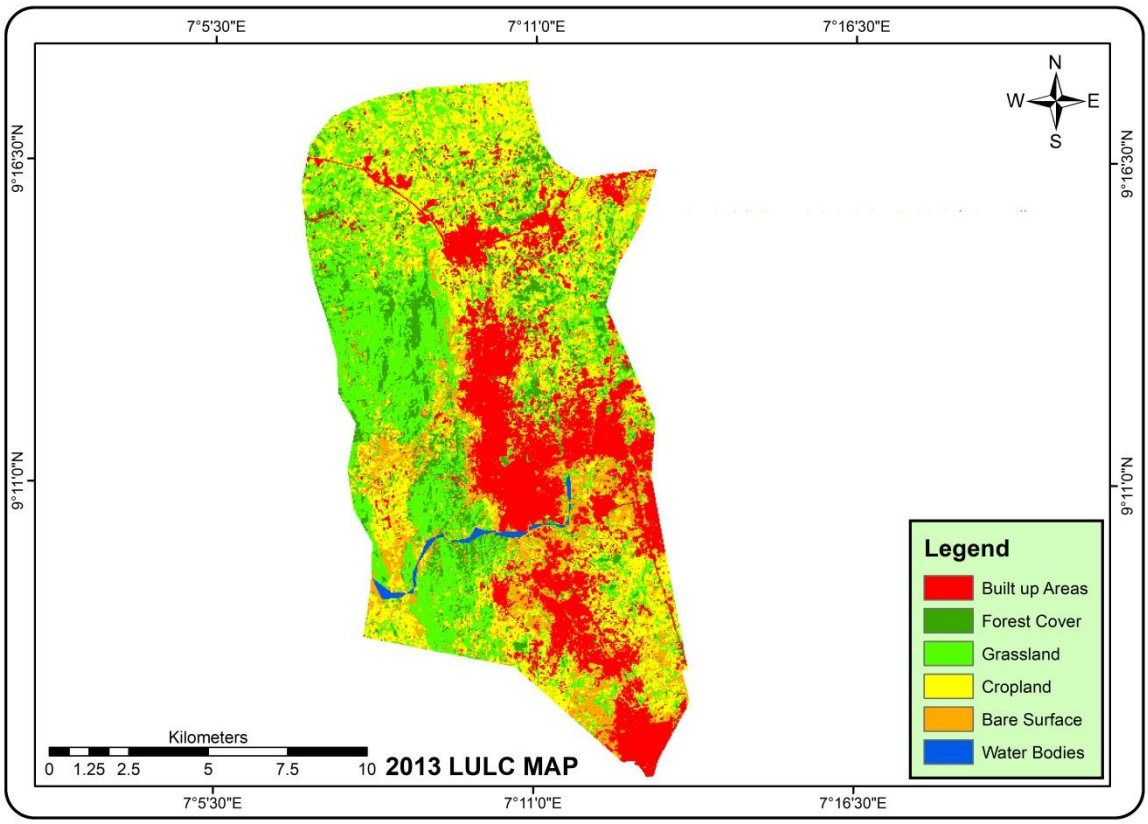

Figure 3. Land use and land cover classification of Suleja Local Government Area in 2013.

