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Characterization of Drainage Basin Parameters for River Basin Management: A Case Study of the Bihar River, Central India

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Abstract: **The morphological attributes of a river basin, encompassing its structural configuration, longitudinal profile, drainage network, and topographical features, are essential for an in-depth understanding of its dynamic processes. The prevailing global environmental issues demand an extensive evaluation of river hydro-morphology and watershed management to formulate efficacious tactics for sustainable development. Hydrogeomorphic assessment of the Bihar River basin was conducted by utilizing satellite data (SRTM) in combination with geospatial technology in order to improve the quantitative management of the drainage basin and to optimize groundwater potential for the purposes of watershed advancement. This basin is characterized by minimal surface runoff, well-developed geomorphological features, significant infiltration capacity, and reduced erosional potential, exhibiting a dendritic drainage configuration, northwestern elongation, and an increased prevalence of its first-order streams, all indicative of favorable conditions for aquifer recharge. The riverine network and gradient are precisely designed to enhance sediment transport and manage excess flow, thereby increasing susceptibility to flooding in the lower basin. Furthermore, on the basis of analysis of above parameters, this study infers that the north-western elongation of the river basin and partial tilting of its left bank may be the signature of neo-tectonic activity which may be ascertained by further detail investigation.**

Index Terms: **Bihar River Basin, Morphometry, Geospatial, Hypsometry Integral**

I. Introduction

Drainage basin investigation plays a key role in hydrological study, offering essential insights into groundwater potential and management. The key physiographical features of watersheds, such as their shape, size, and slope, are closely related to various hydrological phenomena (Waikar, 2014; Mustafa et al., 2016). Factors including geology, structural elements, geomorphology, soil types, and vegetation influence the formation and development of drainage systems (Clark, 1996; Pati, 2006; Prakash, 2016a). Detailed morphometric assessment of a river basin delivers an in-depth quantitative profile of watershed, which is vital for precise basin characterization and management (Strahler, 1964). Understanding hydrological processes (Eze & Efiong, 2010), measuring flash flood risks (Angillieri, 2008; Perucca & Angillieri, 2010), analyzing drainage features (Mesa, 2006), and assessing reactions to climate change all benefit from this research. The comprehension of river basin parameters is essential for the management of hydrological events and land surface development, as it provides insights into upstream controls along with shifts in climate and subsurface geology (Singh, 1992; Patel et al., 2012b; Dar, 2013; Singh, 2013; Yadav et al., 2013; Prakash et al., 2016b). Evaluating linear, aerial, and relief parameters is a component of morphometric analysis (Nautiyal, 1994; Nag & Chakraborty, 2003; Magesh, 2012b;

Rai 2017). In India, such analyses have been used for watershed management and to prioritize micro-watersheds (Singh, 2014; Prabu & Baskaran, 2013; Withanage et al., 2014; Pankaj & Kumar, 2009; Sarmah, 2012; Vandana, 2013).

This study emphasizes on the hydrogeomorphic assessment of the Bihar Watershed (Fig.1). Situated in a semi-arid part of Rewa, MP, India, the Bihar River is a crucial rain-fed water source. Spanning approximately 75 kilometers, it traverses various geological formations, including the Semri (Lower Vindhyan), Rewa, and Bhander groups (Upper Vindhyan), before merging with the Tons River. Flowing northwest through the Rewa district, the river plays a key role in supplying essential water resources to the region. Emerging from the Kaimore Hills near Kharamkheda village, situated at an altitude of 600 meters, the Bihar River meanders through the rugged terrain of Amarpatan and the elevated plateaus of Huzur and Sirmour Tehsil. As it flows past Chachai village, it forms the striking Chachai Falls, cascading approximately 115 meters before converging with the Tons River. Encompassing around 1597 km² within the Vindhyan Plateau, the Bihar River basin depends primarily on surface rainwater and shallow wells for its groundwater needs, which are concentrated in limited alluvial deposits and fractured rock formations. This research seeks to enhance the understanding of watershed dynamics and groundwater potential in the Bihar River basin by leveraging cutting-edge geospatial techniques to provide a more nuanced approach to basin management and resource optimization.

