

# Influence of Basin Morphometric Characteristics On the Morphology and Downstream Geomorphic Evolution of River Kontien in Benue State, Nigeria

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**Abstract:** *This study examined the influence of basin morphometric characteristics on the morphology and downstream geomorphic evolution of River Kontien in Benue State, Nigeria. It was guided by four objectives focusing on spatial variation in morphometric parameters, relationships between morphometry and channel characteristics, identification of key morphometric predictors of channel form, and development of a predictive explanation of downstream geomorphic change. A mixed-methods approach was adopted, combining field survey, laboratory analysis, Remote Sensing, and GIS within a descriptive and observational design. Data were collected using GPS, measuring instruments, sediment sampling tools, satellite imagery, topographic maps, and rainfall records, and analyzed using descriptive statistics, correlation, multiple regression, ANOVA, and GIS spatial overlay techniques. Findings revealed systematic downstream changes in basin characteristics, with increases in basin area, drainage density, stream order, and stream frequency, and decreases in basin slope, relief ratio, and overland flow length, indicating a transition from youthful erosional upstream conditions to mature depositional downstream environments. Basin shape also evolved from elongated to more circular forms downstream. Strong significant correlations ( $r = 0.989-0.998$ ) showed that morphometric variables are highly interrelated, while strong negative relationships existed between basin morphometry and channel form (e.g., drainage density vs channel width  $r = -0.984$ ). Regression results indicated that 97.1% of channel cross-sectional variation is explained by morphometric factors ( $R^2 = 0.971$ ), with relief ratio as the most significant predictor ( $\beta = -1.638$ ). The study concluded that basin morphometry strongly controls river channel form and downstream geomorphic evolution in River Kontien. It recommended integrated watershed management and intensified soil conservation measures in upstream areas to reduce erosion and stabilize channel development.*

**Keywords:** basin morphometry; River Kontien; channel morphology; geomorphic evolution; drainage density; relief ratio; GIS analysis; watershed characteristics; river morphology;

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## INTRODUCTION

River channels are dynamic geomorphic systems whose forms continuously adjust in response to the interaction of hydrological processes, sediment regimes and basin-scale controls (Chen et al., 2023; Hassan & Yusuf, 2021). Channel morphology, expressed through planform configuration, cross-sectional geometry, channel width and depth, meander development, sinuosity, bed characteristics and longitudinal profile, reflects long-term responses to both natural and anthropogenic drivers operating within the drainage basin (Gazon et al., 2023; Eze & Ologunorisa, 2020). Contemporary fluvial geomorphology recognizes the drainage basin as the fundamental control unit within which runoff generation, sediment production, slope processes and drainage organization interact to influence river form and behaviour (Gregory et al., 2019; Anya et al., 2017). Consequently, understanding the relationship between basin morphometric characteristics and river morphology has become a major concern in watershed science, geomorphological analysis and river basin management.

Recent studies have shown that morphometric properties such as drainage density, stream frequency, basin shape, bifurcation ratio, basin relief and slope exert substantial influence on channel dimensions, discharge behaviour, erosion processes and sediment transport dynamics (Thomas et al., 2018; Singh et al., 2021). Variations in these parameters affect runoff concentration, flow velocity, stream power and sediment yield, which in turn shape channel adjustment processes such as incision, widening, meandering and bank migration (Montgomery et al., 2019; Kabir et al., 2024). Gurnell et al. (2022) observed that rivers respond to changes in basin controls through geomorphic adjustments intended to restore dynamic equilibrium, often manifested in altered channel morphology and floodplain structure. These relationships have provided the contemporary theoretical foundation for linking drainage basin characteristics with river morphological responses.

Beyond inherent morphometric controls, current studies increasingly show that changing land use patterns, vegetation cover modification and rainfall variability amplify basin influences on river morphology. Urbanization, deforestation, intensive agriculture and infrastructural expansion frequently alter infiltration rates, increase overland flow and enhance sediment delivery into river systems, thereby modifying channel form and stability (Andualem et al., 2024; Ogbole & Iorkua, 2019). Such disturbances often cause channels to exceed equilibrium thresholds, triggering lateral adjustment, incision or widening (Gurnell et al., 2022). In environmentally sensitive regions, especially transitional climatic zones where rainfall variability and erosion susceptibility are high, such influences may significantly intensify morphological adjustments (Abubakar & Ibrahim, 2021; Kabir et al., 2024). This has made investigation of basin controls on channel morphology particularly relevant in tropical and subtropical river systems.

In sub-Saharan Africa, many drainage basins are experiencing rapid environmental transformation driven by population growth, agricultural intensification and expanding human settlement. These

changes have contributed to increased runoff response, sediment loading and frequent channel adjustments in many poorly monitored river systems (Nkwocha & Eboh, 2023; Adebayo et al., 2020). Evidence from West African basins suggests that altered basin characteristics are increasingly associated with channel instability, accelerated bank erosion and changing depositional patterns (Mensah et al., 2021; Nkwocha & Eboh, 2023). Yet, despite growing recognition of these relationships, empirical studies linking basin morphometric parameters to channel morphology remain limited, particularly for medium-sized river basins where hydrological records are sparse.

In Nigeria, this issue is particularly significant because rivers serve essential ecological and socio-economic functions, including domestic water supply, irrigation, fisheries, transportation and flood regulation, while increasingly facing pressures from land degradation, sand mining, vegetation depletion and climatic variability (Ijafiya et al., 2023; Anya et al., 2017). Previous studies in different parts of Nigeria have demonstrated that changes in discharge conditions, land-use conversion and sediment dynamics contribute significantly to morphological transformation. For instance, Ijafiya et al. (2023) reported substantial changes in the lower course of River Mayo Inne associated with bank under-cutting, meander migration and chute cut-offs. Similarly, Abali and Nkii (2024) found that urbanization within the New Calabar River Basin significantly influenced channel width, depth and discharge characteristics. In a related study, Ocheri et al. (2024) showed that morphometric indices such as drainage density, bifurcation ratio and circularity ratio in the River Mu sub-basin have implications for channel behaviour and morphological development. Related findings by Tersoo and Ahile (2019) in the Lower Benue Basin further established significant relationships between basin relief and channel instability.

