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Spatio-Temporal Dynamics of Riparian Land Use/Land Cover and Its Effects on Channel Morphology Along Dasin Hausa-Jimeta Reach of River Benue in Adamawa State, Nigeria.

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***Abstract-** This study examines the spatio-temporal dynamics of riparian land use/land cover (LULC) changes and their implications for channel morphology along the Dasin Hausa–Jimeta reach of River Benue in Adamawa State, Nigeria. Multi-temporal satellite data for the years 1992, 2005, 2015, and 2025 were analyzed using geospatial techniques to quantify changes in key land use classes, including water bodies, sandbars, grassland/shrub, bare surfaces, riparian vegetation, built-up areas, and agricultural land. The results reveal a significant transformation of the riparian landscape over the 33-year period, characterized by a substantial increase in agricultural land from 40.0% to 71.9% and built-up areas from 0.8% to 3.2%. Conversely, natural vegetation types, particularly grassland/shrub and riparian vegetation, declined drastically by 22.11% and 6.94%, respectively. Sandbar expansion (+0.63%) and a reduction in water bodies (−0.36%) were also observed, indicating active geomorphological adjustments within the river channel. The findings suggest that intensified agricultural activities and human encroachment into riparian zones have accelerated soil erosion and sediment transport, leading to increased sediment deposition and channel instability. These processes have contributed to observable changes in channel morphology, including sandbar formation and potential alterations in flow regimes. The study underscores the strong linkage between land use changes and fluvial processes, highlighting the need for sustainable riparian management strategies to mitigate environmental degradation and preserve channel stability. It is recommended that riparian buffer zones be enforced and integrated land use planning be adopted to ensure the long-term sustainability of the river system.*

***Index Terms-** Land Use/Land Cover (LULC), Riparian Zone, Channel Morphology, Remote Sensing, GIS Analysis, River Benue.*

I. INTRODUCTION

Riparian zones are dynamic transitional environments that connect terrestrial and aquatic ecosystems. They play critical roles in maintaining ecological balance, regulating sediment transport, stabilizing riverbanks, and supporting biodiversity. These zones are highly sensitive to both natural processes and anthropogenic disturbances. Riparian zones are the transitional areas between the aquatic and the terrestrial environment (Betz *et al.,* 2018). They encompass the space between flowing water at low levels and the highest watermark where vegetation is influenced by floods, elevated water tables, and soil type (González *et al.,* 2017). Riparian zones comprise riverbed, banks, vegetation, adjacent land and the floodplain (Maraseni and Mitchel, 2016). A riparian corridor encompasses sharp environmental gradients, ecological processes and communities (Naiman *et al.,* 1993). The width and functional attributes of a riparian zone are affected by stream size, stream position in drainage system, hydrology and geomorphology (Naiman and Décamps, 1997; Maruani and Amit-Cohen, 2009). Hydrology is the powerful factor that regulates structural and functional aspects of riparian zones (Mitsch and Gosselink, 2007; Ye *et al.,* 2017).

Land use/land cover (LULC) change is a major driver of environmental transformation, particularly in riverine ecosystems where human activities directly influence hydrological and geomorphological processes (Stieger and McKenzie, 2024). Riparian zones, which serve as transitional interfaces between terrestrial and aquatic environments, play critical roles in maintaining river health, including bank stabilization, sediment regulation, and biodiversity conservation (Pedraza *et al.,* 2021; Graziano *et al.,* 2022).

In recent decades, increasing population pressure and agricultural expansion in developing regions such as Nigeria have intensified the conversion of natural landscapes into cultivated and built-up areas (Stieger and McKenzie, 2024). These changes often result in vegetation loss, increased surface runoff, and enhanced soil erosion, all of which significantly impact river channel morphology (Stutter *et al.,* 2019; Feld *et al.,* 2018).

Globally, land use/land cover (LULC) change has emerged as a major driver of environmental degradation. In developing countries such as Nigeria, rapid population growth, agricultural expansion, and urban development have intensified pressure on riparian environments. These changes often result in vegetation loss, increased erosion, sedimentation, and alteration of hydrological regimes. Changes in land use and land cover therefore, predates history and are the direct and indirect consequences of human actions to secure essential resources (Zhao and Pitman, 2002). Over the past decades, one-third of the global land use has been changed either once or on multiple occasions (Winkler *et al.,* 2021). The dynamicity of Land Use and Land Cover change has triggered issues related to environmental, ecosystem, water, food security, climate change, etc. (Song et al., 2018; Winkler *et al*., 2021). The land use/land cover science includes characterization of land cover and land use and quantification of their changes and their consequences. Drivers of these changes are either natural, such as climate variability and change, or anthropogenic, such as socio-economic or political (Roy and Roy, 2010). Land use/land cover changes impact a river basin from various perspectives have been studied (Chin, 2006), including runoff and water availability (Wang *et al.,* 2017), discharge (Petchprayoon *et al.,* 2010), water yield (Geng *et al.,* 2015), headwater fluvial (Harden, 2006), morphology and structure (Kudnar, 2020; Yousefi *et al.,* 2019) and dam construction (WWF, 2004). River Benue is one of the major river systems in Nigeria and west Africa and plays a vital role in supporting livelihoods, agriculture, and ecosystem services. However, increasing human activities along its banks have significantly altered its riparian landscape through conversion of natural vegetation into agricultural and built-up areas which are heavily driven by human activity rather than natural forces. Despite its importance, there is limited comprehensive analysis of long-term LULC dynamics within its riparian corridor. Therefore, this study aims to assess the Spatio-temporal changes in riparian land use/land cover (LULC) and its effects along the Dasin Hausa-Jimeta reach of the river over a 34-year period (1992–20225).

