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PRIORITIZATION OF DADIN KOWA CATCHMENT SUB-BASINS FOR SOIL EROSION MANAGEMENT

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Abstract

Dadin Kowa Dam was constructed to provide water for agricultural activities and generation of electricity. However, the catchment of the dam has been faced with hydrological hazards especially soil erosion and flooding. Therefore, in regions characterized by diverse topography and hydrological complexity, such as the Dadin Kowa Dam's catchment in understanding the spatial distribution of erosion susceptibility is paramount for effective erosion management. Geospatial techniques were used to acquire Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data which was used to delineate the Dadin Kowa catchment extent and to extract the streams and rivers within the catchment. The DEM data were also used to delineate fifteen sub-basins within the catchment. Fifteen morphometric parameters were also used for the assessment. The prioritization of the sub-basin for soil erosion was achieved by using the mean value of each of the parameters to categorize erosion risk into three: high, moderate and low. The results revealed that calculated morphometric parameters reflect the susceptibility of each of the basin to soil erosion. The prioritization and ranking of the sub-basins based on the adopted methods was also found to be effective as the sub-basins which were ranked as high risk are mainly those in the highland and Jos Plateau where soil erosion has been a serious hazard. The assessment of other hydrological hazard such as flooding using sub-basin prioritization is suggested for further studies.

Keywords: Dadin Kowa catchment, Basin prioritization, Morphometric analysis, Soil erosion

1. Introduction

A watershed is an area of land draining into a common body of water, such as a river, wetland, reservoir, or ocean (Caleb & Beth, 2018). It is separated from other watersheds by high points in the area such as hills or slopes. The term watershed is sometimes used interchangeably with the terms drainage basin and catchment but Caleb & Beth, (2018) distinguish them from each other: River Basin is the land contributing water to a river system, from the headwaters to the river mouth. Watershed in the other hand is the land contributing water to a tributary of the river system, which means the river basin may consist of several watersheds. While catchment was described as a small area of land contributing water to a specific stream or to a specific feature, such as a reservoir. The term catchment has been adapted for this study in line with Caleb & Beth, (2018) seeing that the Dadin Kowa reservoir is an entrapment on the larger Gongola Basin. Covino *et al*, (2021) in their work on spatial organization of hydrological and biogeochemical fluxes concluded that watershed is the most natural geomorphologic spatial unit on the terrestrial landscape because it contains and defines the geophysical and ecological processes related to surface water and its movement to a common point. Thomas *et al.,* (2004) stated that watershed comprises biophysical and ecological (such as provision of water of sufficient quantity and quality) as well as economic (such as sustainable provision of natural resource products) or social and cultural (such as protection and improvement of livelihoods) goods and services. Therefore, human modification of these units, their soils and vegetation have a direct impact upon the delivery of water, sediments, and nutrients into these river drainage systems.

The functions of catchment cannot be overemphasized, Shukla (2019) Categorized the functions as follows: Ecological functions which include ensuring water flow and quality within the catchment and further downstream and also provision of erosion control, soil fertility, biodiversity, clean air and carbon sequestration; Economic functions such as production of food, fuel wood, timber, water, fish, and hydraulic energy required for the basic needs of the local population; Support income generating opportunities especially sustenance of livelihoods; Social and Cultural functions among which are maintenance of social structures, protect and develop knowledge and lifestyle arrangements , maintain and revitalize cultural identity and values and also provide recreational opportunities.

The importance of this catchment extends beyond its geographical boundaries, serving as a lifeline for communities that depend on its waters for sustenance and livelihoods. Though watersheds are saddled with so much benefits to man and his environment, but anthropogenic as well as natural factors have contributed to the degradation of most watersheds in the world (Bashir and Ikusemoran2019). Among the major environmental hazards in in the catchment is soil erosion. The erosion threat is not merely an ecological concern; it directly jeopardizes the integrity of the Dadin Kowa Dam, risking sedimentation that could compromise its effectiveness in water storage and supply. As such, the need for strategic erosion management within the catchment is paramount to ensure the sustainability of this vital water source (AbdulRazak *et al.,* (2021). Soil erosion poses a significant environmental challenge, impacting landscapes, water quality, and infrastructure. In regions characterized by diverse topography and hydrological complexity, such as the Dadin Kowa Dam catchment in Gombe State, understanding the spatial distribution of erosion susceptibility is paramount for effective erosion management. Given the extensive nature of the Dadin Kowa Dam catchment and its significance in supporting agricultural activities and water supply, prioritizing sub-basins for erosion management is imperative. By evaluating the morphometric properties of each sub-basin, this study aims to provide a robust foundation for targeted erosion control strategies. The findings will not only inform sustainable land use planning but also contribute to preserving the ecological integrity of the catchment, ensuring the longevity of the Dadin Kowa Dam as a vital water resource.

2. The Study Area

The Dadin Kowa basin is located between Latitude 8° 30'N to 11° 30'N and Longitude 8° 50'E to 12° 20'E (Dawha*et al.*, 2023). The total catchment area that contributes water to the reservoir was estimated to be 32,155.1 km^2. The Gongola River enters the reservoir as an 11th-order stream (based on the 30-meter resolution SRTM DEM Data). The basin has its source at Jos Plateau in Plateau State of Nigeria. It is a long, leaf-like basin that drains portions of 5 states of Plateau, Bauchi, Yobe, Borno, and Gombe States.