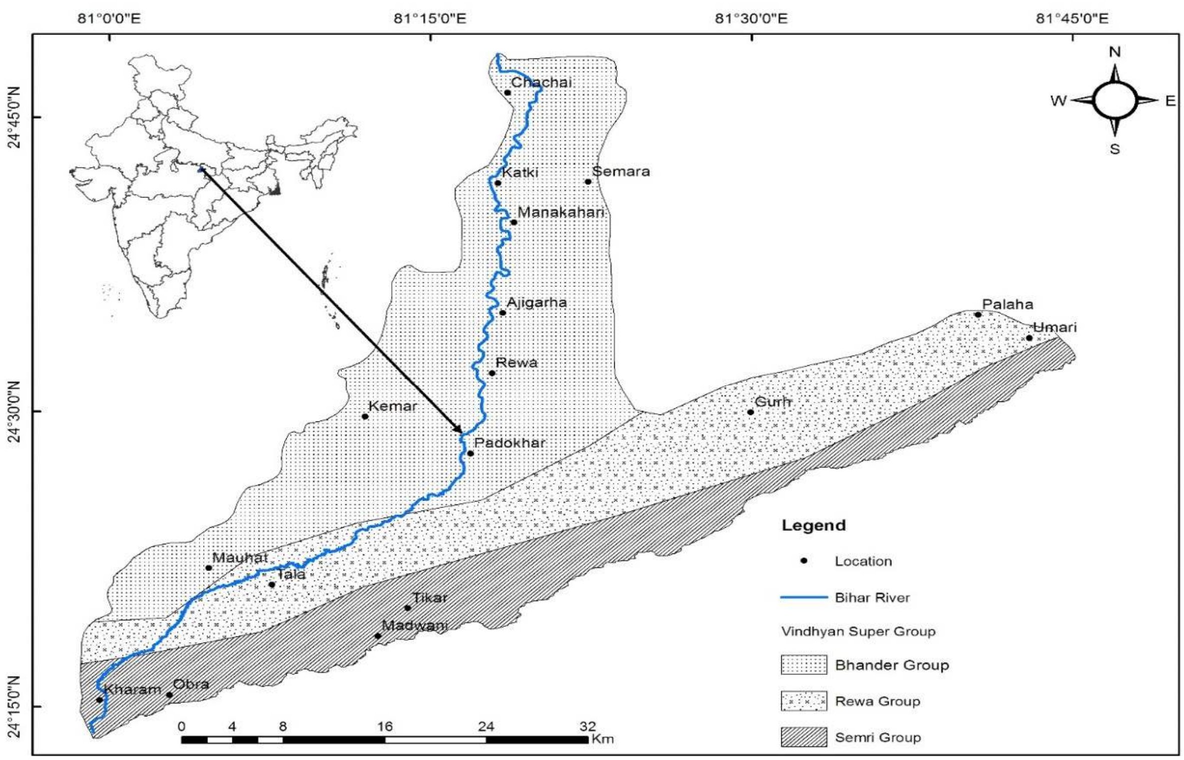

Fig. 1. Map depicting the location of the Bihar River Basin.

II. GEOLOGY

The Vindhyan Basin, the largest of the Purana Basins, is also the 2nd largest Proterozoic basin globally. Covering over 100,000 km^2 in central India, this Precambrian basin is the most extensive intra-cratonic basin known. The Vindhyan Supergroup, dating from the Paleoproterozoic to the Neoproterozoic, exhibits some of the best-preserved examples of the transition between shallow marine and non-marine depositional settings. Spanning the period from 1721 to 650 million years ago, these sequences offer a valuable record of Earth's climatic development, sedimentary processes, and early life forms Gangetic alluvial plain to the north, and Deccan Traps to the southwest, with the Bijawar Group defining its southeastern edge. This Proterozoic basin is predominantly composed of various lithologic units such as sandstone, shale, and limestone, intermixed with conglomerates and volcaniclastic strata. The basin exhibits a synclinal structure, trending ENE-WSW with a gentle westward plunge. The height of dem ranges from 159 to 698 meters in the basin (Fig.2). The region is characterized by low-amplitude open folds, including anticlines, synclines, and doublyplunging folds, resulting in distinctive rolling dips. The basin's rock formations are divided into Lower Vindhyan, i.e. Semri Group, and Upper Vindhyan i.e. Kaimur, Rewa, and Bhander Groups.