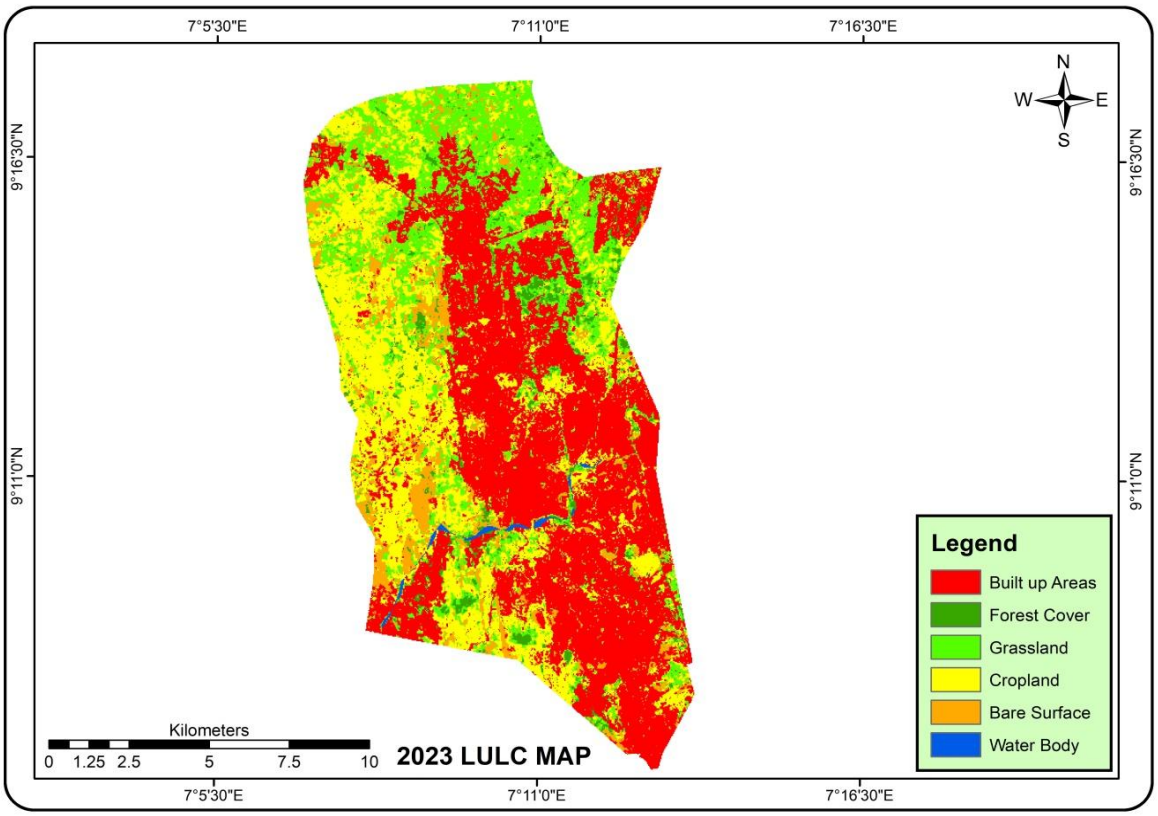

Figure 4. Land use and land cover classification of Suleja Local Government Area in 2023.

Table 3. Land Use and Land Cover Distribution (1993, 2013, and 2023)

Land Use / Land Cover Category	1993 Area (km²)	1993 (%)	2013 Area (km²)	2013 (%)	2023 Area (km²)	2023 (%)
Built-up areas	21.04	11.93	43.04	24.40	77.67	44.06
Forest cover	19.74	11.19	14.89	8.44	5.60	3.18
Grassland	29.30	16.61	48.87	27.70	33.15	18.80
Cropland	54.48	30.88	46.66	26.45	46.34	26.29
Bare surface	51.71	29.31	21.95	12.44	12.86	7.30
Water bodies	0.13	0.07	1.00	0.57	0.65	0.37
Total	**176.39**	**100.00**	**176.41**	**100.00**	**176.28**	**100.00**

The expansion of built-up areas observed in 2013 has important implications for flood vulnerability. Impervious surfaces associated with urban development limit water infiltration and increase the speed and volume of runoff, thereby elevating flood risk in low-lying and downstream areas. In agriculturally dependent communities such as Suleja, this process not only heightens flood exposure but also exacerbates the vulnerability of remaining agricultural land. Farmlands located near expanding urban zones are increasingly exposed to floodwater accumulation, sediment deposition, and contamination from urban runoff. Similar patterns have been reported in other Nigerian cities, where unregulated urban expansion has intensified flood impacts on agricultural and peri-urban land systems (Adeleye *et al*., 2019).

The 2023 LULC classification reveals a further intensification of these trends, with built-up areas becoming the dominant land use type across the study area (**Figure 4**). Cropland and grassland continued to decline, while forest cover reached its lowest extent over the entire study period. This substantial transformation of the landscape represents a critical shift from predominantly agricultural land use to an urban-dominated system. Such changes

significantly alter hydrological processes, increasing flood magnitude and frequency due to reduced storage capacity and disrupted natural drainage pathways (Meresa *et al*., 2021; Li *et al*., 2022).

The quantitative distribution of land use categories across the three epochs, presented in **Table 3**, clearly illustrates the progressive expansion of built-up areas and the corresponding decline of agricultural and natural land covers. This trend has direct consequences for agricultural productivity and livelihood sustainability. As cropland shrinks, farming activities become increasingly concentrated on smaller parcels of land, often located in marginal or flood-prone areas. Consequently, farmers face higher risks of crop loss during flood events, which undermines food security and household income stability. These findings align with previous studies emphasizing the role of land use change in shaping flood vulnerability and agricultural resilience in developing regions (Feliciano *et al*., 2022).

The overall trend of land use and land cover categories from 1993 to 2023 is illustrated in **Figure 5**, highlighting the continuous expansion of built-up areas and the corresponding decline in agricultural and natural land covers.