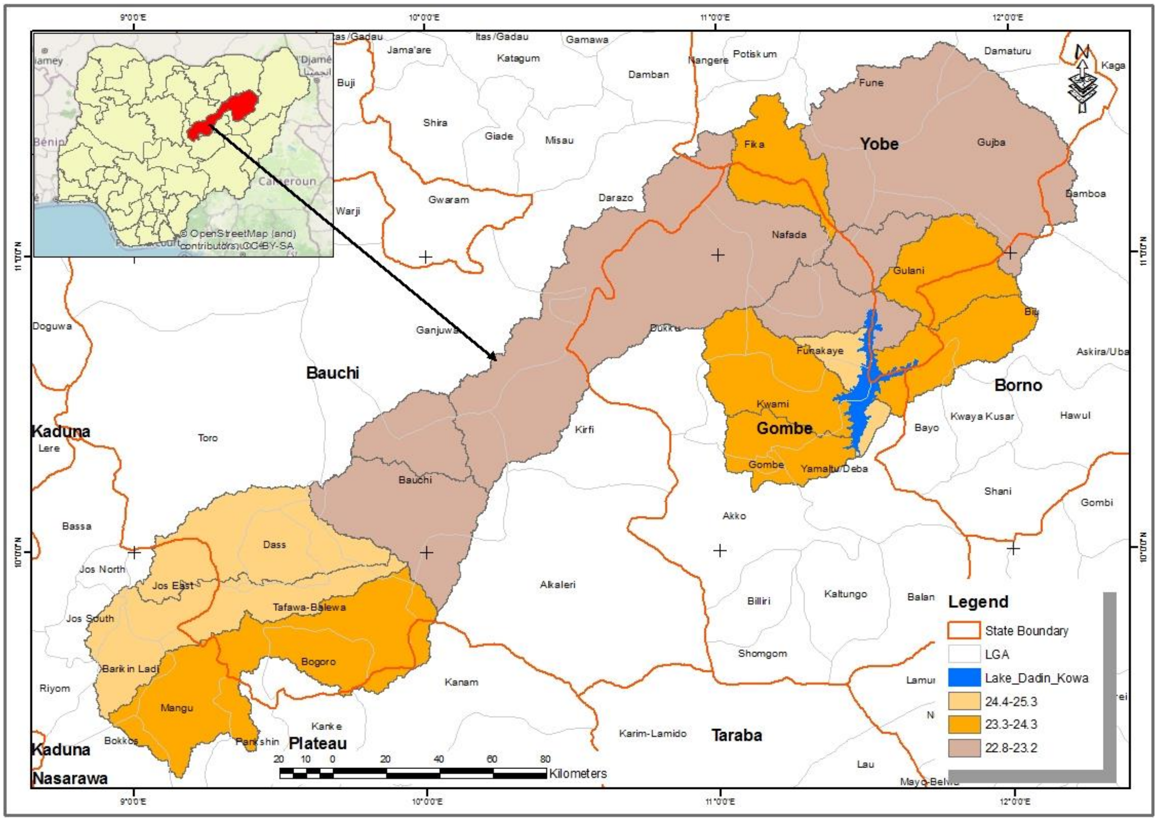

Figure 1. Dadin Kowa catchment showing Dadin Kowa Dam
Source: Researcher's Analysis

Dawha*et al.*, (2023) reiterated that 'the central geographical feature of the Dadin Kowa dam catchment is the Dadin Kowa dam itself''. The dam was constructed for water storage and management andfor sustainable utilization of the region's water resources. The catchment also serves as source of water supply that are being utilized for agricultural, industrial, and domestic purposes (Dawha*et al.*, 2023). The Dadin Kowa dam catchment consists of complex geologic structure which comprises the crystalline Basement Complex rocks and sedimentary formations (Dawha*et al.*, 2023). The upper course of the basin is the Jos Plateau with high relief and hilly environment. The basin possesses substantial ecological resources, including forests, grasslands, or other forms of natural vegetation (Dawha, *et al.*, 2023). According to AbdulRazak *et al.*, (2021), the Gongola basin (which the Dadin Kowa is a catchment of) covers drainage area of about 56, 000 km^2 with about 570 km River Length which is the largest tributary to River Benue, with an estimated annual run off volume of 60 billion m^3. The catchment is located within two climatic zones namely the Guinea Savannah and the Sudan Savanna zones. Rainfall occurs between May and September with variation of the mean annual rainfall from 1200mm around the Jos Plateau to about 700 mm in the North East. The catchment's annual temperature also varies, though generally about 26^0C but lower on the Jos Plateau.

3. Methodology

3.1 Delineation of basin and sub-basins and extraction of streams

The extent of Dadin Kowa Basin was delineated by the use of Basin delineation module of ArcGIS 10.8. The delineated basin formed the shape file of the study. The shape file was used to extract the study area from the SRTM DEM data. The extracted DEM was processed to delineate fifteen (15) sub-basins within the catchment. The streams and rivers within the basin were also delineated using the DEM data. The stream order was numbered automatically by the use of the stream ordering module of ArcGIS 10.8.

3.2 Calculations of Morphometric Characteristics

While GIS techniques were adopted to derive the sub-basins area and perimeter, other parameters were derived by using their appropriate formula as presented in Tables 1-3.