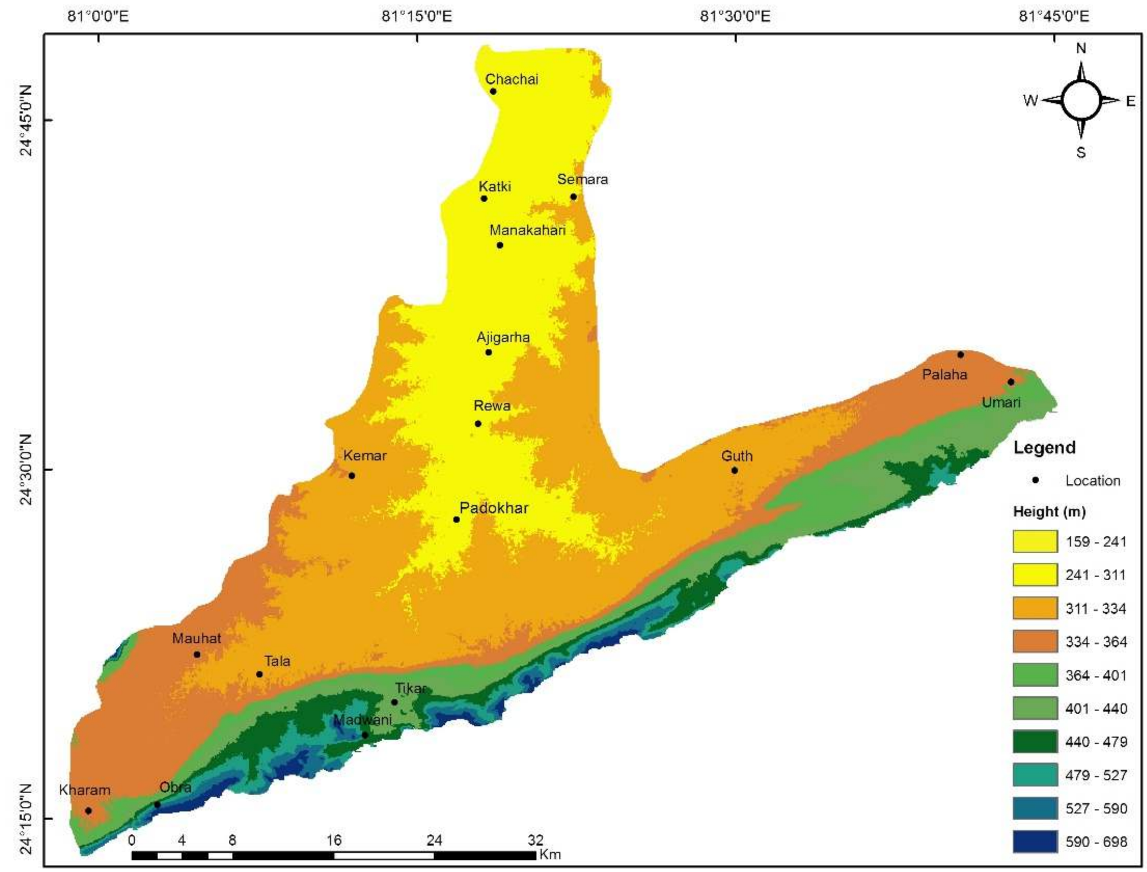

Fig. 2. Elevation Map of Bihar River Basin.