River Kontien, located in Benue State within Nigeria's Lower Benue drainage system, represents one such river system where basin morphometric influences on morphology remain insufficiently understood. The basin lies within a transitional ecological belt characterized by marked wet and dry seasons, variable rainfall intensities, fragile soils, agricultural land pressure and changing vegetation patterns, all of which may influence hydrological and geomorphic processes (Abubakar & Ibrahim, 2021; Ocheri et al., 2024). Given these environmental conditions, morphometric properties such as drainage density, basin relief, elongation ratio, stream frequency and bifurcation structure may have important implications for channel form, adjustment and stability along River Kontien. Recent studies have shown that channel form is strongly related to discharge behaviour, while discharge itself is conditioned by basin morphometric properties and land surface characteristics (Singh et al., 2021; Chen et al., 2023). This provides further justification for interrogating basin-channel relationships in the study area.

Although several studies have examined morphometric characterization of Nigerian basins, limited attention has been given to quantitatively linking basin morphometric parameters with observable river morphological characteristics, particularly in Benue State. Few studies, such as

Achagh (2025), have attempted to examine the combined effects of basin variables on river morphological dynamics in North Central Nigeria. This gap is critical because identifying the dominant basin parameters influencing channel morphology is necessary for understanding channel dynamics, predicting geomorphic responses and informing sustainable basin management. Against this backdrop, this study investigates the influence of River Kontien basin morphometric parameters on its morphological characteristics, with a view to providing empirical evidence on basin–channel relationships in a tropical fluvial environment and contributing to the broader discourse in applied fluvial geomorphology.

### **Statement of the Research Problem**

River systems in many parts of Nigeria have undergone noticeable morphological transformations arising from both natural and anthropogenic alterations in basin characteristics, yet the extent, processes and controlling mechanisms of these changes remain insufficiently documented (Ijafiya et al., 2023). Increasing deforestation, cultivation on marginal and steep slopes, sand mining, poorly regulated settlement expansion and other land-use pressures have intensified runoff generation, sediment yield and channel instability in many Nigerian basins (Ogbole & Iorkua, 2019; Ijafiya et al., 2023). These pressures often alter channel geometry through bank erosion, sediment deposition, channel widening, incision and lateral migration, thereby threatening the geomorphic stability and ecological functioning of river systems. In north-central Nigeria, these processes are further compounded by highly variable rainfall, undulating topography, fragile soils and diverse lithological conditions, which together heighten erosion susceptibility and promote morphological adjustments in river channels (Adeniran et al., 2018; Abubakar & Ibrahim, 2021). Despite increasing recognition that basin characteristics exert considerable influence on river morphology, empirical studies that comprehensively integrate basin morphometric parameters, hydrological processes and morphological indicators remain limited, particularly in medium-sized tropical basins. Existing studies in Nigeria have largely emphasized isolated aspects of basin morphometry, land-use change or channel instability without sufficiently examining the combined influence of drainage characteristics, rainfall variability, land cover dynamics, soil properties and sediment processes on channel morphology (Abali & Nkii, 2024; Ocheri et al., 2024). As a result, there remains inadequate understanding of the dominant basin controls responsible for morphological adjustments in many river systems. This gap constrains the ability to predict channel responses to environmental change and weakens scientific support for sustainable watershed management and river restoration planning.

The River Kontien basin exemplifies this problem. Although observable evidence suggests recurring channel migration, bank erosion, widening of channel sections and sediment accumulation particularly after peak rainfall events, there is little scientific evidence quantifying these morphological changes or explaining the basin processes driving them. More importantly, it remains unclear which basin variables, whether drainage density, basin slope, land-use and land cover dynamics, vegetation conditions, rainfall characteristics, soil properties or sediment load, exert the greatest influence on the morphology of the river. This uncertainty creates a major

research gap, particularly because morphological responses are often basin-specific and cannot be reliably inferred from studies conducted in other river systems. While studies on the New Calabar River Basin, River Mayo Inne and River Mu sub-basin have demonstrated significant relationships between basin conditions and channel adjustments (Ijafiya et al., 2023; Abali & Nkii, 2024; Ocheri et al., 2024), such findings cannot be generalized to River Kontien due to differences in climatic setting, morphometric structure, geology and land-use conditions.

A further problem lies in the paucity of studies identifying the major basin parameters that most strongly influence channel morphology in River Kontien. While several basin characteristics may interact to shape channel form, their relative contributions and combined effects remain unknown. Without such knowledge, it is difficult to determine whether observed morphological instability is primarily driven by morphometric controls, hydro-climatic variability, land-use disturbances, sediment dynamics or their interactions. This unresolved problem represents both a scientific and practical challenge, particularly in a region where river systems support agriculture, water supply and local livelihoods.

Failure to address this knowledge gap may have serious environmental and socio-economic implications. Continued morphological instability in River Kontien could intensify flooding, accelerate loss of arable land through bank erosion, damage infrastructure, degrade aquatic habitats and reduce water quality, thereby threatening ecosystem sustainability and human livelihoods. Moreover, in the absence of empirical evidence on basin–morphology relationships, policy interventions and watershed management strategies may remain reactive, fragmented or ineffective. It is against this background that this study seeks to investigate the influence of basin characteristics on the morphology of River Kontien, with a view to providing empirical evidence on the processes shaping channel form and generating scientific information for sustainable river basin management in north-central Nigeria.

