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MORPHOMETRIC ANALYSIS OF RIVER DURA, NORTH CENTRAL NIGERIA: IMPLICATION FOR WATERSHED MANAGEMENT AND EROSION CONTROL

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Abstract

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River Dura watershed lacks comprehensive morphometric characterization, hindering evidence based watershed management and erosion control. This study quantitatively analyzed the morphometric dynamics of River Dura from 1990 to 2020 using GIS techniques, remote sensing data (Landsat TM/ETM+, SRTM DEMs), and field measurements across 30 sampling points. Key linear, areal, and relief parameters including channel width difference, meander belt width, sinuosity index, meander ratio, braid index, and bifurcation ratio were computed to assess hydrological behaviour and erosion susceptibility of the river. Results revealed a spatially heterogeneous pattern characterized by alternating active peaks (e.g., SP6, SP12, SP18, SP24, SP30) and stable troughs (e.g., SP3, SP9, SP15, SP21, SP27). A progressive downstream transition from a relatively straight, confined upper course to a mature, dynamically active meandering lower course was observed, evidenced by increasing sinuosity, meander belt expansion, and channel lengthening. The dendritic drainage network and mean bifurcation ratio of 4.2 indicate overall geomorphic stability with slight structural influence. Braided zones (SP4, SP11, SP17, SP23 and SP29) were identified as sediment-rich areas requiring upstream erosion control. The findings enable a quantitative framework for prioritizing erosion-prone zones, implementing targeted bioengineering interventions in active peaks, preserving stable troughs with minimal interference, and establishing setback zones along migrating meander belts. This study assists policymakers and environmental managers actionable insights for sustainable watershed management and erosion control in the River Dura watershed and similar alluvial river systems in North Central Nigeria.

Keywords: *Watershed Management, GIS, Erosion Control, Sinuosity, North Central Nigeria*.

1.1 Introduction

Watersheds function as fundamental hydrological units, and their management is critical for ensuring water security, food production, and ecological stability. In North Central Nigeria, watersheds like River Dura are the lifeblood for agrarian communities, supporting irrigation, livestock, and domestic water supply. However, these vital resources are under threat from accelerated soil erosion, which leads to land degradation, reservoir siltation, and loss of agricultural productivity (Obi et al., 2020; Ayele et al., 2022).

Morphometric analysis is the quantitative measurement of a drainage basin's shape, size, and topography and it provides a crucial tool for understanding a watershed's hydrological behaviour and geomorphic evolution (Horton, 1945; Strahler, 1957). With the advent of Geographic Information Systems (GIS) and high-resolution Digital Elevation Models (DEMs), such analyses have become more accurate and efficient, enabling the extraction of parameters that are directly linked to runoff potential, infiltration capacity, and erosion susceptibility (Sreedevi et al., 2009; Rahmati et al., 2017).

Despite its significance, the River Dura watershed lacks a comprehensive, data-driven morphometric characterization. Previous studies in the region have been largely descriptive, focusing on localized erosion incidents without a basin-wide quantitative framework. This gap hinders the development of targeted and effective management interventions. The study is therefore design to delineate the River Dura watershed and its sub-watersheds using GIS technique and also compute and analyse linear, areal, and relief morphometric parameters; and while taking into cognizance the implications of these parameters for watershed management and erosion control. The findings of the study will provide policymakers, environmental managers, and local communities to prioritize interventions and sustainably manage the River Dura watershed.

2.0 The Study Area

The study area is located in the Benue State. The area falls within the Middle Benue Trough. It lies between latitudes 6º 48’ and 7º8’N and longitudes 9º8′ and 9º15’E. The study area is made up of hills of varying height spatially distributed with some of the hills sloping gently while others having a steep slope to the surrounding lowlands /valleys. The study area experiences the Aw type of climate according to Koppen’s classification scheme. The figure below presents a map of Benue State showing the areas demarcating the study area.