III. METHODOLOGY

The study leveraged geospatial data from the CGIAR Consortium for Spatial Information Geoportal, which provided SRTM and digital elevation model data at a 90-meter spatial resolution globally. SRTM DEM data facilitated the identification of key geomorphological characteristics, such as slope gradients and aspects. DEM data were mosaicked, georeferenced and its hydrological features were delineated using ArcGIS 10.3. Additionally, LANDSAT imagery was utilized to detect structural anomalies, including fractures, joints, and drainage patterns, which were analyzed as lineaments within the basin. The stream order classification followed Strahler's established methodology, and the computation of morphometric parameters and tectonic parameters was conducted using the mathematical techniques and formulas as outlined in the mentioned tables, i.e., 1 & 2.

Table I: Morphometric analysis formulae for calculating parameters of Bihar River Basin

	Parameter	Definition
Linear aspects		
	Perimeter (P) (km)	
	Basin length (Lb) (km)	
	Stream order (Nu)	Strahler (1957)
	Stream length (Lu) (km)	Horton (1945)
	Bifurcation ratio (Rb)	Rb=Nu/N(u+1), Horton (1945)
	Stream length ratio (Rl)	Rl=Lu/L(u-1), Horton (1945)
	Rho coefficient(R)	R=Rl/Rb, Horton (1945)
Areal aspects		
	Area (A) (km2)	
	Drainage density (Dd) (km km-2)	Dd=∑Lt/A, Horton (1945)
	Stream frequency(Fs) (Km-2)	Fs=Nt/A, Horton (1945)
	Drainage texture(T) (Km km-4)	T=Dd′Fs, Smith (1950)
	Length of overland flow (Lg) (km)	Lg=1/2Dd, Horton (1945)
	Constant of Channel maintenance (C) (km)	C=1/Dd, Schumm (1956)
	Form factor (Ff)	Ff=A/Lb2, Horton (1945)
	Circularity ratio (Rc)	Rc=4∏A/P2, Miller (1953)
	Shape index (Sw)	Sw=1/Ff, Horton (1932)
Relief aspects		
	Basin relief (R) (km)	R= H-h, Schumm (1956)
	Relief ratio (Rr)	Rr= R/Lb, Schumm (1956)
	Relief ratio (Rr)	Rr= R/Lb, Schumm (1956)
	Ruggedness number (Rn)	Rn=R*Dd, Strahler (1958)
	Gradient ratio (Rg)	Rg=Es-Em/Lb, Sreedevi et al.(2004)
	Meltonruggedness ratio (MRn)	MRn=H-h/$A^{0.5}$, Melton (1965)
	Coarses Ratio (CR)	R*Dd/1000 , Choreley (1986)

Table 2: Tectonic parameter formulae for calculating parameters of Bihar River Basin

Tectonics Parameter	
Asymmetry factor (AF)	AF = 100*(Ar/At), Cox (1994)
Elongation ratio (Re)	Re = 1.128√A/Lb, Schumm (1956)
Hypsometric Integral (Hi)	HI = mean-min/max - min, Strahler (1952)
Channel Sinousity (S)	S = SL/VL , Muller (1968)

IV. RESULT

A. MORPHOMETRIC ASPECTS

1. LINEAR ASPECTS

a) Perimeter (P)

Bihar river basin has a perimeter of 270.41 km.

a) STREAM ORDER (NU)

Nu serves as a conceptual indicator of a stream's deposition within the hierarchical structure of tributaries. The categorization of stream order depends on the quantity and type of tributary connections. This classification serves as a significant metric for evaluating drainage basin characteristics, such as stream dimensions and discharge capacity. Bihar River is a 6th-order stream. A total of 2170 streams belonging to multiple orders were identified with 1607, 415, 111, and 31,5,1 stream in I, II, III, IV, V, and VI orders, respectively, as depicted in (Fig.3) which proficiently demonstrates inverse relation amongst stream order and stream number (Horton, 1945).

b) STREAM LENGTH (LU)

The Bihar River basin shows a total stream length of 2401.71 km, with 1175.28, 533.98, 336.3, 187.36, 80, and 88 km lengths for I, II, III, IV, V, and VI order streams simultaneously. The length of stream segments displays a notable magnitude for Ist order streams, which then decreases as Nu increases, which reflects the substantial influence that geological formations and structures have on drainage networks.

c) BIFURCATION RATIO (RB)