II. STUDY AREA

The study area is a reach along the River Benue in Adamawa State, Nigeria stretching to a distance of about 57 km and covered 22556 km^2 of the riparian zone from both sides of the river bank extending from Dasin Hausa in Fufore Local government to Jimeta Bridge in Yola North Local government. The area lies between latitude 9° 10' 00" N to 9° 25' 00" N and longitude 12° 27' 00" E and 12° 51' 00" E and on an average altitude of 286m (Figure 1 and 2).

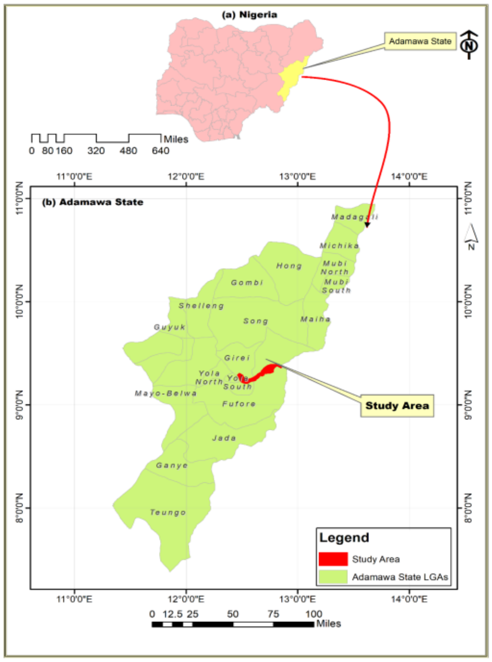

Figure 1: Adamawa State Showing Reach of the River Benue in the study area

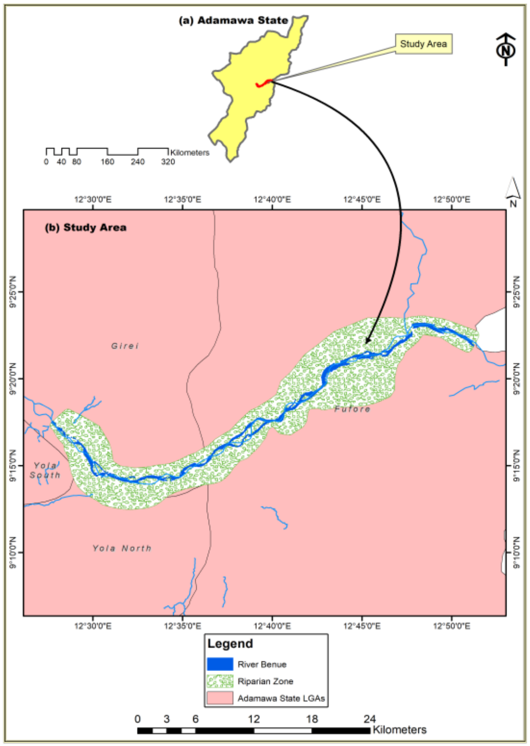

Figure 2: Dasin Hausa-Jimeta Reach of a River Benue in Adamawa State, Nigeria Showing the Study Area.

The reach is characterized by undulating floodplains in the south and west and sedimentary rocks of clastic group which could be clean having silica cement, matrix rich greywacke and the arkosic type. The main drainage system in the study area is the River Benue which flows within a depression less than 150 meters above mean sea level. The river is characterized by sand bars (within the channel) and point bars along the channel banks, thus changing the plan form of the river and the Benue River flows all year round with the peak in the month of august to October in the wet season. The reach lies within the Sudan savannah zone which is marked with a tropical climate that is characterized by dry and wet seasons. The dry season commence in November and ends by March while the raining season commence in April and ends in October. Climate is the most important cause of flood in the study area, as the climate change high amount of rainfall is recoded at the upper course of the river and lead to inundation of the floodplains. The temperature is generally high throughout the year with maximum temperature fluctuating between 33°C and 41°C (Figure 3). The rainy season last for about seven months with mean annual rainfall of 800mm to 1000mm, whereas 1260.1mm of rainfall was recorded in 2016 (UBRBDA, 2016) which is the highest in 34 years from 1992 to 2025 (Figure 4). The pronounced seasonality is critical to understanding the irrigation dynamic that emerged from the LULC analysis: during the dry season, rainfall is insufficient for crop cultivation, creating strong economic demand for river water abstraction.