### **Objectives of the Study**

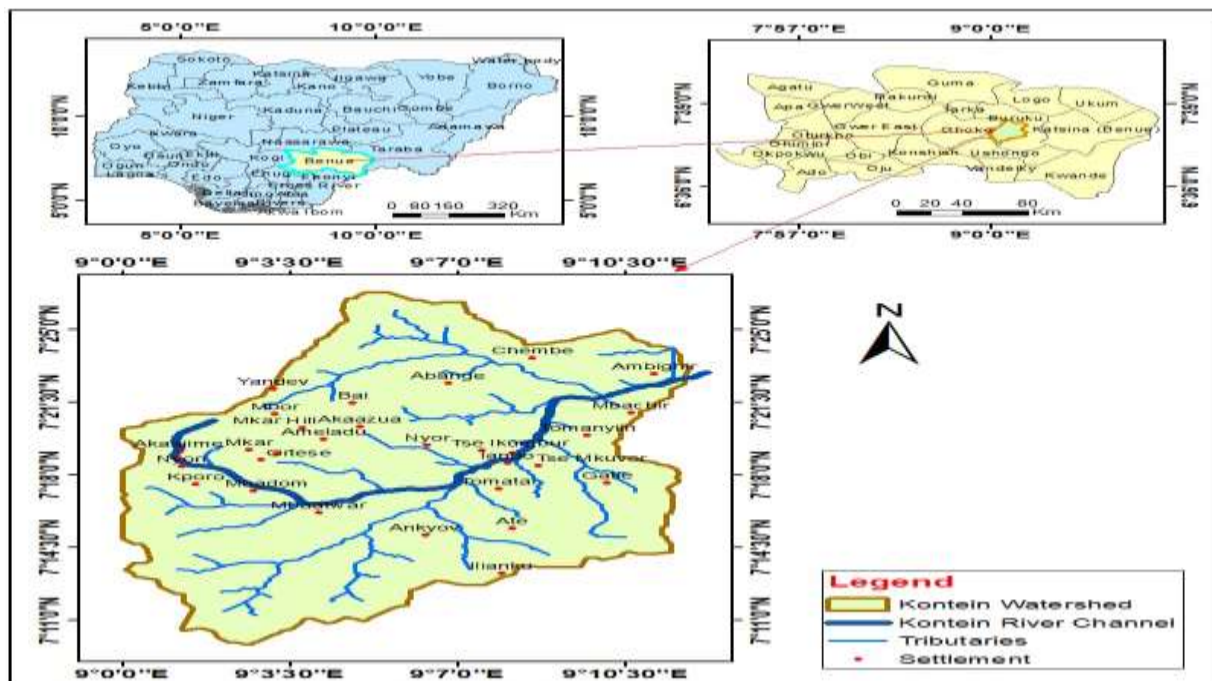
The aim of this study influence of basin morphometric characteristics on the morphology and downstream geomorphic evolution of River Kontien in Benue State, Nigeria. Specifically the study seeks to:

1. evaluate spatial variations in basin morphometric parameters across the River Kontien basin.
2. examine the relationships between basin morphometric parameters and channel morphological characteristics of River Kontien.
3. determine the dominant morphometric predictors of channel cross-sectional area and morphological adjustment in River Kontien.
4. develop a predictive explanation of how basin morphometry influences downstream morphological evolution of River Kontien.

## METHODOLOGY

This study adopted a mixed-methods approach combining field survey, laboratory analysis, Remote Sensing, and Geographic Information System (GIS) techniques to examine the influence of basin processes on the morphology of River Kontien within the study area (mapped and delineated using GIS). A descriptive survey and observational research design were employed to generate both spatial and environmental data relevant to the study objectives.

The study was conducted in the River Kontien Basin from the source of the River at Mkar hills to where it empties its water in River Buruku, Buruku Local Government Area, Benue State. River Kontien Basin is found on the Northwestern part of Benue State and cuts across the parts of Gboko and Buruku Local Government Areas. This Basin is located between latitude  $7^{\circ}10'00''N$  and  $7^{\circ}28'15''N$  as well as longitude  $9^{\circ}1'00''E$  and  $9^{\circ}12'00''E$  and it occupies a total area of 445 km<sup>2</sup> according to the high-resolution topographic analysis of the area. The basin, being a sub-basin of the River Katsina-Ala, has its main stem measuring a total of sixty-two (62) kilometres long and drains into the River Katsina-Ala. Such location situates the Kontien basin in Benue State, which is a transitional area between Nigeria's humid south and the arid north, whose social and ecological conditions and processes are highly dynamic and changing with increased rates. The location of the study area is shown in Figure 1.



Source: Researcher's Field work, 2026  
 Figure 1. Drainage Map of River Kontien

Primary data were obtained through field measurements of channel morphology (width, depth, cross-sectional area, and sinuosity), soil and sediment sampling, and direct observation of land use activities within the River Kontien basin, while secondary data were sourced from satellite imagery, topographic maps, and rainfall records obtained from the Nigerian Meteorological Agency (NiMet). The study area was delineated and mapped using GIS and Remote Sensing techniques to produce spatial representations of the basin and its geomorphological characteristics. A stratified and systematic sampling technique was used to divide the river into upper, middle, and lower reaches, from which 30 sample points and corresponding soil and sediment samples were selected for analysis. GIS and Remote Sensing were used for basin delineation, morphometric analysis, and land use/land cover mapping of the study area, while laboratory procedures were applied to determine soil and sediment properties influencing channel morphology.

Data were analyzed using descriptive statistics (mean, percentage, and standard deviation), Pearson Product Moment Correlation to determine relationships between basin processes and river morphology, multiple regression analysis to assess predictive relationships, and Analysis of Variance (ANOVA) to test differences in morphological characteristics across the river reaches. Spatial overlay techniques were further used to integrate mapped data and examine the influence of basin processes on river channel form within the study area.

## RESULTS

This result is presented in line with the objectives of the study:

### Drainage Basin Morphometric Parameters of River Kontien Basin

Data on drainage basin morphometric parameters of River Kontien in the selected 30 points in the basin such as Basin Area (BASAREA), Drainage Density (DD), Stream Order (SO), Shape Factor (SF), Bifurcation Ratio (RB), Basin Slope (BS), Relief Ratio (RR), Circulatory Ratio (RC), Elongation Ratio (RE), Form Factor (FF) and Length of Overland Flow (LOF).