3.3 Prioritization of Sub-basins for soil erosion susceptibility

Sub-basins are prioritized in order to find critical areas with high erosion activity so that the proper conservation measures can be performed to reduce soil erosion in the basin. According to Biswas *et al.,* (2014) morphometric parameters which are termed Erosion Risk Assessment Parameters can be used to prioritize sub-basin for erosion management. These parameters are termed: linear parameters (drainage density, stream frequency, mean bifurcation ratio, drainage texture, length of overland flow) which are directly related to the erodibility of the basin while shape parameters which include elongation ratio, circularity ratio, form factor, basin shape, and compactness coefficient have inverse relationships with erodibility of the basin (Nooka*et. al.*, 2005). The highest value of the linear parameters was evaluated as rank 1, (according to the number of sub-basins under consideration) the second highest value as rank 2, the ranking was made till the least value.

After ranking each of the indicators, the indicators were prioritized, and a compound value (Cp) was computed. The compound factor was calculated by adding the values of all the linear and shape parameters, and divide them by the total number of the parameters. High Cp values were assigned low priority, whilst low Cp values were assigned high priority. Based on the compound values (Cp), the sub-basins were then categorized into three priority zones: High (less than 7.45), Medium (7.45-8.66), and Low (8.67 and above) Ali and Ali (2014).

Table 1. Linear Basin morphometric Parameters and their functions and Applications

S/ No.	Morphometric Parameters	Equation/ Definition	Reference	Functions of the parameters	Application and Relevance in this Study
1	Stream order (u)	Hierarchical order	Strahler 1952,	Establishes the hierarchical relationship of the streams in the basin which reflects their relative discharge	stream ordering (u) and deriving Bifurcation Ration (Rb)
2	Stream Length (L_u)	Length of the stream of order u	Horton 1945	This refers to the total length of each order of the streams in the basin and reveals surface runoff characteristics	Driving the Linear attributes (Lu), Lūand (Rl)
3	Mean steam length ($l_{\bar{u}}$)	Lsm=Lu/Nu; Where, Lu=Mean stream length of a given order u in (km), Nu=Number of stream segment. of order u	Horton 1945	used to determine the mean (ū)stream length of order u	Determining the mean length in order u
4	Stream length ratio (RL)	RL= Lu / Lu-1 Where, Lu= Total stream length of order (u), Lu-1=The total stream length of its next lower order.	Horton 1945	helps determine the level of maturity in the river's geomorphic development and also reveal the differences in slope between the different stream orders	Determine the stage of the stream
5	Bifurcation Ratio (Rb)	Rb = Nu / Nu+1 Where, Nu=Number of stream segments present in the given order Nu+1= Number of segments of the next higher order	Schumm 1956	Helps to determine how well the basin is drained of excess water	Determine how well the basin is drained

Source: Adapted from Babu, (2016) and Walker *et ael.*,(2014)

Table 2. Basin Relief morphometric parameters, their functions and applications

S/ No.	Morphometric Parameters	Equation/ Definition	Reference	Functions of the parameters	Application and Relevance in this Study
1	Basin relief (Bh)	Vertical distance between the lowest and highest points of basin.	Schumm 1956	An indicator of the gradient of the slope basin	An index for determining absolute height
2	Relief Ratio (Rh)	Rh = Bh / Lb Where, Bh=Basin height, Lb=Basin length	Schumm 1956	Measures the overall steepness of the basin and is an indicator of the intensity of erosion in the basin	Index for determining gradient of streams
3	Ruggedness Number (Rn)	Rn = Bh×Dd Where, Bh= Basin relief, Dd = Drainage density	Schumn 1956	Tells how rough the basin terrain is. It is an indicator of the basin geometric characteristics and helps us predict tendencies of flash flood in the basin	Determine roughness of the basin terrain,for predictingflash flood in the basin. Flood prediction index

Source: Adapted from Babu, (2016) and Walker et al., (2014)

Table 3. Basin Arial morphometric parameters, their functions and Applications

S/ No.	Morphometric Parameters	Equation/ Definition	Reference	Functions of the parameters	Application and Relevance in this Study
1	Drainage density (Dd)	Dd=L/A Where, L=Total length of stream, A= Area of basin.	Horton 1945	Expresses the unit length per unit area of the basin. It is an index of basin dissection	Determine the rate of the stream dissection
2	Stream frequency (Fs)	Fs=L/A Where, L=Total number of stream, A=Area of basin	Horton 1945	Measures the number of stream segment per unit area	Expresses the frequencies per unit area
3	Texture ratio (T)	T=N1/P Where, N1=Total number of first order stream, P=Perimeter of basin.	Horton 1945	is an indicator of type of topographic dissections by the stream and reflects the rock (material) in the basin and its resistance to erosion	Indicator of topographic dissection by streams and reflects the geology of the basin and its resistance to erosion.
4	Form factor (Rf)	$RF = \frac{A}{(LB)}$Where, A=Area of basin, Lb=Basin length	Horton 1945	Expresses the elongation or crookedness of a river. Helps in predicting flow intensity of the river in a defined area	Explain the morphology of the basin and stream flow intensity.
5	Circulatory ratio (Rc)	Rc=4πA/P Where A= Area of basin,π=3.14, P= Perimeter of basin.	Miller 1953	It signifies the shape of the basin and has influence on the rate of infiltration and how much time it takes for the water to reach the outlet subject to slope,, geology and vegetation cover	Signifies the shape or circularity of the basin
6	Elongation ratio (Re)	Re=√(Au/π)/ Lb Where, A=Area of basin, π=3.14, Lb=Basin length	Schumm 1956	indicates whether the stream is elongated or circular in nature	indicates the basin elongation or its circular nature defines the basin morphology
7	Length of overland flow (Lg)	Lg=1/2Dd Where, Drainage density	Horton 1945	Indicates how long water flows over land before merging into a definite stream	
8	Constant of channel maintenance(C)	Lof=1/Dd Where, Dd= Drainage density	Rekhaet al. 2011)	An indicator of rate of runoff and permeability	
9	Rho coefficient (Rho)	Rho = RL/Rbie the ratio of stream length to bifurcation ratio	Horton (1945	it gives us a measure of physiographic development of the basin relative to the drainage system its measure indicates how susceptible the area is to erosion	