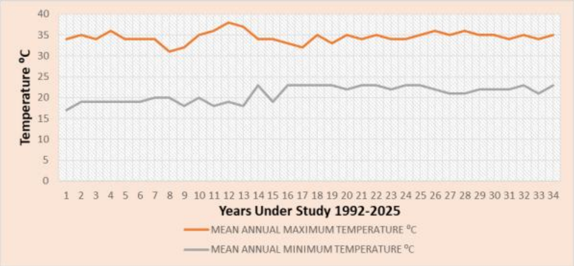

Figure 3: Mean Annual Maximum and Minimum Temperatures

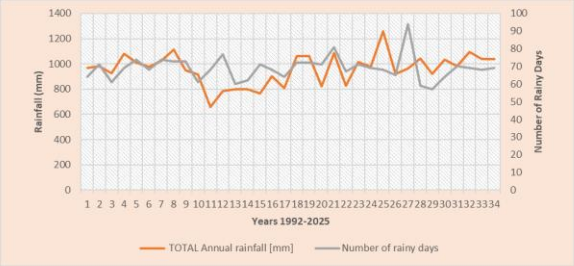

Figure 4: Total Annual Rainfall and Number of Riny Days

The area falls within the northern Guinea savannah (Akosim, *et'al.,* 1999). It is characterized by short grasses interspersed with few trees. The vegetation is of secondary successions due to the activities of man which have altered the natural vegetal cover. The vegetation usually changes seasonally; it appears green and fresh in rainy season but turn yellowish brown and patches with the ushering of dry season. However, the study area is characterized by low vegetation cover and less infiltration capacity and this led to inundation of floodplains during the rainy season. Vegetation along the riparian corridors of the Benue system corresponds to the local vegetation of the area within which the river traverses. However, along the banks of the river Benue is an extension of grassland area which is mainly used as range lands.

The indigenous vegetation was replaced by a secondary vegetation mainly ornamental and economic trees such as Mango plantation, Afzelia*africana*,Khaya*seneglensis* Annona *senegalensis*, Burkia*african*a Eucalyptus spp and Neem (*Azadirachta Indica*) e.t.c and grasses such as *Andropogon, Bracharia* and*Aristida*.e.t.c. The increasing reliance on biomass as the source of house hold energy and expansion of agricultural land use and urban development have led to the clearance of the vegetation which invariable exposes the soil to erosion, increases the run off and the large volume of sediments are washed into the river; thereby altering the morphology and hydrology of the river (Bashir, 2015).

The distributional pattern of discharge regime from Dasin Hausa and Yola Stations shows a variation in the distribution with the discharge in Dasin Hausa ranging from 1500m^3/s in 1990 which is the lowest discharge recorded Dasin Hausa station and 6800m^3/s in 2012 which is the highest discharge recorded at Dasin Hausa station while in Yola Station the pattern of discharge regime shows a variation in the distribution with discharge ranging from 2215m^3/s in 2019 which is the lowest within the study period and 7040m^3/s in 1999 which is the highest discharge recorded in Yola station in 34 Years (Figure 5).

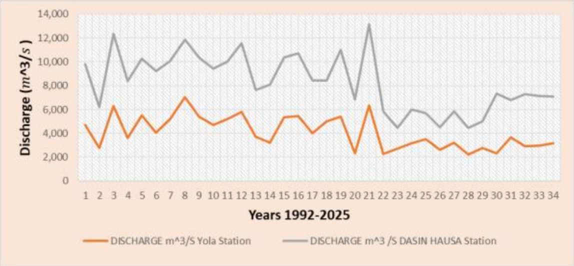

Figure 5: Total Annual Discharge (m^3/s) for Dasin Hausa and Yola Stations.

The riverbed consists primarily of sand and fine gravel, with exposed sandbars forming during the dry season when water levels recede by two to three meters below wet-season highs. These dry-season low-flow conditions are precisely when irrigated agriculture is most active, as receding water levels expose pump intakes and create accessible river margins for cultivation.

III. MATERIALS AND METHODS

Data and Sources

The data for land use/land cover analysis was collected from USGS and Landsat Level-2 surface reflectance products from Google Earth Engine for four epochs corresponding to the study years. A supervised classification of the satellite imageries of 1992, 2005, 2015 and 2025 were analyzed and seven classes of data were generated for analysis and they are; water body, sandbars, bare surfaces, riparian vegetation, shrubs/grassland, Buildup areas and Agricultural lands. All images were acquired during the dry season from January to March to minimize cloud cover and to expose sandbars for accurate classification. Dry-season acquisition is also critical for the detection of irrigated agriculture. During the dry season, rainfed fields are fallow and appear spectrally similar to grassland or bare ground, with low NDVI values. Irrigated fields, by contrast, maintain photosynthetic activity and appear green with high NDVI values. This spectral difference; green, high-NDVI vegetation adjacent to the channel during the dry season served as a diagnostic indicator of irrigation that was used in training polygon selection and in the interpretation of classification results.