**Table 4: Basin Morphometric Parameters of River Kontien Basin in the Upper Reach**

S/N	Site	Reach	BASAREA (km <sup>2</sup> )	DD (Km/ km <sup>2</sup> )	SO	SF	RB	BS	RR	RC	RE	FF	LOF (km)
1	Mkar	Upper	42	1.70	2	1.9	3.8	0.42	0.030	0.52	0.68	0.36	0.59
2	Ameladu	Upper	45	1.75	2	2.0	3.7	0.40	0.029	0.53	0.69	0.37	0.57
3	Mbadom	Upper	48	1.80	2	2.1	3.6	0.39	0.028	0.54	0.70	0.38	0.56
4	Mbaamandev	Upper	52	1.85	2	2.2	3.5	0.38	0.027	0.55	0.71	0.39	0.54
5	Tomanyiin11	Upper	55	1.90	2	2.3	3.4	0.37	0.026	0.56	0.72	0.40	0.53
6	Anikyov	Upper	58	1.95	3	2.4	3.3	0.36	0.025	0.57	0.73	0.41	0.51
7	Mkar Hills	Upper	38	1.65	2	1.8	3.9	0.45	0.033	0.50	0.66	0.34	0.61
8	Ilianku	Upper	40	1.68	2	1.9	3.8	0.44	0.032	0.51	0.67	0.35	0.60
9	Bai	Upper	60	2.00	3	2.5	3.2	0.35	0.024	0.58	0.74	0.42	0.50
10	Akaajime	Upper	35	1.60	2	1.7	4.0	0.46	0.034	0.49	0.65	0.33	0.63

Source: Author's Field Work, 2026

Table 1 revealed that the upper reach of River Kontien is characterized by small basin sizes, steep slopes, and low drainage integration, indicating a youthful geomorphic stage. Basin area ranges from 35 km<sup>2</sup> at Akaajime to 60 km<sup>2</sup> at Bai, showing limited hydrological contribution at headwater locations. Drainage density is relatively low to moderate, ranging from 1.60 to 2.00 km/km<sup>2</sup>, reflecting limited channel development and moderate infiltration conditions. Stream order is mainly second order, confirming an early stage of drainage development. The basin shape is predominantly elongated, with low form factor values (0.33–0.42) and circularity ratios between 0.49 and 0.58, indicating delayed runoff concentration. Basin slope is steep (0.35–0.46) and relief ratio is relatively high (0.024–0.034), showing strong erosional energy and vertical incision. Overall, the upper reach reflects a youthful drainage basin dominated by steep slopes, elongated basin shape, and active erosion processes.

### Basin Morphometric Parameters of River Kontien Basin at the Middle Reach

Data on drainage basin morphometric parameters of River Kontien in the selected 30 points in the basin such as Basin Area (BASAREA), Drainage Density (DD), Stream Order (SO), Shape Factor (SF), Bifurcation Ratio (RB), Basin Slope (BS), Relief Ratio (RR), Circulatory Ratio (RC), Elongation Ratio (RE), Form Factor (FF) and Length of Overland Flow (LOF).

**Table 2: Basin Morphometric Parameters of River Kontien Basin at the Middle Reach**

S/N	Site	Reach	BASAREA (km <sup>2</sup> )	DD (Km/ km <sup>2</sup> )	SO	SF	RB	BS	RR	RC	RE	FF	LOF (km)
11	Tomatar Mbachigh	Middle	70	2.10	3	2.6	3.1	0.34	0.023	0.59	0.75	0.43	0.48
12	Agasha	Middle	75	2.15	3	2.7	3.0	0.33	0.022	0.60	0.76	0.44	0.47
13	Mkovur	Middle	78	2.20	3	2.8	2.9	0.32	0.021	0.61	0.77	0.45	0.45
14	Tomataan Manga	Middle	82	2.25	3	2.9	2.8	0.31	0.020	0.62	0.78	0.46	0.44
15	Kporo	Middle	85	2.30	3	3.0	2.7	0.30	0.019	0.63	0.79	0.47	0.43
16	Gyura	Middle	88	2.35	3	3.1	2.6	0.29	0.018	0.64	0.80	0.48	0.43
17	Tse Kumbur	Middle	92	2.40	3	3.2	2.5	0.28	0.017	0.65	0.81	0.49	0.42
18	Ambighir	Middle	95	2.45	3	3.3	2.4	0.27	0.016	0.66	0.82	0.50	0.41
19	Chembe	Middle	98	2.50	3	3.4	2.3	0.26	0.015	0.67	0.83	0.51	0.40
20	Ambigbere	Middle	102	2.55	4	3.5	2.2	0.25	0.014	0.68	0.84	0.52	0.39

**Source: Author's Field Work, 2026**

Table 2 shows the middle reach which represents a transition zone between youthful and mature stages. Basin area increases significantly from 70 km<sup>2</sup> at Tomatar Mbachigh to 102 km<sup>2</sup> at Ambigbere, indicating greater tributary contribution. Drainage density increases to 2.10–2.55 km/km<sup>2</sup>, while stream order rises to third order, showing improved drainage integration. Stream frequency also increases (2.6–3.5 streams/km<sup>2</sup>), indicating a denser and more organized channel network. Basin slope reduces to 0.25–0.34, and relief ratio declines to 0.014–0.023, showing reduced erosional energy. Basin shape becomes more balanced, with increasing form factor (0.43–0.52) and circularity ratio (0.59–0.68), indicating improving basin compactness.