Rb is represented as Nu/Nu+1, where Nu stands for the number of streams in the following order. For the Bihar basin, Rb ranges from 3.0 to 5.0, and the mean Rb value is 4.47, indicating substantial control of structures in drainage morphology and the presence of rugged terrain with substantial surface runoff and moderately permeable lithological units.

d) STREAM LENGTH RATIO (RL)

As stated by Horton, RI is defined as the ratio between the mean length of a particular order and that of the next lower order. Any variability in it demarcates variable area, topography, and slope conditions amongst stream segments of different orders. Bihar basin has an RI value of 0.63, which signifies the presence of moderately resistant rocks having low slope variation in terrain.

e) RHO COEFFICIENT (R)

The R-value is vital in correlating drainage density with any physiographic development in a basin. Furthermore, it helps as a crucial tool in order to assess the storage potential of the drainage network, thereby functioning as an element of the essential degree by which drainage has been developed with time within each watershed, as proposed by Horton. High Rho coefficient values indicate a substantial potential for water storage, while lower values suggest a reduced capacity for storage. The observed Rho coefficient value of 0.14 for this basin signifies a limited capacity for water storage.

2 AREAL ASPECTS

a) Area (A)

Bihar watershed has an area of 1597.91 km² (Table 3).

b) DRAINAGE DENSITY (DD)

DEFINED AS THE EXTENT OF STREAM SEGMENT PRESENT PER UNIT AREA OF THE WATERSHED. IT IS INDICATIVE OF THE POROSITY AND PERMEABILITY CONDITIONS OF THE SUBSTRATUM AS WELL AS ITS INFILTRATION PROPERTIES. BIHAR BASIN HAS A DD VALUE OF 1.5, I.E., < 2.0, AS DEPICTED IN (FIG.4), WHICH IS INDICATIVE OF HIGH POROSITY AND PERMEABILITY AS WELL AS A HIGH INFILTRATION RATE FOR THE SUB-STRATUM. IT DISPLAYS MODERATE LINEAMENT DENSITY (FIG.5).

c) DRAINAGE TEXTURE (T)

It represents the spatial arrangement of stream channels within a given area, reflecting the impact of differential environmental causes such as climate, precipitation, vegetation, soil and geological characteristics, infiltration rates, topography, and the basin's developmental stages. As per the classification system proposed by Smith, the Bihar River basin is characterized as having a very coarse drainage texture, which is attributed to its low Dd (<2).

d) LENGTH OF OVERLAND FLOW (LG)

Lg represents the distance from the crest line where flow concentration occurs and is articulated as the half inverse of Dd. Lg value resembles the extent of flowing water across the surface before converging into a distinct stream, and it is equivalent to the length of sheet flow over extensive areas. For the Bihar basin, the Lg value is 0.65, indicating that a considerable distance is required for the concentration of flow, i.e., the distant parts of the river basin showing peak discharge.

e) CONSTANT OF CHANNEL MAINTENANCE (C)

Defined as inverse to that of Dd, influenced by the basin slope, characteristics of the underlying geology, and erosional processes duration. High C values demarcate greater rock permeability, while lower values suggest the opposite. The recorded C value for the Bihar watershed is 0.66. Regions with diminished C values are characterized by dense dissection and structural constraints. In contrast, higher C values denote increased infiltration and an advanced river development stage.

f) FORM FACTOR (FF)

Ff serves as a predictive indicator for the flow intensity within a watershed of a given size. Elevated Ff values (>0.28) recorded in the Bihar sub-watershed suggest a tendency towards high peak flow within a compressed time period.

g) CIRCULATORY RATIO (RC)

Dimensionless, Rc embodies the proportion of the basin area to the circle area with an identical perimeter. This ratio ranges between 0-1 and is controlled by factors including the length of the stream, stream frequency, climatic conditions, topographical relief, basin slope, and geological formations. Rc demarcates the river's developmental stage, i.e., lower values typically signify a youthful stage, and higher values reflect successive mature stages. Rc values for the Bihar watershed, measured at 0.27, suggest an elongated morphology, mature topography, and drainage network configuration as dendritic type.

h) SHAPE INDEX (SW)

Sw for the Bihar watershed was measured to be 3.56, suggesting elongated basin topography, which is associated with a higher potential for peak discharge rates.