Source: Adapted from Babu, (2016) and Walker *et al.*, (2014)

4. Analysis of Results

4.1 Morphometric Characteristics of the Sub-basins

The 15 delineated sub-basins and the results of the calculated parameters are shown in Fig. 2 and Table 1.

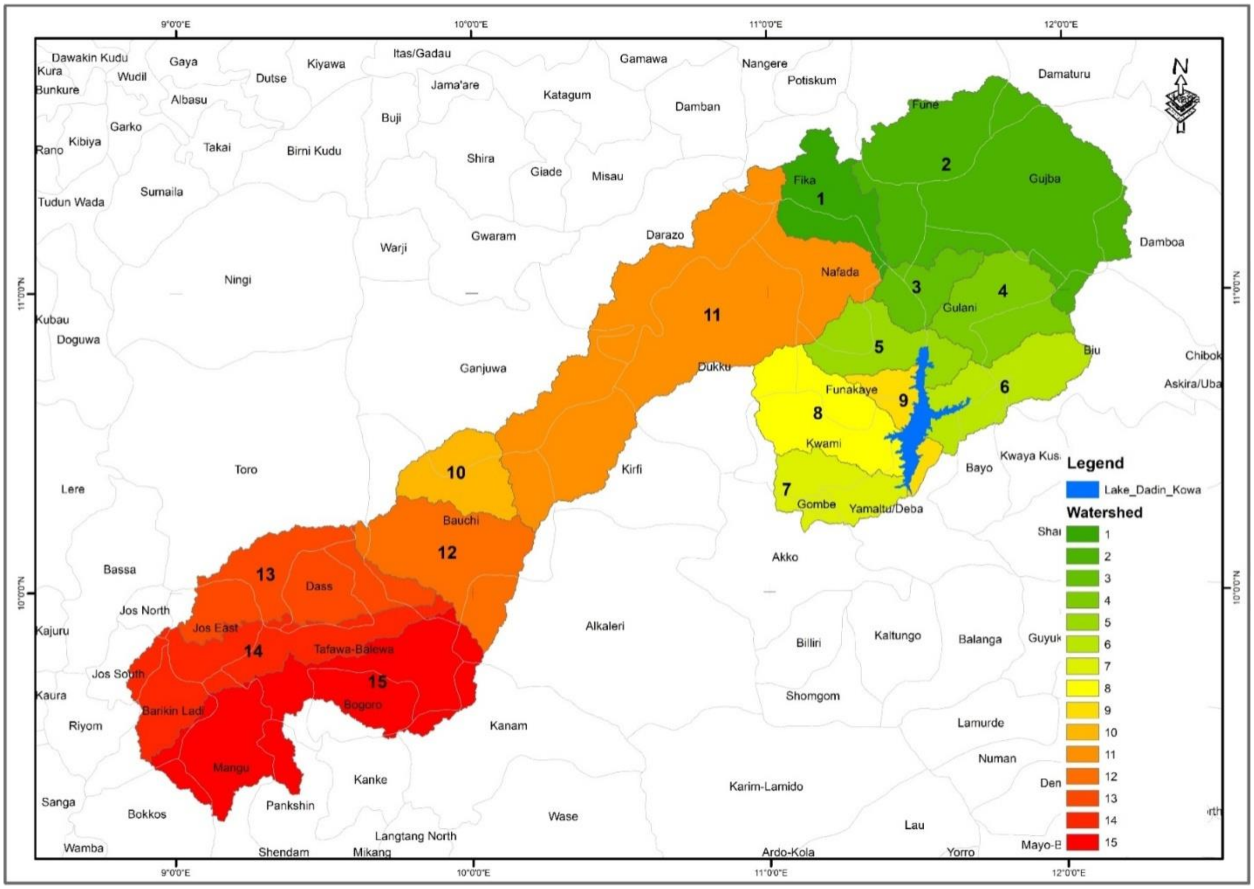

Figure 2. The fifteen sub-basins of Dadin Kowa catchment

Source: Researcher's Analysis

Table 1: Morphometric Data of Sub-basins of Dadin Kowa Dam Basin

Parameters	Sub- Basins														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Basin Area (SqKm) A	1137.19	5324.41	667.07	1314.26	1110.71	1350.64	980.89	1683.54	590.03	954.88	6847.42	2014.90	2247.43	2216.33	3715.41
Basin Perimeter (Km)	322.11	655.05	215.68	283.33	287.94	299.95	239.14	304.81	209.77	240.49	866.80	373.63	450.69	600.76	675.80
Stream Length (Km) Lu	26701.15	121308.59	15368.51	31195.95	25677.62	32819.59	23073.27	39514.75	14916.1	21783.98	157945.68	46712.57	56404.07	55937.95	89285.54
Stream Number Nu	261363.00	1318755.0	114646.0	232441.0	192562.0	232659.0	174327.0	292971.0	86568.0	168088.0	1217309.0	354501.0	402472.0	403732.0	671363.0
Basin Length	58.85	93.21	39.78	54.90	47.01	70.76	50.04	69.26	50.99	4706.00	162.12	61.93	94.51	129.07	126.82
Drainage density (Dd	23.48	22.78	23.04	23.74	23.12	24.30	23.52	23.47	25.28	22.81	23.07	23.18	25.10	25.24	24.03
Stream frequency (Fs)	229.83	247.68	171.86	176.86	173.37	172.26	177.72	174.02	146.72	176.03	177.78	175.94	179.08	182.16	180.70
Circularity ratio (Rc)	0.14	0.16	0.18	0.21	0.17	0.19	0.22	0.23	0.17	0.21	0.11	0.18	0.14	0.08	0.10
Form factor (Rf)	0.33	0.61	0.42	0.44	0.50	0.27	0.39	0.35	0.23	0.00	0.26	0.53	0.25	0.13	0.23
Elongation ratio (Re)	0.65	0.88	0.73	0.75	0.80	0.59	0.71	0.67	0.54	0.01	0.58	0.82	0.57	0.41	0.54
Drainage Texture (Rt)	811.41	2013.20	531.55	820.39	668.75	775.66	728.99	961.15	412.68	698.94	1404.38	948.80	893.00	672.03	993.44
Compactness coefficient (Cc)	2.69	2.53	2.36	2.20	2.44	2.30	2.15	2.10	2.44	2.19	2.95	2.35	2.68	3.60	3.13
Shape Factor	3.05	1.63	2.37	2.29	1.99	3.71	2.55	2.85	4.41	2.31	3.84	1.90	3.97	7.52	4.33
Length of Overland Flow	0.09	0.09	0.09	0.08	0.09	0.08	0.09	0.09	0.08	0.09	0.09	0.09	0.08	0.08	0.08
Basin Relief	338.00	557.00	299.00	569.00	377.00	718.00	496.00	389.00	673.00	308.00	456.00	757.00	1240.00	1122.00	1205.00

Source: Researchers Analysis (2023)

Basin Area

The basin area distribution across the 15 sub-basins of the Dadin Kowa Dam catchment reveals a significant variation in the spatial extent of drainage areas. Notably, sub-basin 11 stands out with the largest basin area, suggesting a substantial influence on the overall hydrology of the catchment. Sub-Basins 2, 13, 14, and 15 also exhibit considerable basin areas, indicating their significant roles in the hydrological processes. Conversely, Sub-Basins 3, 9, and 10 have smaller basin areas, suggesting more localized drainage patterns. Understanding the morphometric properties of each sub-basin is critical for comprehending the catchment's hydrological dynamics, as variations in basin areas can influence water flow, storage, and distribution (Dawha, 2023).