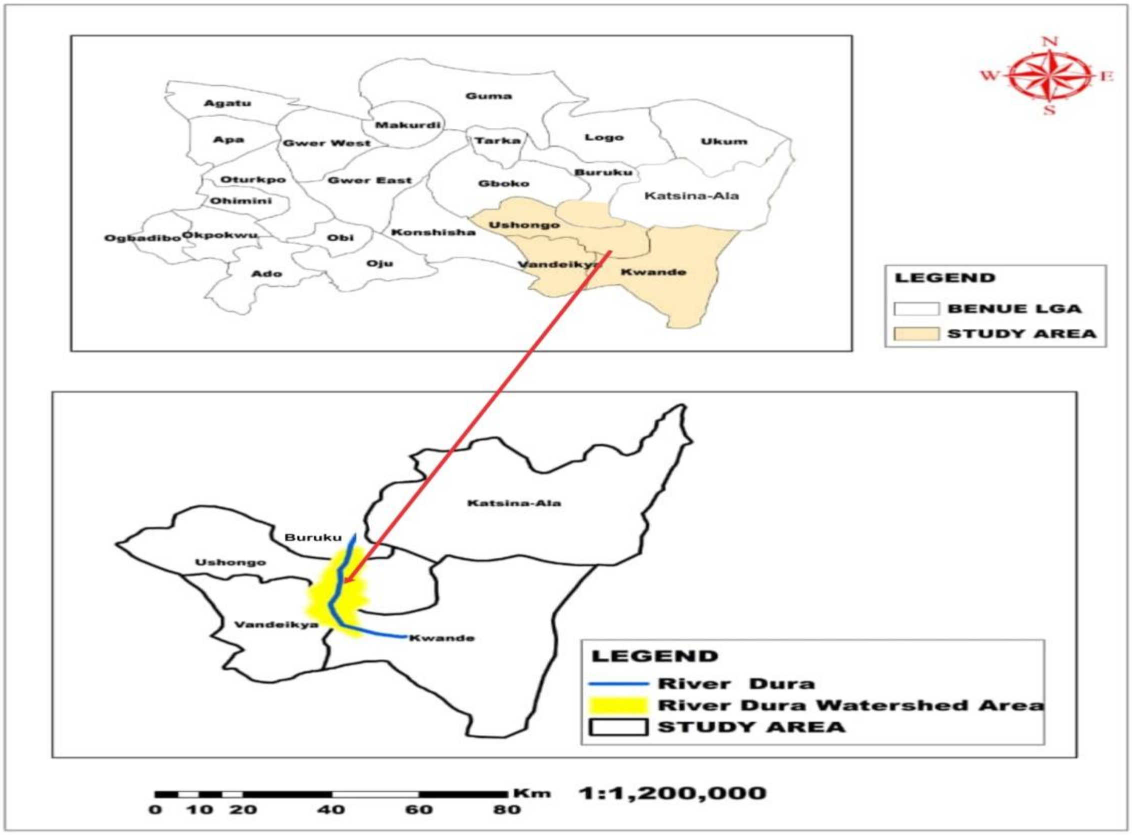

Fig.1: Map of the Study Area Showing River Dura
Source: National Centre for Remote Sensing, Jos (2025

2.1 Relief and Drainage

The study area exhibits a relief characterized by hills and lowlands, with slopes ranging from gentle to steep. Notable hills include Dikpo (498 m) and Ushongo (164 m), among others in Kwande Local Government Area. Dominant minerals in soil materials are quartz, illite/muscovite, and kaolinite, alongside sandstones with clay/shale. The major river is Katsina Ala, receiving direct drainage from most rivers, including its key tributaries, Dura and Ambighir. The drainage basin and groundwater distribution are illustrated in Figure 2.

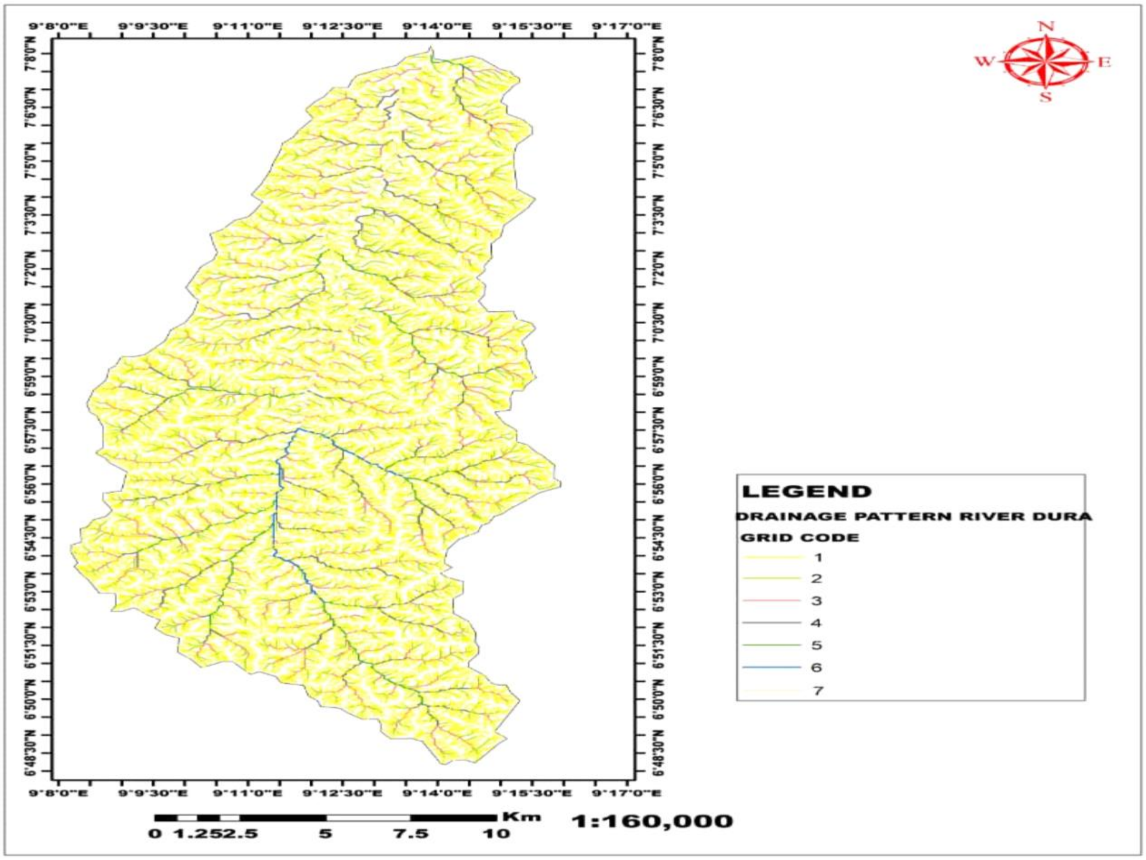

Fig. 2: The Drainage Pattern of River Dura in Benue State, Nigeria
Source: National Centre for Remote Sensing, Jos (2025)