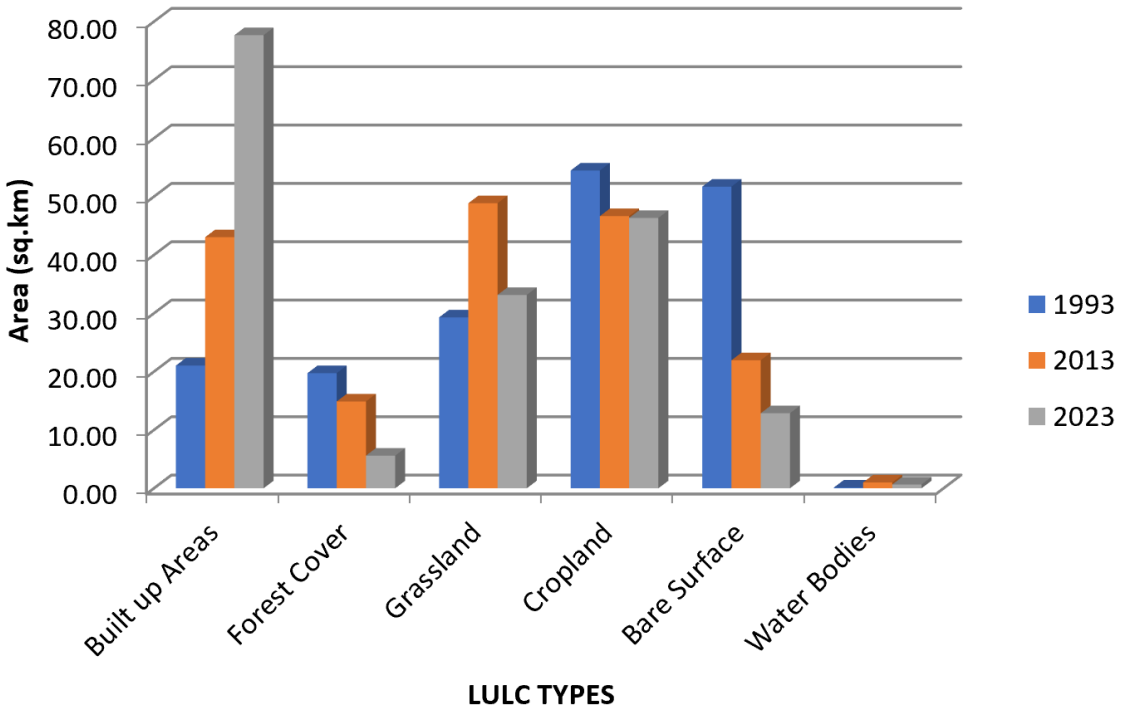

Figure 4. Land use land cover categories (1993, 2013, and 2023)

Furthermore, the decline in forest cover and grassland reduces the landscape's capacity to regulate water flow and stabilize soils. Vegetation loss accelerates erosion processes, leading to sedimentation of rivers and drainage channels, which further increases flood susceptibility. In the context of Suleja, where hydrological data are limited, and flood management infrastructure is insufficient, land use change becomes a dominant driver of flood risk (Lamine *et al*., 2021). The observed land transformation, therefore, reflects not only urban growth but also a weakening of natural systems that support agricultural production and flood mitigation.

Overall, the results demonstrate that land use change in Suleja has followed a trajectory that intensifies flood vulnerability while simultaneously constraining agricultural land availability. The increasing dominance of built-up areas has reshaped surface characteristics, altered runoff dynamics, and heightened exposure of land-based livelihood systems to

flooding. These patterns underscore the need for integrated land use planning that balances urban development with the protection of agricultural land and flood-regulating ecosystems. Without such interventions, continued land conversion is likely to exacerbate flood impacts on food production systems and rural livelihoods, particularly under projected climate variability.

The observed land use transitions in Suleja have broader implications for agricultural sustainability and flood risk management. As shown by the progressive increase in built-up areas and the corresponding decline in cropland and natural vegetation (**Figures 2–4** and **Table 3**), land conversion has altered the balance between impervious and permeable surfaces across the landscape. This imbalance intensifies hydrological responses to rainfall, increasing peak runoff and reducing the capacity of the land to absorb excess water. In agricultural settings, such changes directly affect soil moisture dynamics, crop resilience, and the stability of farming systems. Croplands located near urbanized zones are particularly vulnerable, as floodwaters originating from impervious surfaces often accumulate on adjacent agricultural land.

The reduction of forest cover and grassland further exacerbates flood vulnerability by diminishing the ecological functions that regulate water flow and protect soil structure. Vegetation plays a critical role in intercepting rainfall, enhancing infiltration, and stabilizing soils against erosion. Its removal increases sediment yield, which can clog drainage channels and riverbeds, thereby reducing channel capacity and amplifying flood risk. In Suleja, where flood management infrastructure remains limited, these land cover changes represent a significant challenge for both agricultural production and livelihood security. Similar observations have been reported in other flood-prone regions of Nigeria, where land degradation and unregulated development have weakened natural flood mitigation mechanisms (Adeleye *et al*., 2019; Nkwunonwo *et al*., 2020).