Methods of Data Analysis

Unsupervised classification was used for land use/land cover analysis. This was conducted on 1992, 2005, 2015 and 2025 satellite images. The Satellite data comprising of four different multi-temporal imageries: Landsat 5 Thematic Mapper TM (1992) from LT05/C02/T1 collection, Landsat 7 Enhanced Thematic Mapper Plus (2005) from LE07/C02/T1 collection, Landsat 8 Operational Land Imager 1 (2015) from LC08/C02/T1 collection, Landsat 9 Operational Land Imager-2 (2025) from LC09/C02/T1collection were used. The Landsat imagery dataset was sourced from the Earth explorer platform from United States Geological Surveys (USGS). Changes in land cover were measured using time series of remotely sensed data (Landsat TM and OLI). Table 1 gives a summary of the image characteristics for the dataset used. Dry season images of the four data sets were acquired from January to March in order to reduce the effects of clouds that are prevalent during the rainy season. The ground truth data was in the form of reference points collected using Geographical Positioning System (GPS), high resolution Google earth images were also used to aid in classification and overall accuracy assessment of the classification results.

The Pre-processing of satellite images before detection of changes is a very vital procedure and has a unique aim of building a more direct association between the biophysical phenomena on the ground and the acquired data were preprocessed in ERDAS imaging for band combination and sub-setting of the image on the basis of Area of Interest (AOI). The pre-processing included cloud masking using the QA_PIXEL band, which identifies pixels contaminated by clouds, cloud shadows, and cirrus. Median compositing over the dry season window (January to March) was applied to reduce atmospheric and phenological noise while preserving the dominant land cover signal. Spectral indices were calculated including the Normalized Difference Vegetation Index (NDVI) for vegetation greenness, the Modified Normalized Difference Water Index (MNDWI) for water body enhancement, the Bare Soil Index (BSI) for exposed sediment detection, and a Sandbar Index specifically designed to distinguish exposed bars from water and vegetation. The simple composite algorithm available in Google Earth Engine was applied to minimize residual cloud and shadow contamination following the method of Roy *et al.,* (2014).

The main objective of image classification is to place all pixels in an image into land use land cover classes in order to draw out useful thematic information**.** Image classification was done in order to assign different spectral signatures from the Landsat datasets to different land use/land cover. This was done on the basis of reflectance characteristics of the different land use/land cover types. Different color composites were used to improve visualization of different objects on the imagery. Infrared color composite NIR (4), SWIR (5) and Red (3) was applied in the identification of varied levels of vegetation growth and in separating different shades of vegetation. Other color composites such as Short Wave Infra-red (7), Near Infra-red (4) and Red (2) combination which are sensitive to variations in moisture content were applied in identifying the built-up areas and bare soils. This was supplemented by a number of field visits and use of goggle earth software that made it possible to establish the main land use/land cover types. For each of the predetermined land use land cover type, training samples were selected by delineating polygons around representative sites. Spectral signatures for the respective land use land cover types derived from the satellite imagery were recorded by using the pixels enclosed by these polygons. A satisfactory spectral signature is the one ensuring that there is 'minimal confusion' among the land covers to be mapped (Gao and Liu, 2010). The class categories generated are buildup areas, dry arable land, forest/mountain vegetation, riparian vegetation/crop land, sand bars/ dry surfaces, shrubs/grassland and water bodies. The seven classes generated gives an insight on the existing land use/land cover of the entire study area.

Table 1: Satellite Image Characteristics

Landsat series	Collection	Sensor	Spatial resolution (m)	Wave length range(µm)	Selected bands	Acquisition date	Source
5	LT05/C02/T1	TM	30	0.45 - 0.90	1-4	13th Jan, 1992	USGS
7	LE07/C02/T1	ETM+	30	0.45 - 1.75	1-5	27th Jan, 2005	USGS
8	LC08/C02/T1	OLI	30	0.43 - 2.29	1-7	30th Dec, 2015	USGS
9	LC09/C02/T1	OLI-2	30	0.45 - 2.29	2-7	26th Dec, 2025	USGS

Land Use/Land Cover (Lulc) Classification

Seven land use and land cover (LULC) classes were identified using the Random Forest algorithm, a non-parametric ensemble classifier known for its high accuracy in riparian LULC mapping and its robustness against overfitting (Belgiu and Drăguţ, 2016). The seven classes included: water body (permanent channels and open water bodies), sandbars (exposed sediment surfaces), grassland/shrubs (seasonally flooded herbaceous vegetation and woody vegetation under three meters tall), bare surfaces (unconsolidated sediments and eroded banks), riparian vgetatio(a mixture of plant groups adopted to wet or periodically flooded conditions that grow along river banks) built-up (settlements and infrastructure), and agriculture (cropland and fallow fields).