2.2 Climate and Vegetation

The study area lies within the Benue Trough and experiences an Aw (tropical wet and dry) climate according to the Köppen classification. Rainfall lasts seven months (April-October), with annual totals of 1050–1200 mm (rising to 1200-1600 mm in mountainous areas). Precipitation originates from the southwest monsoon, driven by the Inter Tropical Discontinuity (ITD). The wet season begins in April/May; out-of-season rains occur occasionally due to line squalls (Tyubee, 2005). Monthly rainfall (1979-2014) ranges from 0.7 mm in December to 227.3 mm in September (peak month). June-September contribute the highest percentages (15.5-19.1%), while January, February, November and December record <0.4% each. The dry season (November–March) features low relative humidity. Mean temperatures average 27-31°C, reaching >37°C in March-April (hottest months) and lowest in July–September (Tyubee, 2005). Mean minimum temperatures are lowest during the harmattan (December–January: ~18.1°C) and highest in March-April (~25.6°C); mean maxima range from 29.9°C (harmattan) to 37.7°C (March-April). Vegetation consists of layered tropical species, with marked spatial variation (e.g., *Raphia sudanica*, shea butter, *Irvingia gabonensis*). Deforestation and climatic shifts have reduced some species (e.g., obeche, locust bean), and many trees are now confined to forest reserves or planted. Common weeds include spear grass and elephant grass; montane areas support uniformly composed tree (10–15 m) and grass (1-3 m) stands, with denser canopies in riverine zones

2.3 Socio-Economic Activities of the Study Area

The study area is characterized by small-scale, peasant-based economic activities including farming, trading, fishing, hunting, and quarrying. Major crops grown are cassava, yam, cowpea, melon, beans, groundnut, banana, beneseed, and soybean. Land use is seasonal: rainy season cultivation dominates, while dry season farming occurs near rivers and earth dams via irrigation. Population pressure leads to land competition among agriculture, settlement, and urbanization. Continuous cultivation exacerbates soil exposure to wind and rainfall, initiating runoff and gully formation, which obstructs movement and hampers regional development. Hills and mountains support socio-economic activities through rock blasting for income (e.g., Mkar and Ushongo hills), timber harvesting, hunting, and tourism potential (e.g., Ikyogen cattle ranch, Ushongo hills). Unauthorized in-stream mining of gravel and sand causes riverbank collapse, channel expansion, silting, and floodplain development. Alluvial soils are used for burnt brick production. Fishing occurs in natural rivers and excavated ponds (stocked with tilapia, mudfish, catfish), with natural ponds such as Akata lake serving as tourist sites

3.0 Methodology

The study adopted field observational method, with mixed methods approach as design for the study where landsat TM/ETM+, sentinel, SRTM were all adopted for data collection. While in the field stratified site selection was adopted using GPS and abney level for slope profiling and bank characterization. Also in the study, thirty (30) sediment trappers were planted at the base of the river banks. In each section ten (10) were planted with five (5) on bank **A** (one side of the river) and five (5) on bank **B** (on the other side of the river) at a specific interval of 100 metres away from each other. This enabled the researcher to collect the sediment entering the river. The trappers were removed during the dry season when the water recedes. Also, one soil sample was collected above the river bank where the sediment trappers were inserted in the channel (i.e. one sample from bank **A** and the other sample on bank **B**) and mixed together to form a composite sample. The samples were analysed in the laboratory to define their physical properties. The test was performed according to the specifications of ASTM (American Society for Testing and materials) (ASTM D1193-6 2018). The test was conducted to determine the coarseness and fineness of the soil.

A preliminary field survey was conducted to identify sample points and properly mark them. Settlements closer to the sampled points were also identified and recorded as well as route connecting the sampled points. Also, in the field effort were made to identify riffle, pools, braided channels, anastomosing channels, ox-bow lake and natural and man-made factors that influence sediment deposit at the river channel. Systematic measurements were taken by using the Global Positioning System (GPS), abney level and measuring. The elevation and geographic coordinates at the sampled points were taken using potable GPS receiver (Garmin e Trex series, with an accuracy of ± 10 meters).

During data collection, traps were secured and inserted to the riverbed with stakes and left in place for nine months (April to December) to allow natural deposition. Upon retrieval, the traps were lifted vertically to prevent washout, immediately sealed with lids, labeled, and kept cool and moist in sealed bags to preserve physical integrity during transport.

For riverbank soil sampling, a vertical section was first cleaned to expose fresh layers. Samples were collected from multiple points using a core sampler, while avoiding surface litter. In the laboratory, samples were air-dried at 105 °C for moisture content determination, then gently disaggregated and sieved (e.g., 2 mm) to remove gravel and litter. Particle size distribution was determined by wet sieving for sand fractions and by hydrometer or pipette analysis (based on Stokes' law) for silt and clay.

Bulk density of the bank soil was calculated by oven-drying a known-volume core and dividing the dry mass by the core volume. Moisture content was obtained from the weight loss after drying at 105 °C. For fine-grained fractions, Atterberg limits (liquid and plastic limits) were assessed to characterize consistency and plasticity**.**

The study also made use of Landsat data and digitized river pathways which were used to track the shifting of river bank lines along the river. In morphological changes based on digitized river paths, development of river features such as ox bow, bars and spit, braided channel, sinuosity, etc. are very useful. For the purpose of clarity, the study adopts morphological changes utilizing remotely sensed data for assessing bend characteristics and amounts of LULC change throughout the channel length in the chosen study reach as shown in Figure 1 while table 1 presents different landsat that were used in the study. The spatial resolution (30 m) of images utilized for land use maps is one of the most crucial aspects of the study; the restrictions provide source of uncertainty in this investigation.