Basin Perimeter (km)

The evaluation of sub-basin perimeters across the Dadin Kowa Dam catchment's 15 sub-basins reveals distinctive patterns in the spatial extent of the drainage areas. Sub-basin 11 has the largest perimeter, reflecting its extensive boundary and potentially complex drainage network. Sub-basins 2, 13, 14, and 15 also exhibit substantial perimeters, indicating significant spatial reach and potentially intricate hydrological patterns. Sub-basins 3, 9, and 10 have smaller perimeters, suggesting more confined drainage boundaries. The variation in sub-basin perimeters is crucial for understanding the catchment's morphological diversity, as it directly influences the length of watercourses and the overall connectivity of the drainage network (Mayuri*et al.*, 2016). This analysis underscores the importance of considering both basin area and perimeter in tandem for a comprehensive morphometric understanding of the Dadin Kowa dam catchment.

Stream Length (km) Lu

The analysis of sub-basin stream lengths within the Dadin Kowa Dam catchment, provides valuable insights into the hydrological dynamics of the region. Notably, Sub-basin 11 being the longest stream length, indicates an extensive and potentially complex drainage network. Sub-basins 2, 13, 14, and 15 also exhibit substantial stream lengths, highlighting their significant contributions to the overall flow patterns within the catchment. Conversely, Sub-basins 3, 9, and 10 have comparatively shorter stream lengths, suggesting more localized drainage pathways. The variation in stream lengths across the sub-basins is crucial for understanding the connectivity and spatial distribution of watercourses within the catchment (Chouldhari*et al.*, (2018). This analysis underscores the heterogeneity of hydrological features, emphasizing the need for a comprehensive morphometric assessment to inform effective water resource management strategies in the Dadin Kowa Dam catchment.

Stream Number (Nu)

The evaluation of sub-basin stream numbers reveals significant variations in the density of the drainage network across the catchment. Sub-basin 11 had the highest stream number, indicating a dense and intricate network of watercourses. Sub-basins 2, 13, 14, and 15 also exhibit substantial stream numbers, reflecting their roles in contributing to the overall complexity of the hydrological system. However, Sub-basins 3, 9, and 10 have comparatively lower stream numbers, suggesting less intricate drainage networks. The variation in stream numbers across sub-basins is critical for understanding the catchment's hydrological connectivity and the potential for water flow redistribution (Rai *et. al.*, 2019). This analysis underscores the diverse hydrological characteristics present within the Dadin Kowa Dam catchment, emphasizing the need for a nuanced morphometric assessment to inform sustainable water resource management in the region.