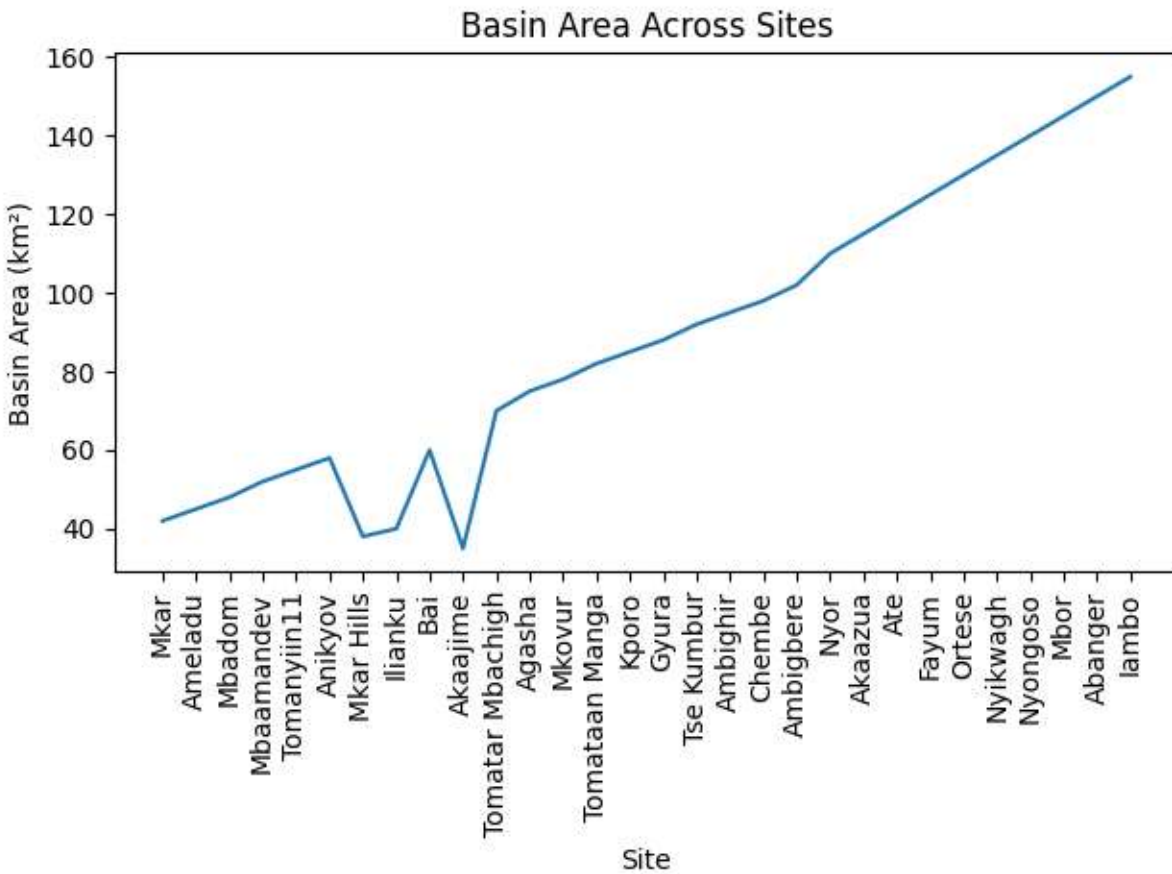
Overall, the middle reach reflects a transitional geomorphic stage with increasing drainage integration, moderate slopes, and mixed erosional–depositional processes.

**Table 4: Basin Morphometric Parameters of River Kontien Basin in the Lower Reach**

S/N	Site	Reach	BASAREA (km <sup>2</sup> )	DD (Km/ km <sup>2</sup> )	SO	SF	RB	BS	RR	RC	RE	FF	LOF (km)
21	Nyor	Lower	110	2.60	4	3.6	2.1	0.24	0.013	0.69	0.85	0.53	0.38
22	Akaazua	Lower	115	2.65	4	3.7	2.0	0.23	0.012	0.70	0.86	0.54	0.38
23	Ate	Lower	120	2.70	4	3.8	1.9	0.22	0.011	0.71	0.87	0.55	0.37
24	Fayum	Lower	125	2.75	4	3.9	1.8	0.21	0.010	0.72	0.88	0.56	0.36
25	Ortese	Lower	130	2.80	4	4.0	1.7	0.20	0.009	0.73	0.89	0.57	0.36
26	Nyikwagh	Lower	135	2.85	4	4.1	1.6	0.19	0.008	0.74	0.90	0.58	0.35
27	Nyongoso	Lower	140	2.90	4	4.2	1.5	0.18	0.007	0.75	0.91	0.59	0.34
28	Mbor	Lower	145	2.95	4	4.3	1.4	0.17	0.006	0.76	0.92	0.60	0.34
29	Abanger	Lower	150	3.00	4	4.4	1.3	0.16	0.005	0.77	0.93	0.61	0.33
30	Iambo	Lower	155	3.05	4	4.5	1.2	0.15	0.004	0.78	0.94	0.62	0.33

**Source: Author's Field Work, 2026**

Table 3 reveals that the lower reach shows a fully mature drainage system with the largest basin areas, ranging from 110 km<sup>2</sup> at Nyor to 155 km<sup>2</sup> at Iambo, reflecting cumulative upstream drainage contribution. Drainage density is highest, ranging from 2.60 to 3.05 km/km<sup>2</sup>, and stream order reaches fourth order, indicating a well-developed drainage network. Stream frequency is also highest (3.6–4.5 streams/km<sup>2</sup>), showing intense channel development. Basin slope is very gentle (0.24–0.15) and relief ratio is very low (0.013–0.004), indicating low erosional energy and dominance of depositional processes. Basin shape becomes more compact, with higher circularity ratios (0.69–0.78) and form factor values (0.53–0.62). Overall, the lower reach reflects a mature fluvial environment characterized by gentle slopes, efficient drainage, floodplain development, and stable channel systems.



**Figure 1 shows basin area across sites.**  
**Source: Author's Analysis, 2026**

Figure 3 shows that basin area varies systematically across the sampled sites of River Kontien and exhibits a clear longitudinal increase from the upper reach through the middle reach to the lower reach of the drainage basin, reflecting progressive hydrological integration along the river course.