Training data were manually delineated in Google Earth Engine using dry-season composites for each epoch. For each class and epoch, between 30 and 50 polygons were collected, evenly distributed along the study reach, resulting in approximately 500–800 pixels per class. Special care was taken to capture the full variability of irrigated agriculture, including different crop types and field conditions. Training samples for irrigated fields were placed within 300 meters of the channel, showed high NDVI values during the dry season, and exhibited distinctive geometric patterns typical of pump irrigation (linear planting near the channel and visible pump intakes in high-resolution imagery). Rainfed agriculture, usually found on higher terraces and left fallow in the dry season, was absent within the geomorphic buffer and therefore did not require separate classification.

The Random Forest model was implemented with 100 trees to balance accuracy and computational efficiency. The input feature set consisted of ten spectral and index-based variables: Landsat bands 1–5 and 7 (surface reflectance), NDVI, MNDWI, BSI, and the Sandbar Index. Accuracy assessment followed a stratified random sampling approach, using 100 validation points per class (700 total per epoch). Reference data were independently interpreted using high-resolution imagery from Google Earth (including SPOT and Planet data where available) and supplemented by field observations from the March 2024 reconnaissance. Confusion matrices were used to derive overall, user's, and producer's accuracies, along with the Kappa coefficient. The classification aimed to achieve an overall accuracy above 85% and a Kappa coefficient greater than 0.80, aligning with accepted standards for remote sensing-based land cover classification (Foody, 2002). For the agriculture class specifically, both user's and producer's accuracies were targeted to exceed 85%.

IV. RESULTS AND DISCUSSION

Classification of the Riparian Land Use /Land Cover Changes

Land use/Land cover analysis is very important in understanding the hydro-geomorphic responses of a drainage basin and river channel morphology (Leta *et al.,*). To this effect, satellite images of 1988, 2002, 2012 and 2022 were analyzed for land use and land cover detection. The land use and land cover generated are; Water Body, Sandbars, Grassland/Shrub, Bare Surfaces, Riparian Vegetation, Built-up Area and Agriculture Land (Figures 6 and 7).

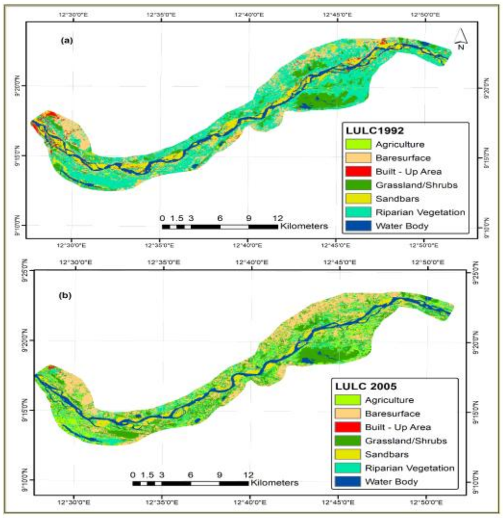

Figure 6: LULC Changes 1992 and 2005.
Source: Satellite Image Analysis of 1992 and 2025

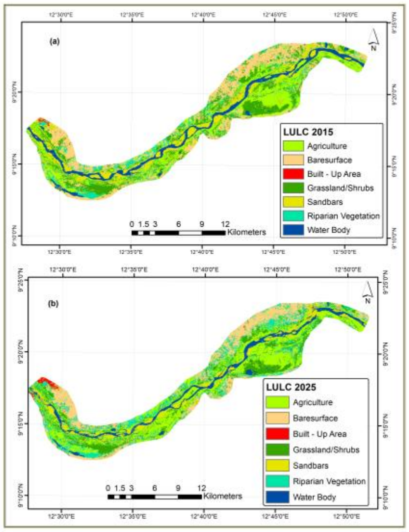

Figure 7: LULC Changes 2015 and 2025.
Source: Satellite Image Analysis of 2015 and 2025

Spatio-Temporal Dynamics of Land Use/Land Cover (1992–2025)

The analysis of land use/land cover (LULC) within the study area between 1992 and 2025 reveals significant transformations in landscape composition, despite the total area remaining constant at 22,556 ha. The results indicate a pronounced shift from natural vegetation to anthropogenically driven land uses, particularly agriculture and built-up areas (Table 2 and 3) refer.

Table 3: Land use/Land cover Classification and change detection analysis for 1992, 2005, 2015 and 2025 in Hectares (Ha).