Basin Length

The assessment of sub-basin lengths highlights a diverse range of spatial extents within the drainage network. Sub-basin 11 had an extensive basin length, indicating a significant geographical reach and potentially complex hydrological dynamics. Sub-basins 2, 13, 14, and 15 also exhibit substantial lengths, suggesting considerable contributions to the overall spatial distribution of the drainage network. Sub-Basins 3, 9, and 10 have comparatively shorter lengths, indicating more confined drainage pathways. The variation in sub-basin lengths underscores the heterogeneity of the catchment's morphological features, emphasizing the importance of considering basin length alongside other morphometric parameters for a comprehensive understanding of the hydrological characteristics within the Dadin Kowa Dam catchment.

Drainage Density (Dd)

The evaluation of sub-basin drainage density across the Dadin Kowa Dam catchment, indicates a relatively consistent pattern of drainage networks throughout the catchment. The values suggest that the catchment's drainage patterns are moderately dense, with minimal variation among the sub-basins. Sub-Basins 8 and 13 exhibit slightly higher drainage densities, indicating potentially more interconnected watercourses within these regions. However, Sub-basins 2 and 9 show slightly lower drainage densities, suggesting a less dense network of streams and rivers. The overall consistency in drainage density values suggests a balanced distribution of watercourses across the catchment, contributing to a stable and interconnected hydrological network.

Stream Frequency (Fs)

The assessment of sub-basin stream frequencies within the Dadin Kowa Dam catchment, provides insights into the density of the stream network across the catchment. The values indicate a relatively consistent stream frequency pattern, suggesting a balanced distribution of streams within each sub-basin. Sub-Basins 8, 13, and 14 exhibit slightly higher stream frequencies, indicating a greater number of streams per unit area, while Sub-basins 9, 3, and 4 have slightly lower stream frequencies, suggesting a more dispersed stream network. The overall uniformity in stream frequencies across the sub-basins implies a relatively even distribution of watercourses (Sandeep 2016), contributing to a well-connected and cohesive hydrological network within the Dadin Kowa Dam catchment.

Circularity Ratio (Rc)

The evaluation of sub-basin circularity provides insights into the shapes and forms of these drainage areas. The circularity ratio values reflect the degree of circularity or elongation of each sub-basin. Sub-Basins 7, 8, and 13 exhibit relatively higher circularity ratios, indicating more circular or compact shapes. Sub-Basins 10, 12, and 14 have slightly lower circularity ratios, suggesting more elongated or irregular shapes. The variations in circularity ratios highlight the morphological diversity of the sub-basins, influencing their hydrological behaviors and water distribution patterns. A comprehensive understanding of circularity ratios, combined with other morphometric parameters, is crucial for effective water resource management especially in regions with diverse topography (Ikusemoran*et al.*, 2018), like the Dadin Kowa Dam catchment.

Circularity Ratio (Rc)

The examination of sub-basin circularity ratios reveals diverse shapes and forms within the drainage areas. Sub-basins 7, 8, and 13 exhibit relatively higher circularity ratios, suggesting more circular or compact shapes. In contrast, Sub-basins 10, 12, and 14 have lower circularity ratios, indicating more elongated or irregular shapes. The variations in circularity ratios highlight the morphological diversity of the sub-basins, each contributing to a unique hydrological signature within the catchment. Sub-basins with higher circularity ratios may exhibit more centralized and balanced drainage patterns, while those with lower ratios might have more pronounced variations in topography (Ali and Ali 2014). Understanding these circularity ratios is crucial for comprehensive morphometric analysis, providing valuable insights into the catchment's geomorphic characteristics and aiding in effective water resource management strategies.

Elongation Ratio (Re)

The evaluation of sub-basin elongation ratios (Re) provides insights into the degree of elongation or compactness of the drainage areas. Sub-Basins 2, 4, 5, 6, and 12 exhibit higher elongation ratios, indicating more elongated or stretched shapes, while Sub-basins 9, 13, 14, and 15 have lower elongation ratios, suggesting more compact or circular configurations. Sub-Basin 10 with an elongation ratio of 0.01 signals a nearly circular shape. The variation in elongation ratios underscores the morphological diversity of the sub-basins, influencing their hydrological behaviors and water distribution patterns (Yahya*et al.*, 2016). Understanding these ratios contributes valuable insights to the overall morphometric analysis, aiding in the characterization of the catchment's geomorphic features

Drainage Texture (Rt)

Sub-Basins 2, 4, 5, and 11 exhibit higher Drainage Texture values, suggesting more intricate and potentially textured drainage patterns. These sub-basins may have complex hydrological dynamics characterized by a mix of various stream orders and tributaries. Conversely, Sub-Basins 9, 13, 14, and 15 have lower Drainage Texture values, indicating potentially smoother and less textured drainage networks. The diversity in Drainage Texture values underscores the morphological complexity of the sub-basins, influencing their hydrological behaviors and water distribution patterns. The assessment of sub-basin Drainage Texture (Rt) values reveals significant variations in the spatial arrangement and texture of the drainage networks (Manoj*et al.*, 2015).

Compactness coefficient (Cc)

Sub-Basins 10, 13, and 14 exhibit higher Compactness Coefficient values, indicating more compact or circular shapes. These sub-basins likely have drainage patterns that are concentrated and well-defined. Sub-Basins 7, 8, and 15 have relatively lower Compactness Coefficient values, suggesting more elongated or irregular shapes. The variation in Compactness Coefficient values underscores the morphological diversity of the sub-basins, influencing their hydrological behaviors and water distribution patterns. The evaluation of sub-basin Compactness Coefficient (Cc) values offers insights into the shape and compactness of the drainage areas (Bashir and Ikusemoran 2019).