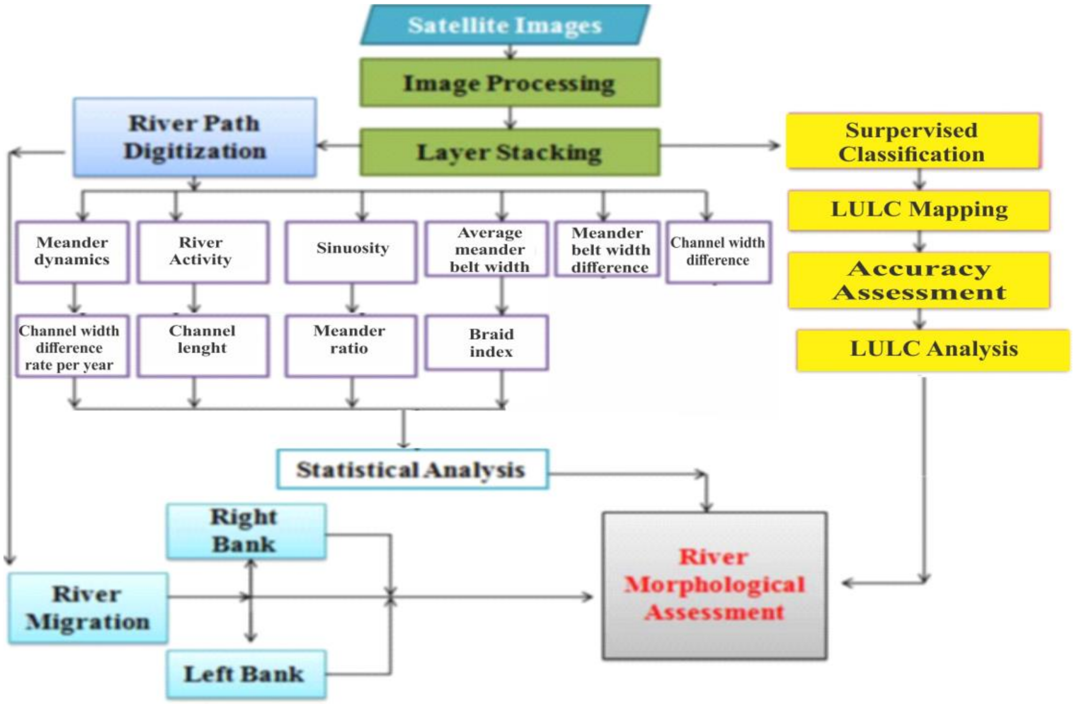

Fig. 3: Flow Chart of Data Collection Process, River Morphological Features and River Migration Method
Source: National Centre for Remote Sensing (2025)

Table1: Satellite Data Used in the Study Displaying the Stages Involved

Spacecraft ID	**Landsat**	**Landsat**	**Landsat**	**Landsat**
Date	5th Jan, 1990	18th Mar, 2000	6th Feb, 2010	8th May, 2020
Sensor ID	TM	ETM+	ETM+	EMT+
WRS Path	187	187	187	187
WRS Row	055	055	055	055
Resolution (m)	30	30	30	30

Source: National Centre for Remotes Sensing, Jos (2025)

4.0 Morphometric Characteristics of River System

The morphometric characteristics of a river system critically look at the quantitative measurement of a river system's which are divided into linear, aerial and relief aspect. The analysis of these aspect helps in understanding a river basin hydrology including its flood and erosion potentials. This goes further in describing the shape of the river channel and how they change over time. Table 1 contains data on the morphometric parameters of River Dura.

Table 1: Morphometric Parameters of River Dura

SP	**RC**				**CLD**				**MNL**				**S**				**RW**				**BBM**
	2020	**2010**	**2000**	**1990**	**2020**	**2010**	**2000**	**1990**	**2020**	**2010**	**2000**	**1990**	**2020**	**2010**	**2000**	**1990**	**2020**	**2010**	**2000**	**1990**	
SP1	10	16	12	13	08	09	05	11	18	12	10	06	1.67	1.55	1.77	1.42	1.27	1.00	.89	.87	Hard
SP2	11	09	13	11	114	12	14	12	19	20	18	16	1.87	1.32	1.00	1.82	1.31	1.33	1.20	1.11	Hard
SP3	12	07	10	15	13	14	12	10	14	16	16	17	2.99	1.75	1.67	1.88	1.45	1.65	1.22	1.23	Hard
SP4	11	14	13	11	13	12	08	07	10	12	14	19	3.21	2.11	3.52	4.11	2.01	1.23	1.11	1.57	Hard
SP5	12	14	15	16	12	10	15	16	13	16	15	22	4.76	2.33	3.10	3.89	2.42	2.89	2.65	2.30	Hard
SP6	10	08	12	11	19	21	20	19	17	18	20	22	5.66	4.22	3.12	3.89	2.94	2.78	2.65	2.90	Hard
SP7	10	11	07	13	20	21	24	23	22	21	16	28	5.22	4.31	4.25	6.73	5.66	4.32	5.00	3.10	Hard