Land uses	1992 Ha	2005 Ha	2015 Ha	2025 Ha	1992 to 2005	2005 to 2015	2015 to 2025	1992 TO 2025
Water Body	429	401	411	347	-28	+10	-64	-82
Sandbars	339	214	283	481	-125	+69	+198	+142
Grassland/Shrub	7895	4962	4060	2907	-2933	-902	-1153	-4988
Bare Surfaces	2323	4159	1386	1084	+1836	-2773	-302	-1239
Riparian Vegetation	2368	1780	1123	803	-588	-657	-320	-1565
Built-up Area	180	372	573	722	+192	+201	+149	+542
Agriculture Land	9022	10668	15293	16218	+1646	+4625	+925	+7196
Total	22,556	22,556	22,556	22,556				

Table 4: Land use/Land cover Classification and change detection analysis for 1992, 2005, 2015 and 2025 in Percentages (%) of Hectares (Ha).

Land uses	1992 Ha Percentage (%)	2005 Ha Percentage (%)	2015 Ha Percentage (%)	2025 Ha Percentage (%)	1992 to 2005 Percentage (%)	2005 to 2015 Percentage (%)	2015 to 2025 Percentage (%)	1992 TO 2025 Percentage (%)
Water Body	1.90	1.78	1.82	1.54	-0.12	+0.04	-0.28	-0.36
Sandbars	1.50	0.95	1.25	2.13	-0.55	+0.31	+0.88	+0.63
Grassland/Shrub	35.00	22.00	17.00	12.896	-13.00	-4.00	-5.11	-22.11
Bare Surfaces	10.30	18.43	6.14	4.81	+8.14	-12.29	-1.34	-5.49
Riparian Vegetation	10.50	7.89	4.45	3.56	-2.61	-2.91	-1.42	-6.94
Built-up Area	0.80	1.65	2.54	3.20	+0.85	+0.89	+0.66	+2.40
Agriculture	40.00	47.30	66.80	71.90	7.30	+20.50	+4.10	+31.90

Land				
Total	100	100	100	100

Agricultural land emerged as the dominant land use class throughout the study period, expanding from 9,022 ha (40.0%) in 1992 to 16,218 ha (71.9%) in 2025, representing a net increase of 7,196 ha (31.9%). This substantial growth reflects intensified agricultural activities, likely driven by increasing population pressure and demand for food production. The expansion occurred at the expense of other land cover types, particularly grassland/shrub and riparian vegetation.

Grassland/shrub experienced a drastic decline from 7,895 ha (35.0%) in 1992 to 2,907 ha (12.9%) in 2025, resulting in a net loss of 4,988 ha (22.11%). This reduction indicates extensive land conversion, primarily for agricultural purposes, and suggests a significant loss of natural vegetation cover. Similarly, riparian vegetation decreased consistently over the study period, from 2,368 ha (10.5%) to 803 ha (3.56%), representing a total loss of 1,565 ha (6.94%). This continuous decline highlights increasing encroachment into ecologically sensitive river buffer zones.

Built-up areas, although occupying a relatively small proportion of the total area, showed a steady increase from 180 ha (0.8%) in 1992 to 722 ha (3.2%) in 2025. This reflects gradual urban expansion and infrastructural development within the study area. The growth in built-up land contributes to increased impervious surfaces, which may influence runoff characteristics and local hydrological processes (Figures 8-11) refer.

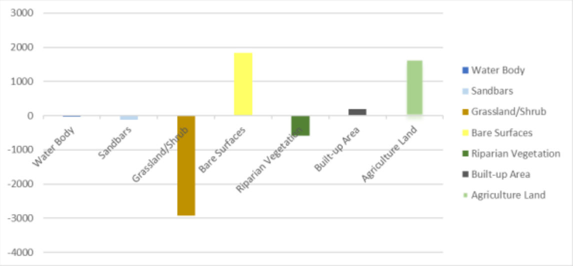

Figure 8: Land Use/Land Cover Changes along the Riparian Corridor from 1992-2005
Source: Satellite Image Analysis of 1992-205

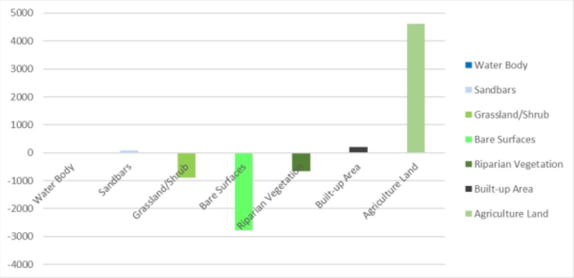

Figure 9: Land Use/Land Cover Changes along the Riparian Corridor from 2005-2015
Source: Satellite Image Analysis of 2005-2015

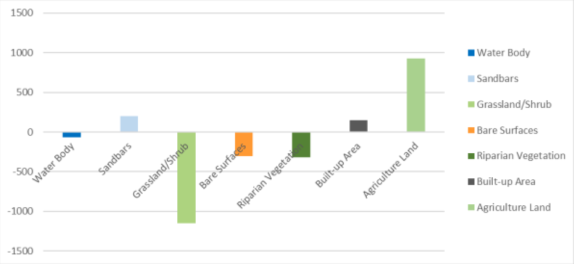

Figure 10: Land Use/Land Cover Changes along the Riparian Corridor from 2015-2025
Source: Satellite Image Analysis of 2015-2025