The implications of these findings extend beyond physical flood processes to encompass socioeconomic dimensions of livelihood vulnerability. Agriculture remains a key source of income and food for many households in the study area. As cropland decreases and flood exposure increases, farmers face heightened risks of crop failure, reduced yields, and income instability. Flood-induced crop losses can disrupt planting cycles, damage stored produce, and increase production costs, thereby undermining household food security. These challenges are compounded by limited access to insurance, credit, and technical support, which restricts farmers' ability to recover from flood impacts. Consequently, land use change emerges as both an environmental and socioeconomic driver of vulnerability in Suleja.

Climate variability further amplifies these risks. Changes in rainfall intensity and distribution, as projected under climate change scenarios, are expected to increase the frequency of extreme precipitation events and associated flooding (Meresa *et al*., 2021; Li *et al*., 2022). When combined with expanding urban areas and shrinking agricultural land, these climatic pressures create a compounding effect that heightens flood impacts on farming systems. The interaction between land use change and climate variability underscores the importance of adopting integrated land and water management strategies that address both current and future flood risks.

The spatial patterns revealed by the LULC maps (**Figures 2–4**) indicate that agricultural land is increasingly fragmented and constrained by urban expansion. Such fragmentation limits farmers' flexibility in crop rotation, land management, and adaptation strategies. It also increases competition for land resources, often pushing agricultural activities into marginal areas that are more prone to flooding. This process not only reduces agricultural productivity but also increases exposure to environmental hazards, reinforcing cycles of vulnerability and

poverty. These findings are consistent with broader assessments of flood exposure in developing regions, which highlight the role of land use dynamics in shaping risk distribution (Smith *et al*., 2019).

The results also have important implications for land use planning and policy. The continued expansion of built-up areas observed in Suleja reflects inadequate enforcement of land use regulations and limited consideration of flood risk in urban development decisions. Floodplain encroachment, conversion of agricultural land, and loss of vegetative cover collectively undermine the resilience of both urban and rural systems. Effective land use zoning that restricts development in flood-prone areas and protects agricultural land is therefore essential. Such measures can reduce flood exposure while preserving land resources critical for food production and livelihood sustainability.

Incorporating flood-sensitive land use planning into agricultural development strategies is particularly important in rapidly urbanizing regions like Suleja. This includes promoting the conservation of forest cover and grassland, encouraging sustainable farming practices that enhance soil infiltration, and integrating green infrastructure into urban landscapes. These approaches align with broader recommendations for reducing flood risk while minimizing environmental and food system impacts in the context of climate change (Feliciano *et al*., 2022). By maintaining functional ecosystems within and around agricultural areas, it is possible to mitigate flood impacts and support long-term agricultural productivity.

The findings of this study also highlight the value of remote sensing and GIS techniques for monitoring land use change and informing flood risk management. In data-scarce environments such as Suleja, where hydrological records are limited, spatial analysis provides critical insights into landscape dynamics and vulnerability patterns (Lamine *et al*., 2021). The integration of multi-temporal satellite data enables the identification of trends that may not be apparent from short-term observations, supporting evidence-based decision-making for land and water management.

Overall, the results demonstrate that land use change in Suleja has progressively increased flood vulnerability while constraining agricultural land availability and resilience. The dominance of built-up areas, coupled with declining cropland and vegetation cover, has reshaped hydrological processes and intensified risks to land-based livelihoods. Addressing these challenges requires coordinated efforts that integrate land use planning, agricultural management, and flood risk reduction. Without such interventions, continued land conversion and climate variability are likely to further exacerbate flood impacts on food production systems and rural livelihoods in the study area. Finally, this study supports SDGs.

4. CONCLUSION

This study demonstrates that land use and land cover change in Suleja Local Government Area have significantly influenced flood vulnerability and the sustainability of agricultural land and livelihood systems. The spatio-temporal analysis reveals a continuous expansion of built-up areas accompanied by a decline in cropland, forest cover, and grassland over the study period. These changes have altered surface characteristics and hydrological processes, leading to increased surface runoff and heightened exposure of agricultural landscapes to flooding. The reduction of vegetative cover and agricultural land has weakened the natural capacity of the environment to regulate water flow and protect soils, thereby intensifying flood impacts on farming activities and land-based livelihoods. The findings highlight that unregulated urban expansion and inadequate land use planning are key drivers of flood vulnerability in the study area. To enhance agricultural resilience and reduce flood risk, the

study underscores the need for flood-sensitive land use zoning, protection of agricultural land, and integrated land management strategies that balance urban development with environmental sustainability and food production needs. This study supports SDGs.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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