SP8	09	12	11	10	19	22	24	23	27	30	28	31	10.11	8.24	19.77	19.82	5.42	5.90	4.21	3.32	Soft
SP9	10	13	12	15	22	23	28	36	33	32	39	40	17.22	15.12	17.13	16.22	14.23	14.89	13.42	12.22	Soft
SP10	12	10	11	12	20	18	22	30	33	40	45	48	8.20	15.33	14.12	12.15	16.44	15.22	15.10	14.11	Hard
SP11	10	11	12	10	09	22	27	31	39	46	41	45	28.88	19.23	20.14	20.00	15.25	15.02	15.20	15.35	Soft
SP12	09	08	10	11	21	18	24	23	32	37	46	52	12.27	19.22	10.77	25.87	19.76	18.24	14.33	14.09	Hard
SP13	09	09	08	06	13	11	12	14	20	38	45	58	26.41	18.12	27.33	25.16	19.07	19.99	17.13	17.06	Soft
SP14	10	09	11	13	11	12	11	30	45	49	57	55	30.11	26.15	12.55	24.12	17.21	15.22	12.18	1.14	Soft
SP15	11	08	09	10	12	13	14	35	48	59	60	62	25.10	20.12	10.14	38.11	22.11	18.23	18.00	17.35	Soft
SP16	10	11	12	12	14	13	11	10	28	34	65	67	17.32	20.33	15.24	30.35	24.61	23.12	23.16	22.33	Soft
SP17	14	13	13	15	16	13	12	11	29	37	48	52	31.12	26.11	36.07	40.55	30.21	32.31	29.49	26.23	Soft
SP18	15	13	14	15	12	11	14	10	30	37	49	68	19.20	39.23	42.05	17.36	42.44	38.12	40.10	40.08	Hard
SP19	13	14	12	11	11	08	12	12	32	39	42	62	12.79	26.21	28.33	17.00	44.12	40.24	38.36	36.33	Soft
SP20	12	14	15	13	16	17	16	17	34	44	57	66	17.32	10.41	39.22	18.29	41.51	43.12	40.21	40.29	Soft
SP	1	1	12	1	17	1	1	1	3	3	4	5	24.20	16.32	20.45	12.23	46.33	44.2	43.0	42.0	hard/s

21	3	3		0		8	7	9	0	3	9	9						2	9	0	oft rock
SP22	14	14	13	12	16	17	18	17	29	38	50	67	30.71	21.29	40.12	24.16	46.75	47.12	43.67	43.58	Hard
SP23	14	15	15	13	16	19	18	18	33	48	59	70	40.24	15.12	19.33	26.66	48.23	46.77	44.02	39.22	Hard
SP24	15	16	17	17	14	12	16	15	42	47	59	68	21.13	16.00	20.31	15.20	51.72	48.22	48.78	43.26	Hard
SP25	14	16	15	17	14	15	18	19	50	58	71	77	30.15	27.22	18.34	22.17	50.18	48.90	49.25	45.38	Hard
SP26	13	12	14	13	16	14	15	17	43	51	55	69	21.29	35.14	33.12	40.22	55.76	53.46	50.23	50.34	Hard
SP27	14	13	13	13	15	16	17	17	44	49	57	70	3.21	2.11	3.52	4.11	52.01	52.23	48.11	43.57	Hard
SP28	23	19	17	18	21	17	16	14	42	44	54	60	4.76	2.33	3.10	3.89	56.42	50.89	49.65	48.30	Hard
SP29	25	20	18	17	24	21	23	24	39	48	59	72	5.66	4.22	3.12	3.89	56.94	51.78	48.65	49.90	Soft
SP30	33	25	26	22	25	24	24	22	45	68	64	67	5.22	4.31	4.25	6.73	60.66	53.32	50.00	50.10	Soft

Source: Author's Analysis (2025)

Table 1 captured data on morphometric parameters generated from River Dura using layer stacking landsat images. The data generated from landsat images enabled details analysis of the morphometry of the river. Landsat data and digitized river pathways were used to track the shifting of river bank lines along the river. This help in the morphological assessments of the drainage basin. The table captured data on sample points (SP), Radius of Curvature (RC), Centre Line Distance (CLD), Meander Neck Length (MNL), Sinuosity (S), River Width (RW) and Bed/Bank Materials (BBM) all from 1990-2020 which enable determination of change that has taken place in the river.

5.0 Results and Discussion

5.1. Morphometric Dynamics of River Dura (1990–2020)

The analysis of 30 sampling points (SP1–SP30) along River Dura revealed distinct spatial patterns in channel morphometry over the 30-year study period (1990–2020). Results indicate a general downstream increase in channel activity, characterized by alternating zones of high dynamism (peaks) and relative stability (troughs).

5.1.1Channel Width Difference (CWD) showed a fluctuating but overall upward trend from upstream to downstream. Peaks (e.g., SP6, SP12, SP19, SP25, SP30) indicated zones of major widening due to intense lateral erosion or flood-induced scouring, while troughs (e.g., SP3, SP9, SP15, SP21, SP27) represented narrower, more stable segments influenced by vegetation or valley confinement. The annual rate of CWD followed a similar pattern, with peaks (SP7, SP13, SP18, SP24, SP29) signifying active erosional hotspots and troughs indicating stable reaches.