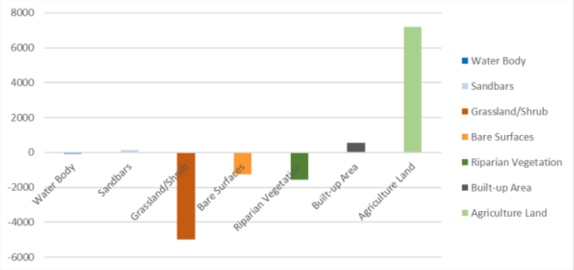

Figure 11: Land Use/Land Cover Changes along the Riparian Corridor from 1992-2025
Source: Satellite Image Analysis of 1992-2025

Transitional Land Cover Changes And Landscape Instability

Bare surfaces exhibited highly dynamic changes during the study period. The area increased sharply from 2,323 ha in 1992 to 4,159 ha in 2005, followed by a significant decline to 1,084 ha in 2025. This trend suggests that bare surfaces initially resulted from vegetation clearing and land degradation, which were subsequently converted into agricultural land.

This transitional behavior highlights active land transformation processes and landscape instability.

Sandbars also showed notable fluctuations, with an overall increase from 339 ha (1.50%) in 1992 to 481 ha (2.13%) in 2025. The most significant increase occurred between 2015 and 2025 (+198 ha), indicating intensified sediment deposition within the river channel. This pattern is often associated with upstream land degradation and reduced vegetation cover, which enhance soil erosion and sediment transport.

Water bodies experienced a slight but consistent decline from 429 ha (1.90%) in 1992 to 347 ha (1.54%) in 2025, resulting in a net loss of 82 ha. This reduction may be attributed to sedimentation processes, channel modification, and possible climatic influences affecting water availability.

Periodic Analysis Of Lulc Changes

A closer examination of the temporal dynamics reveals distinct phases of land transformation. Between 1992 and 2005, there was a rapid increase in bare surfaces (+1,836 ha) and agricultural land (+1,646 ha), accompanied by a substantial decline in grassland/shrub (−2,933 ha). This phase represents an initial period of land clearing and vegetation removal.

From 2005 to 2015, agricultural land expanded dramatically (+4,625 ha), while bare surfaces decreased significantly (−2,773 ha). This indicates a transition from cleared or degraded land into productive agricultural use. During this period, riparian vegetation also declined considerably (−657 ha), suggesting increased encroachment into riverine environments.

Between 2015 and 2025, agricultural expansion continued at a slower rate (+925 ha), while sandbars increased markedly (+198 ha). This phase reflects the environmental consequences of earlier land use changes, particularly increased sedimentation and channel instability.

Implications For Riparian Environment And Channel Morphology

The observed LULC changes have significant implications for the riparian environment and channel morphology. The continuous reduction in riparian vegetation weakens the structural stability of riverbanks, making them more susceptible to erosion. Riparian zones play a critical role in regulating sediment input, maintaining channel form, and protecting water quality; thus, their degradation can lead to profound geomorphological changes.

The increase in sandbar area suggests enhanced sediment deposition within the channel, likely resulting from accelerated soil erosion due to vegetation loss and agricultural expansion. This can alter channel morphology by promoting channel widening, braiding, or blockage of flow paths.

Furthermore, the expansion of agricultural and built-up areas increases surface runoff due to reduced infiltration, which may intensify peak flows and contribute to channel incision or flooding events. The slight reduction in water bodies may also reflect sediment infilling and reduced flow capacity.

Effects Of Lulc Dynamics On Channel Morphology

The spatio-temporal changes in land use/land cover (LULC) along the Dasin Hausa–Jimeta reach of the River Benue have exerted significant influence on channel morphology through modifications in sediment supply, bank stability, and flow regimes. River channels are highly sensitive to watershed disturbances, and alterations in riparian land cover often trigger geomorphological adjustments (Allan, 2004; Naiman and Décamps, 1997).

The substantial expansion of agricultural land (+31.9%) and concurrent reduction in vegetation cover, particularly grassland/shrub (−22.11%) and riparian vegetation (−6.94%), have increased soil exposure to erosive forces. Vegetation removal reduces interception and root reinforcement, thereby accelerating soil erosion and sediment yield. This is consistent with findings by Lambin *et al.,* (2003), who identified land cover conversion as a major driver of increased sediment flux in tropical environments. The observed increase in sandbar area (+142 ha), especially between 2015 and 2025, indicates enhanced sediment deposition within the channel. This process leads to: Channel aggradation, Reduction in channel depth, Diversion of flow paths. According to Odgaard (1987), excessive sediment load promotes mid-channel bar formation, which is a precursor to channel instability and morphological transformation.