**Relationship between Basin Morphometry and River Morphology****Table 5: Correlation Matrix of Basin Morphometric Variables and River Kontien Morphological Characteristics**

		Drainage Density	Bifurcation Ratio	Basin Slope	Relief Ratio	Channel Width	Channel Depth	Cross Section Area	Sinuosity
Drainage Density	Pearson Correlation Sig. (2-tailed)	1							
	N	30							
Bifurcation Ratio	Pearson Correlation Sig. (2-tailed)	.991**	1						
	N	30	30						
Basin Slope	Pearson Correlation Sig. (2-tailed)	.998**	.989**	1					
	N	30	30	30					
Relief Ratio	Pearson Correlation Sig. (2-tailed)	.992**	.997**	.991**	1				
	N	30	30	30	30				
Channel Width	Pearson Correlation Sig. (2-tailed)	-.984**	-.993**	-.985**	- .995**	1			
	N	30	30	30	30	30			
Channel Depth	Pearson Correlation Sig. (2-tailed)	-.962**	-.981**	-.962**	- .983**	.993**	1		
	N	30	30	30	30	30	30		
Cross Section Area	Pearson Correlation Sig. (2-tailed)	-.951**	-.974**	-.952**	- .976**	.989**	.998**	1	
	N	30	30	30	30	30	30	30	
Sinuosity	Pearson Correlation Sig. (2-tailed)	-.982**	-.991**	-.983**	- .995**	.998**	.994**	.990**	1
	N	30	30	30	30	30	30	30	30

\*\* . Correlation is significant at the 0.01 level (2-tailed).

**Source: Author's Field Work, 2026**

The correlation results reveal a very strong and statistically significant relationship ( $p < 0.01$ ) between basin morphometric variables and river channel characteristics in the River Kontien basin. The analysis shows that drainage density, basin slope, bifurcation ratio, and relief ratio are strongly and positively interrelated, with correlation coefficients ranging from  $r = 0.989$  to  $0.998$ . This indicates that these morphometric variables function as an integrated geomorphic system, where

steep slopes are associated with higher relief, denser drainage networks, and more complex stream branching patterns, reflecting a closely linked basin structure controlled by topography and underlying geology.

In contrast, all these morphometric variables exhibit strong negative relationships with channel morphological characteristics. Specifically, drainage density shows a strong inverse relationship with channel width ( $r = -0.984$ ), relief ratio has a very strong negative correlation with sinuosity ( $r = -0.995$ ), and basin slope is negatively related to cross-sectional area ( $r = -0.952$ ). These results indicate that areas characterized by steep slopes and high relief tend to produce narrow, shallow, and relatively straight channels, as the dominant vertical energy promotes incision rather than lateral expansion. Conversely, lower-relief environments are associated with wider, deeper, and more sinuous channels, reflecting reduced gradient energy and increased lateral channel development.

Furthermore, the channel morphological variables themselves channel width, depth, cross-sectional area, and sinuosity are strongly and positively correlated with one another, with values ranging from  $r = 0.989$  to  $0.998$ . This demonstrates a coordinated downstream adjustment process, where increases in discharge and sediment load lead simultaneously to channel widening, deepening, and increased meandering.

**Table 6: Multi-Regression of Basin Morphometric Variables as Predictors of Cross-Sectional Area of River Kontien**

Predictor Variable	R	R <sup>2</sup>	Df	F	B	T	Sig
Constant	.985	.971	25	207.623		6.590	.000
Drainage Density					1.184	1.999	.057
Bifurcation Ratio					-.424	-.927	.363
Basin Slope					-.090	-.161	.874
Relief Ratio					-1.638	-3.281	.003

**a. Dependent Variable: Cross Section Area**

The regression model demonstrates a very high explanatory power, with an  $R^2$  value of 0.971, indicating that 97.1% of the variation in channel cross-sectional area is jointly explained by the selected basin morphometric variables. This implies that river channel size in the River Kontien basin is strongly controlled by underlying geomorphic conditions rather than random variation. Among the individual predictors, relief ratio emerges as the most significant factor, with a negative coefficient ( $\beta = -1.638$ ,  $p = 0.003$ ). This indicates that areas with higher relief are associated with smaller channel cross-sectional areas, largely because steep terrain enhances vertical erosion and limits lateral channel expansion. In such environments, river energy is concentrated on downcutting rather than widening, resulting in relatively confined channels. Drainage density shows a weak positive influence on channel cross-sectional area ( $\beta = 1.184$ ,  $p = 0.057$ ), suggesting that more densely dissected basins may slightly promote channel enlargement through increased

runoff concentration, although its effect is not statistically strong. In contrast, both bifurcation ratio and basin slope are not statistically significant, indicating that their direct influence on channel cross-sectional area is limited within this basin context. The results confirm that relief ratio is the dominant controlling variable shaping channel cross-sectional area in the River Kontien basin, reinforcing the central role of topographic energy in governing river channel morphology and downstream fluvial adjustment processes.

## DISCUSSION OF FINDINGS

The first finding revealed that basin morphometric parameters of River Kontien vary systematically along the longitudinal profile of the basin, showing a clear downstream increase in basin area (35–60 km<sup>2</sup> in the upper reach, 70–102 km<sup>2</sup> in the middle reach, and 110–155 km<sup>2</sup> in the lower reach), drainage density (1.60–2.00 km/km<sup>2</sup> upstream, 2.10–2.55 km/km<sup>2</sup> midstream, and 2.60–3.05 km/km<sup>2</sup> downstream), stream order (2nd order upstream, 3rd order midstream, and 4th order downstream), and stream frequency, while basin slope (0.46–0.35 upstream to 0.24–0.15 downstream) and relief ratio (0.034–0.025 upstream to 0.013–0.004 downstream) consistently decrease. This finding means that River Kontien exhibits a progressive transition from youthful geomorphic conditions in the upper reach, characterized by steep slopes, small basin areas, and limited channel integration, to mature and stabilized fluvial conditions in the lower reach where basin expansion, higher drainage integration, and reduced relief dominate. This also indicates increasing hydrological efficiency and sediment accumulation downstream, which supports floodplain development and lateral channel adjustment. The finding agrees with Sreedevi et al. (2018) who observed that basin slope and drainage density systematically control runoff velocity and sediment transport in tropical basins, and with Avinash et al. (2018) who reported that decreasing relief ratio downstream reflects increasing watershed maturity and reduced erosional energy. Similarly, Altaf et al. (2021) found that downstream increases in basin area and stream order signify a shift from erosional headwater systems to depositional floodplain environments, confirming the same geomorphic transition observed in River Kontien.