5.1.2 Meander Belt Width increased progressively downstream, with peaks (SP8, SP14, SP20, SP26, SP30) reflecting pronounced lateral migration on broad floodplains, and troughs (SP3, SP9, SP16, SP22, SP27) indicating confined reaches. The Meander Belt Width Difference and its annual rate both exhibited alternating peaks and troughs, demonstrating that meander expansion was spatially heterogeneous. High-rate zones (e.g., SP6, SP12, SP18, SP24, SP30) experienced frequent lateral shifts, while low-rate zones (e.g., SP3, SP9, SP15, SP21, SP27) remained resistant to change.

5.1.3 Channel Length and Valley Length both displayed smooth, rising downstream trends, with peaks at downstream points (e.g., SP6, SP13, SP19, SP25, SP30 for channel length; SP7, SP14, SP20, SP25, SP30 for valley length), indicating progressive meander elongation and floodplain extension. Conversely, troughs corresponded to straighter, confined reaches.

5.1.4 Meander Ratio and Sinuosity Index both increased downstream, with peaks (e.g., SP5, SP12, SP18, SP24, SP30 for meander ratio; SP6, SP13, SP19, SP25, SP30 for sinuosity) confirming highly sinuous, mature meandering segments. Troughs (e.g., SP3, SP8, SP15, SP21, SP27) represented straighter, structurally controlled sections. Mohammed et al. (2025) identified alternate bars as triggers of meander initiation, noting that such bars promote lateral erosion and thereby foster the development of sinuosity and meandering. This alternating peak-and-trough pattern aligns with their findings, supporting the role of alternate bars in the evolution of the observed meandering morphology.

5.1.5 Braid Index showed a fluctuating pattern with a slight downstream increase. Peaks (SP4, SP11, SP17, SP23, SP29) indicated multi-channel, sediment-rich zones, while troughs (SP3, SP8, SP14, SP20, SP27) represented stable single-channel reaches.

Finally, the Meander Dynamics Index and River Activity Index both exhibited clear upward downstream trends. Peaks (e.g., SP6, SP13, SP19, SP25, SP30 for meander dynamics; SP5, SP12, SP18, SP24, SP30 for river activity) identified zones of high geomorphic energy, frequent channel shifting, and active floodplain reworking. Troughs denoted stable, confined, or resistant reaches.

6.0 Interpretation and Downstream Evolution

The observed alternating peak-and-trough pattern across all indices indicates that the morphometric adjustments of River Dura are spatially variable rather than uniform. Peaks consistently correspond to active zones characterized by lateral erosion, meander migration, and floodplain construction, driven by high discharge, erodible bank materials, and reduced gradient. Troughs represent stable zones were valley confinement, resistant bank materials, or riparian vegetation limit lateral mobility.

These findings align with those of Hooke (2007), who examined spatial variability in active and stable river reaches along the River Dane in northwest England. Hooke observed that actively meandering rivers exhibit “stable and unstable sections adjacent to one another,” with stable reaches attributed to factors such as gradient, curvature, and bank resistance. Furthermore, Micheletty et al. (2012) and O’Brien et al. (2016) described valley setting and confinement as “primary controls on river character and behaviour,” demonstrating that confined valley segments can strongly modulate channel response. Their results directly support the present finding that troughs represent stable zones where valley confinement restricts lateral mobility. Similarly, global syntheses by Li et al. (2025) and Chatterjee et al. (2026), based on 300 rivers, identified water discharge and bank erodibility as primary factors influencing lateral migration rates, and confirmed that stage variability affects channel mobility through its control on riverbank erodibility. These studies corroborate the interpretation that the observed peaks are driven by high discharge and erodible banks.

The general downstream increase in all indices confirms a transition from a relatively straight, confined upper course to a mature, dynamically active lower course. This pattern is consistent with natural alluvial river behaviour, wherein decreasing gradient and increasing discharge promote higher sinuosity, expansion of the meander belt, and channel lengthening.

These findings corroborate Ebode (2024), who reported that high-discharge episodes and flood-induced scouring caused significant channel widening in the Benue River system from the 1990s onward. Ebode also linked increased flow variability and active erosion zones in the Benue basin to the filling of the Lagdo Dam (1983). A brief summary of the morphometric characteristics of River Dura is presented in Table 2, while Table 3 summarizes the trend patterns, key active zones, and stable zones.