Shape Factor

Sub-Basins 2, 5, 9, and 12 exhibit lower Shape Factor values, indicating potentially more elongated or irregular shapes. These sub-basins may have drainage patterns that are dispersed or less centralized. Sub-Basins 7, 10, and 14 have higher Shape Factor values, suggesting more compact or circular configurations. The variation in Shape Factor values highlights the morphological diversity of the sub-basins, influencing their hydrological behaviors and water distribution patterns. The estimation of sub-basin Shape Factor values provides insights into the overall shapes of the drainage areas. Sub-basins with lower Shape Factor values may exhibit more dispersed watercourses, while those with higher values may have more centralized drainage networks.

Length of Overland Flow

The evaluation of sub-basin Length of Overland Flow values indicates a relatively consistent pattern of overland flow distances across the catchment. The values, hovering around 0.08 to 0.09, suggest a uniformity in the length of overland flow for most sub-basins. This consistency may indicate a similar degree of overland flow dispersion and potential uniformity in surface runoff characteristics within the catchment. The relatively short distances imply that water movement over the land surface is limited, contributing to stable hydrological conditions. A thorough examination of these values, in conjunction with other morphometric parameters, contributes to a comprehensive understanding of the catchment's surface water dynamics, aiding in effective water resource management and environmental conservation in the Dadin Kowa Dam catchment (Dawha, 2023).

Basin Relief

The assessment of sub-basin Basin Relief values reveals variations in the topographic relief across the catchment. Sub-Basins 6, 12, 13, 14, and 15 have higher Basin Relief values, suggesting more pronounced elevation differences within these regions. These sub-basins likely exhibit rugged topography with steeper slopes, influencing the local hydrological dynamics. However, Sub-basins 3, 9, and 10 have lower Basin Relief values, indicating relatively smoother terrains with less elevation variation. The diverse Basin Relief values underscore the topographical complexity of the sub-basins, influencing their hydrological behaviors and water distribution patterns. A detailed analysis of these values, combined with other morphometric parameters, contributes valuable insights to the overall understanding of the catchment's geomorphic features and aids in effective water resource management in the Dadin Kowa Dam catchment (Dawha, 2023).

4.2. Ranking and Prioritization of Sub-Basins for Soil Erosion Management

Based on the methods for prioritization, the sub-basins have been classified into three groups of priority for management as shown in Tables 3 and 4. Sub-basins 7, 9, 12, 5 and 3 are areas with low erosion risks, while sub-basins, 2, 4, 6, and 8 require moderate management and sub-basins 15,13,14,10, and 1 require maximum erosion management strategies in the basin. Based on the ranking, only two out of the five sub-basins that were ranked as ‘high risk’ to soil erosion were not in highland areas or the Jos Plateau. This finding shows that highland areas are more susceptible to soil erosion which was also reported in the work of Bashir and Ikusemoran (2019). Low risk areas were found at the plains of the foot of the Jos Plateau in Bauchi State (sub-basin 12) because of the low relief of the area (AbdulRazak*et al.*, 2021). Other areas with low risk to soil erosion are found along the plains of Dadin Kowa dam itself. The plains of Dadin Kowa dam are also of low relief and hence have low risk of soil erosion. Therefore, the sub-basins in the high relief areas such as the highland areas and the Jos Plateau region were all found to be more prone to soil erosion and therefore, such areas should attract more attentions than the plains when it comes to soil erosion management. Areas that were moderately prone to soil erosion are more in terms of land area than those with high and low risks. Moderately prone areas are generally the plains of the Gongola catchment covering some parts of northern Gombe State, southern Yobe State, south west Borno State and central part of Bauchi State.

Table 2. Prioritization based on morphometric indexes

S/No	Sub basin	Drainage Density (Dd)	Stream Frequency (Fs)	Drainage Texture (T)	Form Factor (Rf)	Shape Factor (Bs)	Circulatory Ratio (Rc)	Compactness Coefficient	Elongation Ratio (Re)	CP	Priority Rank
1	1	8	2	8	8	9	4	12	8	8.78	5
2	2	15	1	1	15	1	6	10	15	10.33	7
3	3	13	14	14	11	6	9	7	11	7.11	15
4	4	6	8	7	12	4	12	4	12	8.56	8
5	5	11	12	13	13	3	7	8	13	7.44	14
6	6	4	13	9	7	10	11	5	7	7.33	9
7	7	7	7	10	10	7	14	2	10	8.22	11
8	8	9	11	4	9	8	15	1	9	8.33	10
9	9	1	15	15	3	14	8	9	3	6.11	12
10	10	14	9	11	1	5	13	3	1	5.67	4
11	11	12	6	2	6	11	3	13	6	7.78	6
12	12	10	10	5	14	2	10	6	14	8.78	13
13	13	3	5	6	5	12	5	11	5	8.33	2
14	14	2	3	12	2	15	1	15	2	7.56	3
15	15	5	4	3	4	13	2	14	4	8.67	1

Source: Researchers Analysis (2023)

Table 3 Management Prioritization Zones and Areas Affected

Prioritization grouping for erosion management

Sub-Watersheds	Management Priority	Percentage of Area km^2
High Risks (15,13,14,10,1)	1st	51.6
Moderate Risks (11, 2, 4, 6, 8)	2nd	17.4
Low Risks (7, 9, 12, 5, 3)	3rd	30.7

Source: Researchers Analysis (2023)