The second finding revealed that basin shape parameters including circularity ratio (0.49–0.58 upstream, 0.59–0.68 midstream, and 0.69–0.78 downstream), elongation ratio (0.65–0.74 upstream to 0.75–0.94 downstream), and form factor (0.33–0.42 upstream to 0.43–0.62 downstream) show a progressive transformation from elongated basin forms in the upper reach to more compact and nearly circular basin forms in the lower reach, while length of overland flow decreases from 0.68–0.50 km upstream to 0.38–0.33 km downstream. This finding means that basin geometry becomes progressively more efficient in transmitting runoff downstream, reducing flow travel distance and increasing the speed of hydrological response as the basin evolves. It also indicates increasing basin integration and improved drainage connectivity in downstream sections, which enhances flood peak synchronization and channel adjustment processes. The finding agrees with Farhan et al. (2018) who reported that higher circularity ratios indicate more mature basins with efficient runoff concentration, and with Nitheshnirmal et al. (2021) who found that increasing

elongation ratio reflects advanced hydrological adjustment and basin maturity. Similarly, Pandey et al. (2023) established that decreasing overland flow length enhances runoff concentration and sediment delivery efficiency, which supports the observed downstream morphological efficiency in River Kontien.

The third finding revealed that the correlation analysis shows a very strong and statistically significant relationship ( $p < 0.01$ ) between basin morphometric variables and river channel characteristics. Drainage density, basin slope, bifurcation ratio, and relief ratio are strongly and positively correlated with each other ( $r = 0.989-0.998$ ), indicating that they function as an integrated geomorphic system controlling basin evolution. However, all these morphometric variables show strong negative correlations with channel form variables, such as drainage density with channel width ( $r = -0.984$ ), relief ratio with sinuosity ( $r = -0.995$ ), and basin slope with cross-sectional area ( $r = -0.952$ ). This finding means that areas with steep slopes, high relief, and dense drainage networks produce narrow, shallow, and less sinuous channels due to dominant vertical erosion and limited lateral development, while low-relief downstream environments encourage wider, deeper, and more sinuous channels due to reduced gradient energy and increased depositional processes. Conversely, channel variables such as width, depth, cross-sectional area, and sinuosity are strongly positively correlated with each other ( $r = 0.989-0.998$ ), indicating coordinated downstream channel adjustment. The finding agrees with Singh et al. (2018) who established that morphometric variables significantly control channel geometry in tropical river basins, and with Alam et al. (2020) who found that basin slope and drainage density are key determinants of channel narrowing and incision processes. Similarly, Kumar et al. (2021) reported that relief ratio strongly governs downstream channel evolution through its control on erosional energy, which supports the pattern observed in River Kontien.

The fourth finding revealed that the multiple regression analysis shows a very high explanatory power ( $R^2 = 0.971$ ), indicating that 97.1% of the variation in channel cross-sectional area is explained by basin morphometric variables (drainage density, bifurcation ratio, basin slope, and relief ratio). Among the predictors, relief ratio is the most significant factor ( $\beta = -1.638$ ,  $p = 0.003$ ), showing a strong negative influence on channel cross-sectional area, meaning that higher relief reduces channel size by enhancing vertical erosion and limiting lateral channel expansion. Drainage density shows a weak positive influence ( $\beta = 1.184$ ,  $p = 0.057$ ), suggesting a marginal contribution to channel enlargement through runoff concentration, while bifurcation ratio and basin slope are statistically insignificant predictors of channel size in the basin. This finding means that topographic energy, particularly relief ratio, is the dominant control of channel morphology in River Kontien, while other morphometric factors play secondary or indirect roles in shaping channel cross-sectional characteristics. The finding agrees with Alam et al. (2020) who emphasized the dominant role of relief in controlling channel incision and morphology, and with Singh et al. (2018) who found that basin slope and drainage characteristics jointly influence channel development but with relief exerting the strongest control. Similarly, Kumar et al. (2021)

reported that relief ratio is the most reliable predictor of fluvial channel evolution in tropical drainage basins due to its direct control on erosional energy and sediment transport dynamics.

## **CONCLUSION**

Based on the findings, the study concluded that the River Kontien basin exhibits a clear downstream geomorphic transformation controlled primarily by basin morphometric parameters. The basin shows progressive increases in basin area, drainage density, stream order, and stream frequency from the upper to the lower reach, while basin slope, relief ratio, and overland flow length consistently decrease, indicating a shift from youthful, steep, and erosion-dominated headwaters to mature, low-gradient, and deposition-influenced downstream environments. Basin shape parameters also transition from elongated forms in the upper reach to more compact and circular configurations downstream, reflecting improved drainage integration and hydrological efficiency. The correlation and regression analyses further confirm that basin morphometry exerts a strong and statistically significant control on river channel characteristics, with relief ratio emerging as the most dominant predictor of channel cross-sectional area. Overall, the study concludes that river channel morphology in the River Kontien basin is fundamentally governed by interacting morphometric variables, particularly topographic relief and drainage organization, which collectively determine the spatial variation in channel form and fluvial processes across the basin.

## **Recommendations**

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

1. Integrated watershed management should be prioritized by relevant environmental and planning authorities to address the strong influence of morphometric characteristics (especially relief ratio, drainage density, and basin slope) on river channel form. This will help in regulating erosion processes and maintaining channel stability across the River Kontien basin.
2. Soil conservation and erosion control measures should be intensified in the upper reach of the basin, where steep slopes, high relief ratios, and high drainage density promote rapid runoff and vertical incision. Practices such as afforestation, terracing, and controlled land use should be adopted to reduce excessive sediment yield and channel degradation.
3. Floodplain management and sustainable land-use planning should be strengthened in the middle and lower reaches, where increasing basin area, stream order, and circularity ratio enhance flood risk and channel widening. Development activities should be carefully regulated to minimize flood vulnerability and preserve the natural geomorphic balance of the river system.