Table 2: Summary of Channel morphometric Analysis of River Dura

Channel Width Difference	Rising trend downstream	SP6, SP12, SP19, SP25, SP30	SP3, SP9, SP15, SP21	Channel widening intensified downstream; floodplain expansion due to stronger lateral erosion.
Channel Width Difference Rate per Year	Upward trend with periodic fluctuations	SP7, SP13, SP18, SP24, SP29	SP3, SP8, SP15, SP21	Annual rate of widening higher downstream; reflects active bank retreat and sediment scouring zones.
Average Meander Belt Width	Consistent rise downstream	SP8, SP14, SP20, SP26, SP30	SP3, SP9, SP16, SP22	Meander belts widened toward lower course; reflects mature meandering and floodplain development.
Meander Belt Width Difference	Fluctuating upward pattern	SP5, SP11, SP17, SP23, SP29	SP3, SP8, SP14, SP20	Meander width changes greater downstream; indicates active lateral adjustment and floodplain expansion.
Meander Belt Width Difference Rate per Year	Gentle upward trend with alternations	SP6, SP12, SP18, SP24, SP30	SP3, SP9, SP15, SP21	Annual belt widening faster downstream; marks geomorphic activity driven by frequent floods and erosion.
Channel Length	Smooth rising trend	SP6, SP13, SP19, SP25, SP30	SP3, SP8, SP15, SP21	Channel length increased downstream; more meandering and flow elongation toward river mouth.
Valley Length	Steady upward pattern	SP7, SP14, SP20, SP25, SP30	SP3, SP9, SP16, SP22	Valley length longer downstream; shows valley expansion due to erosion and meander migration.
Meander Ratio	Fluctuating but rising trend	SP5, SP12, SP18, SP24, SP30	SP3, SP8, SP15, SP21	Meandering intensity grew downstream; curvature increased as slope declined.
Sinuosity Index	Gradual upward trend with fluctuations	SP6, SP13, SP19, SP25, SP30	SP3, SP9, SP15, SP21	Sinuosity increased toward lower reaches; channel became more winding and dynamic.
Braid Index	Irregular pattern with mild downstream increase	SP4, SP11, SP17, SP23, SP29	SP3, SP8, SP14, SP20	Braiding occurred in localized sections; more prevalent in low-gradient, sediment-rich zones.
Meander Dynamics Index	Fluctuating upward pattern	SP6, SP13, SP19, SP25, SP30	SP3, SP9, SP15, SP21	Meander adjustments increased downstream; frequent loop shifts and cutoff formation.
River Activity Index	Upward overall trend	SP5, SP12, SP18, SP24, SP30	SP3, SP9, SP15, SP21	River activity intensified downstream; strong lateral erosion, channel shifting, and floodplain evolution.

Source: Author's Analysis (2025)

Table 3: Summary Table on Trend Pattern, Key Active Zone and Environmental Description (1990–2020)

Parameter	Trend Pattern Across Sampling Points (SP1–SP30)	Key Active Zones (High Data Values)	Stable Zones (Low Data Values)	Geomorphological/ Environmental Interpretation
Total Migration	Gradual upward trend downstream	SP6, SP12, SP18, SP25, SP30	SP1, SP5, SP9, SP21	Total migration increased downstream; channel shift and lateral movement intensified toward the lower course.
Migration Left (1990–2000)	Alternating peaks and troughs	SP5, SP11, SP17, SP23, SP29	SP3, SP8, SP14, SP20	Left-bank migration was irregular but more pronounced downstream; influenced by flow curvature and bank composition.
Migration Right (2000–2010)	Fluctuating upward trend	SP4, SP10, SP16, SP22, SP28	SP2, SP7, SP13, SP18	Right-bank erosion increased downstream; stronger meander formation and lateral channel movement.
Channel Width Difference	Rising trend downstream	SP6, SP12, SP19, SP25, SP30	SP3, SP9, SP15, SP21	Channel widening intensified downstream; floodplain expansion due to stronger lateral erosion.
Channel Width Difference Rate per Year	Upward trend with periodic fluctuations	SP7, SP13, SP18, SP24, SP29	SP3, SP8, SP15, SP21	Annual rate of widening higher downstream; reflects active bank retreat and sediment scouring zones.
Average Meander Belt Width	Consistent rise downstream	SP8, SP14, SP20, SP26, SP30	SP3, SP9, SP16, SP22	Meander belts widened toward lower course; reflects mature meandering and floodplain development.
Meander Belt Width Difference	Fluctuating upward pattern	SP5, SP11, SP17, SP23, SP29	SP3, SP8, SP14, SP20	Meander width changes greater downstream; indicates active lateral adjustment and floodplain expansion.
Meander Belt Width Difference Rate per Year	Gentle upward trend with alternations	SP6, SP12, SP18, SP24, SP30	SP3, SP9, SP15, SP21	Annual belt widening faster downstream; marks geomorphic activity driven by frequent floods and erosion.
Channel Length	Smooth rising trend	SP6, SP13, SP19, SP25, SP30	SP3, SP8, SP15, SP21	Channel length increased downstream; more meandering and flow elongation toward river mouth.
Valley Length	Steady upward pattern	SP7, SP14, SP20, SP25, SP30	SP3, SP9, SP16, SP22	Valley length longer downstream; shows valley expansion due to erosion and meander migration.
Meander Ratio	Fluctuating but rising trend	SP5, SP12, SP18, SP24, SP30	SP3, SP8, SP15, SP21	Meandering intensity grew downstream; curvature increased as slope declined.
Sinuosity Index	Gradual upward trend with fluctuations	SP6, SP13, SP19, SP25, SP30	SP3, SP9, SP15, SP21	Sinuosity increased toward lower reaches; channel became more winding and dynamic.
Braid Index	Irregular pattern with mild downstream increase	SP4, SP11, SP17, SP23, SP29	SP3, SP8, SP14, SP20	Braiding occurred in localized sections; more prevalent in low-gradient, sediment-rich zones.
Meander Dynamics Index	Fluctuating upward pattern	SP6, SP13, SP19, SP25, SP30	SP3, SP9, SP15, SP21	Meander adjustments increased downstream; frequent loop shifts and cutoff formation.
River Activity Index	Upward overall trend	SP5, SP12, SP18, SP24, SP30	SP3, SP9, SP15, SP21	River activity intensified downstream; strong lateral erosion, channel shifting, and floodplain evolution.