The continuous decline in riparian vegetation has weakened the structural integrity of riverbanks. Riparian vegetation plays a crucial role in reinforcing bank materials through root networks and reducing near-bank flow velocity. Its removal results in: Increased bank erosion, Channel widening, Lateral channel migration. These processes are characteristic of unstable alluvial channels responding to external disturbances (Allan, 2004). Over time, such instability may lead to the development of braided or anabranching channel patterns, especially under high sediment load conditions.

The increase in built-up areas (+2.4%) and agricultural land has altered the hydrological response of the watershed. Impervious surfaces and compacted soils reduce infiltration and increase surface runoff. This leads to: n Higher peak discharge, shorter lag time during storm events, Increased flow velocity. Foley *et al.,* (2005) noted that land use change significantly modifies hydrological cycles, often resulting in more extreme flow conditions. These changes enhance the river's ability to erode, transport, and deposit sediments, thereby reshaping channel morphology.

The decline in water body extent (−0.36%) combined with increased sediment deposition suggests progressive channel infilling. As sediments accumulate: Channel depth decreases, Flow capacity is reduced, Overbank flooding becomes more frequent. This condition is typical of aggrading river systems where sediment supply exceeds transport capacity.

Based on the observed trends, the study reach is likely undergoing a transition from a relatively stable channel system to a more dynamic and unstable morphology. Indicators include: Increased sandbar formation, reduced vegetation stabilization, and enhanced sediment load. Such conditions favor the development of: Braided channels (multiple flow paths around sediment bars), Widened meandering channels with unstable banks. Turner *et al.,* (2007) emphasized that sustained land cover change can push fluvial systems beyond geomorphic thresholds, resulting in new channel forms.

Conceptual Link Between Lulc and Channel Morphology

The relationship between LULC change and channel morphology in the study area can be summarized as follows:

Vegetation Loss → Increased Erosion → Higher Sediment Yield → Sandbar Formation → Channel Instability → Morphological Adjustment

This conceptual framework highlights the cascading effects of land use change on river systems.

LULC Change
↓
Vegetation Loss
↓
Soil Erosion ↑
↓
Sediment Load ↑
↓
Sandbars ↑ + Channel Infilling
↓
Channel Instability
↓
Morphological Chang

Synthesis Of Lulc Transformation

Overall, the LULC dynamics indicate a progressive transformation from a natural, vegetation-dominated landscape to a human-dominated system characterized by extensive agricultural activities. This transformation has led to:

- Significant loss of natural vegetation
- Increased pressure on riparian ecosystems
- Enhanced sedimentation and channel instability
- Alteration of hydrological and geomorphological processes

These findings underscore the need for sustainable land management practices and effective riparian zone conservation strategies to mitigate further environmental degradation.

V. CONCLUSION

This study examined the spatio-temporal dynamics of land use/land cover (LULC) changes within the study area from 1992 to 2025, revealing a substantial transformation of the landscape driven primarily by human activities. The findings demonstrate a clear shift from natural vegetation-dominated land cover to an agriculture-dominated system, with agricultural land increasing significantly from 40.0% to 71.9% of the total area.

The expansion of agricultural land occurred largely at the expense of grassland/shrub and riparian vegetation, which experienced severe declines of 22.11% and 6.94%, respectively. These changes indicate increasing anthropogenic pressure on ecologically sensitive areas, particularly riparian zones that are critical for maintaining riverbank stability and ecosystem health.

In addition, the study observed a steady increase in built-up areas, reflecting gradual urbanization, and significant fluctuations in bare surfaces, suggesting active land conversion processes. The notable increase in sandbar areas, especially in the later years, points to enhanced sediment deposition within the river channel, likely resulting from intensified soil erosion due to vegetation loss and agricultural expansion.

The reduction in water bodies, although relatively small, further highlights potential impacts of sedimentation and changing hydrological conditions. Collectively, these changes have important implications for channel morphology, including increased channel instability, altered flow regimes, and heightened risk of flooding.

Overall, the study establishes a strong link between LULC changes and environmental degradation within the riparian corridor, emphasizing the need for sustainable land management and conservation strategies to protect the integrity of the river system.

VI. RECOMMENDATIONS

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

Riparian Buffer Protection

- Establish and enforce riparian buffer zones to prevent further encroachment into riverbanks
- Promote reforestation and afforestation along riparian corridors

Sustainable Agricultural Practices

- Encourage climate-smart agriculture and sustainable land management practices
- Introduce soil conservation techniques such as contour farming and cover cropping

Land Use Planning and Policy Enforcement

- Implement strict land use regulations to control indiscriminate land conversion
- Integrate geospatial monitoring (GIS and Remote Sensing) into land management policies

Erosion and Sediment Control

- Develop measures to reduce soil erosion, such as vegetative cover restoration
- Construct check dams or sediment traps where necessary

Urban Growth Management

- Promote planned urban expansion to minimize environmental impacts
- Increase green infrastructure in built-up areas

Continuous Monitoring

- Establish a long-term LULC monitoring framework using satellite data
- Conduct periodic assessments to track environmental changes

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