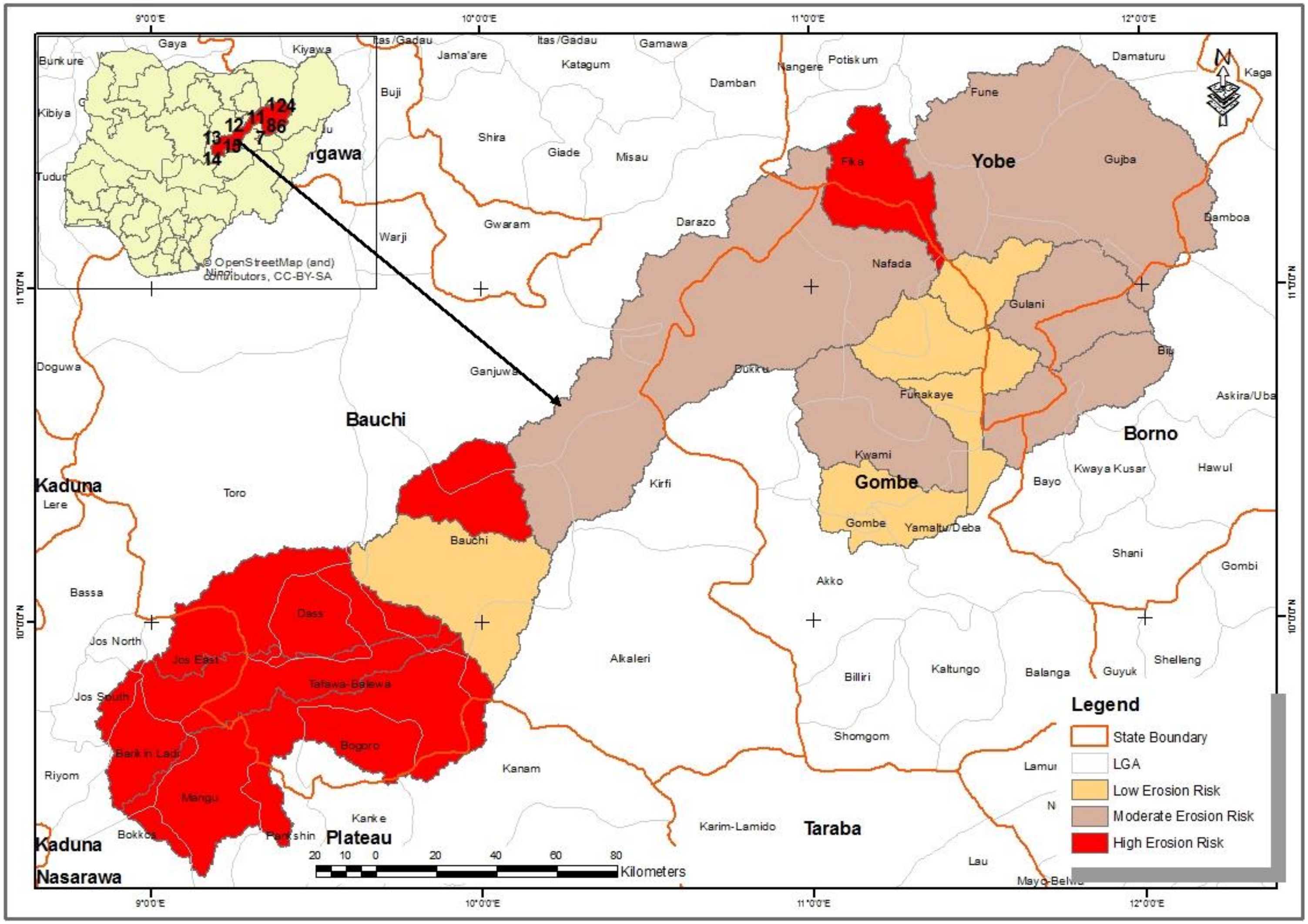

Figure 3. Categorization of sub-basins based on susceptibility to soil erosion
Source: Researcher's Analysis

5.0 Conclusion

The delineation of the sub-basins of Dadin Kowa catchments as well as the calculations of the morphometric parameters of each sub-basin have been carried out in this study. The delineated sub-basins were also prioritized into three risk categories for the assessment of soil erosion susceptibility in the catchment. The results of the calculated morphometric parameters reflect the susceptibility of each of the basin to soil erosion. For instance, sub-basin 11 was the largest basin area, suggesting a substantial influence on the overall hydrology of the catchment, while small area sub-basins suggest more localized drainage patterns. Sub-Basins with lower Drainage Texture values signifies potentially smoother and less textured drainage networks which influence their hydrological behaviors and water distribution patterns and the resultant impact on soil erosion. The prioritization and ranking of the sub-basins based on the adopted methods was also found to be effective as the sub-basins which were ranked as high risk are mainly those in the highland and Jos Plateau where soil erosion has been a serious hazard. The assessment of other hydrological hazard such as flooding using sub-basin prioritization is suggested for further studies.

6.0 Recommendations

The following recommendations are proffered based on the findings in this study:

(i) Sub-basin prioritization for soil erosion susceptibility have been proven effective and therefore can be adopted for prioritization of soil erosion management

(ii) The sub-basins at the highland and Jos Plateau areas should be of high priority following their prone to soil erosion hazard.

(iii) The sub-basins within the Dadin kowa catchment should be sustainably utilized so as to sustain the catchment and prevent the degradation of the catchment

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