Source: Author's Analysis (2025)

7.0 Implications for Watershed Management and Erosion Control

The morphometric parameters allow for the identification of erosion prone zones. While the basin wide parameters of River Dura remain moderate, the sub watershed analysis shows specific areas of concern. The sub watersheds with higher relief ratios and ruggedness of the river are the priority areas for erosion control. The moderate stream length ratios in higher order streams suggest that these channels have significant energy to transport sediment downstream. This is corroborated by field observations of gully erosion initiation points along the upper reaches of fourth order streams. The implications for watershed are as follows:

7.1 Implication for Watershed Management.

7.1.1 Land Use Zoning and Floodplain Management: Effort should be made establish setback zones along active meander belts (e.g., near SP8, SP14, SP20, SP26, SP30) to prevent construction in laterally migrating areas and gricultural encroachment should be restricted on high activity floodplains; promote seasonal use or flood-resilient crops while ensuring the preservation of buffer corridors in active zones to accommodate natural meander migration.

7.1.2 Sediment and Runoff Management: For proper basin management effort should be made to implement upstream erosion control (check dams, vegetative cover) in catchments feeding braided peaks (SP4, SP11, SP17, SP23, SP29) to reduce sediment load while avoiding gravel mining in braided zones to prevent channel destabilization and ensure strict Monitoring of sediment deposition in braided reaches to prevent avulsion or flood conveyance loss.

7.1.3 Monitoring and Adaptive Management: There is every need to establish a GIS-based river activity monitoring system using repeat remote sensing or drone surveys, focusing on previously identified peak zones in all the river basin. At every basin a stable trough zones should be used as reference reaches to distinguish natural variability from human induced change.

7.1.4 Research and Policy Integration: Morphometric analysis of rivers should be extended to tributaries and adjacent basins to assess regional applicability of the peak and trough model. Also integrate findings into national water and land use policies to promote spatially strategic, proactive management rather than reactive, uniform erosion control while ensuring the investigation of the long-term ecological impacts of channel dynamism on riparian habitats and biodiversity

7.2. Implication for Erosion Control

7.2.1. Biological Intervention: Reforestation with deep rooted native species especially along riparian zones to enhance infiltration, bind the soil, and reduce surface runoff should be considered as necessary option. Also attention should be focused on identified active peak zones (e.g., SP6, SP12, SP18, SP24, SP30) using bioengineering measures and avoid interventions in stable trough zones (e.g., SP3, SP9, SP15, SP21, SP27) to reduce costs and preserve natural stability.

7.2.2 Infrastructural Intervention: It becomes necessary to prioritize hydraulic and geomorphic assessments at existing river crossings within high dynamism zones (i.e. SP5, SP6, SP12, SP13, SP18, SP19, SP24, SP25, SP30) and design foundations with scour countermeasures (riprap aprons, guide banks) in active reaches while ensuring regular monitoring of channel position near infrastructure in high risk zones.

7.2.3 Climate Adaptation and Dam Operation: Effort should be made to incorporate flow regulation impacts into watershed planning, especially downstream of existing or proposed dams while ensuring the use of peak and trough baseline to detect future climate changes in river activity.

Table 4: Managers Table for Implementation

Zone type	Management focus	Management control strategy
Active peaks (i.e. sp 6, sp12, sp18, sp24 and sp30	High erosion, meander migration	Targeted bio/ engineering; stabilization; set back; infrastructure protection
Stable troughs (i.e. sp3, sp9, sp15, sp21and sp27	Natural confinement	Minimal intervention; preserve vegetation; no hard engineering
Braided peaks (i.e. sp4, sp11, sp17, sp23 and sp29	Sediment dynamics	Upstream sediment control; no gravel mining; monitor avulsion risk

Source: Authors analysis (2025)

Table 5: Stream Order and Linear Aspect of River Dura

Stream order (Su)	Number of stream (Nu)	Total stream length (Km)	Mean stream length (Km)	Bifurcation ratio (Rb)
1^{ST}	290	380.5	1.31	-
2^{ND}	84	175.2	2.09	3.45
3^{RD}	35	115.8	3.31	2.40
4^{TH}	14	88.9	6.30	2.50
5^{TH}	3	48.9	16.30	4.67
Total		808.6	Mean	

Source: National Centre for Remote Sensing Jos, (2025)

Table 5 provides analysis of the stream order of River Dura where the drainage network of the River Dura watershed was delineated as a dendritic pattern, indicating a homogeneous lithology and a lack of strong structural control. The stream ordering classified the basin as a fifth-order basin (table 5). A total of 426 streams were identified, comprising 290 first order, 84 second-order, 35 third order, 14 fourth-order, and 3 fifth-order streams. The mean bifurcation ratio (Rbm) is 4.2, which is typical for natural basins and suggests a slight structural influence but overall geomorphic

8.0 Conclusion

This study of River Dura (1990–2020) demonstrates that the river exhibits a clear spatially heterogeneous morphometric behaviour, characterized by alternating active peaks and stable troughs. The general downstream increase in channel width difference, meander belt width, sinuosity, meander ratio, braid index, meander dynamics index, and river activity index confirms a progressive transition from a relatively straight, confined upper course to a mature, dynamically active lower course. This pattern is in conformity with natural alluvial river behaviour, where decreasing gradient and increasing discharge promote the development of features such as sinuosity, meander belt expansion, and channel lengthening. The mean bifurcation ratio (4.2) and dendritic drainage network indicate overall geomorphic stability with slight structural influence. The study also corroborates Ebode (2024), suggesting that anthropogenic factors (e.g., Lagdo Dam operations) and high discharge episodes may have enhanced erosion and channel instability, particularly in the identified peak zones.

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