## REFERENCES

- Abubakar, A., & Ibrahim, M. (2021). Land use change and fluvial response dynamics in North Central Nigeria. *Journal of Environmental Hydrology*, 29(4), 215–230.
- Adebayo, O. A., Salami, R. B., & Oyeleke, M. O. (2020). Basin transformation and hydrological response in selected West African catchments. *African Journal of Earth and Environmental Sciences*, 12(2), 89–104.
- Alam, A., Singh, S., & Kumar, R. (2020). Morphometric analysis and its influence on river channel characteristics in a tropical drainage basin. *Journal of Hydrology and Earth System Sciences*, 24(3), 145–158.
- Altaf, S., Meraj, G., & Romshoo, S. A. (2021). Morphometric analysis to infer hydrological behaviour of a Himalayan watershed. *Environmental Earth Sciences*, 80(6), 1–15.
- Andualem, T., Bekele, M., & Desta, H. (2024). Impacts of land-use change on channel instability in tropical river basins. *Geomorphology*, 452, 109112.
- Anya, C. J., Okeke, F. C., & Udo, I. A. (2017). Watershed characteristics and channel morphology dynamics in southeastern Nigeria. *Nigerian Journal of Hydrological Sciences*, 5(1), 44–58.
- Avinash, K., Jayappa, K. S., & Deepika, B. (2018). Drainage morphometry and its influence on basin development: A GIS-based approach. *Geomatics, Natural Hazards and Risk*, 9(1), 1–20.
- Chen, X., Liu, Y., & Zhang, H. (2023). Basin controls on river morphology under changing hydro-climatic conditions. *Catena*, 227, 107145.
- Eze, B. E., & Ologunorisa, T. E. (2020). Fluvial adjustments and morphological variability in selected Nigerian river systems. *Journal of Geography and Regional Planning*, 13(6), 135–148.
- Farhan, Y., Anaba, O., & El Gayar, M. (2018). Morphometric analysis and flood susceptibility mapping of Wadi Basin. *Arabian Journal of Geosciences*, 11(10), 1–16.
- Gazon, P., Moreau, S., & Klein, J. (2023). Sediment dynamics and channel adjustment in alluvial rivers under environmental change. *Earth Surface Processes and Landforms*, 48(11), 2673–2689.
- Gregory, K. J., Toone, J., & Hooke, J. (2019). Contemporary perspectives in fluvial geomorphology and river channel adjustment. *Progress in Physical Geography*, 43(5), 665–689.
- Gurnell, A. M., Bertoldi, W., & Corenblit, D. (2022). River channel adjustment, geomorphic thresholds and floodplain evolution. *River Research and Applications*, 38(7), 1174–1190.
- Ijafiya, A. A., Bwala, M. A., & Hamidu, S. (2023). Morphological changes in the lower course of River Mayo Inne, Adamawa State, Nigeria. *Journal of Environmental Geography*, 16(2), 71–85.
- Kabir, M., Bello, A., & Haruna, S. (2024). Rainfall variability and basin response in sub-Saharan African river systems. *Hydrological Processes*, 38(5), e15127.

- Kumar, P., Gupta, R., & Sharma, A. (2021). Influence of morphometric parameters on drainage basin evolution. *International Journal of River Basin Management*, 19(4), 377–390.
- Mensah, E., Boateng, K., & Asare, P. (2021). Basin disturbance and river instability in West African tropical catchments. *African Geographical Review*, 40(3), 233–249.
- Nitheshnirmal, S., Raj, G., & Kumar, P. (2021). Basin elongation ratio and watershed development assessment. *Environmental Monitoring and Assessment*, 193(7), 1–14.
- Nkwocha, E., & Eboh, C. (2023). Basin dynamics and channel morphology in tropical African rivers. *Journal of African Earth Sciences*, 199, 104836.
- Ocheri, M. I., Ochai, F. C., & Agber, P. I. (2024). Morphometric analysis of River Mu sub-basin in the Lower Benue Basin, Nigeria. *Applied Water Science*, 14(3), 76–91.
- Ogbole, J. O., & Iorkua, S. A. (2019). Anthropogenic land-use change and runoff dynamics in Nigerian drainage basins. *Environmental Monitoring and Assessment*, 191(8), 512.
- Pandey, A., Singh, M., & Sharma, V. (2023). Overland flow length and hydrological response in tropical river basins. *Hydrological Processes*, 37(2), e14789.
- Saha, S., Roy, P., & Das, D. (2019). Stream frequency and its role in watershed hydrology. *Geocarto International*, 34(8), 890–905.
- Singh, A., Gupta, R., & Kumar, P. (2018). Morphometric controls on drainage basin evolution and channel morphology. *Journal of Hydrology*, 565, 1–14.
- Singh, R., Prasad, V., & Kumar, A. (2021). Morphometric controls on channel geometry and discharge response in tropical watersheds. *Journal of Hydrology*, 603, 126989.
- Singh, V., Kumar, R., & Sharma, P. (2022). Drainage morphometry and watershed development in humid tropical regions. *Environmental Earth Sciences*, 81(3), 1–18.
- Sreedevi, P. D., Sreekanth, P. D., & Ahmed, S. (2018). Morphometric analysis of drainage basins using GIS techniques. *Journal of Geomorphology*, 312, 45–58.
- Tersoo, P. T., & Ahile, U. T. (2019). Relief characteristics and channel instability in the Lower Benue Basin, Nigeria. *Nigerian Journal of Geomorphology and Environmental Management*, 7(2), 56–72.
- Thomas, J., Joseph, S., & George, A. (2020). Basin slope and its influence on fluvial processes. *Quaternary International*, 550, 123–134.