3. RELIEF ASPECTS

a) Basin relief (R)

R values for the Bihar basin are measured to be 0.33, indicating low infiltration within the subsurface and high surface runoff.

b) RELIEF RATIO (RR)

Rr compares the vertical elevation range and horizontal area of the watershed is dimensionless and represents the gradient characteristics of the watershed. The calculated relief ratio value of 0.004 for the Bihar basin suggests conditions marked by low to moderate surface runoff with reduced stream energy, i.e., less erosion.

c) COARSE RATIO (CR)

Cr is demonstrated as a ratio of the basin's relief to its perimeter and increases in tandem with rising drainage density and basin relief. The Measured Cr value for the Bihar basin is 0.506, indicating lower susceptibility to soil erosion and reflecting inherent structural complexities linked with basin relief and drainage density.

d) RUGGEDNESS NUMBER (RN)

The Rn value, calculated as the product of R and Dd, suggests the Bihar watershed has an elevated ruggedness value (0.006). This heightened ruggedness indicates increased vulnerability to soil erosion, which is correlated with the basin's relief and drainage density features.

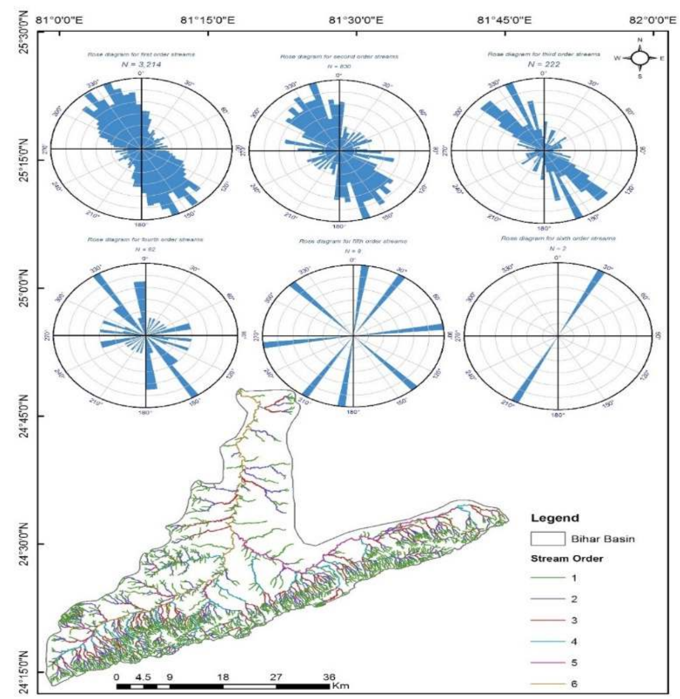

Fig. 3. Stream Order Map of Bihar River Basin.

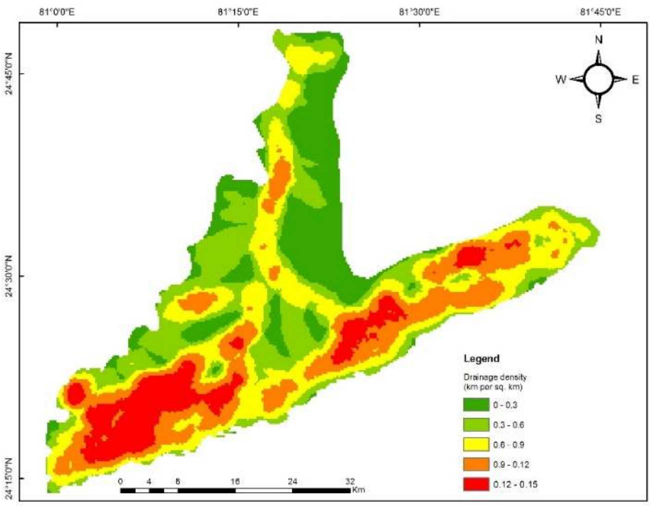

Fig. 4. Drainage Density Map of Bihar River Basin.

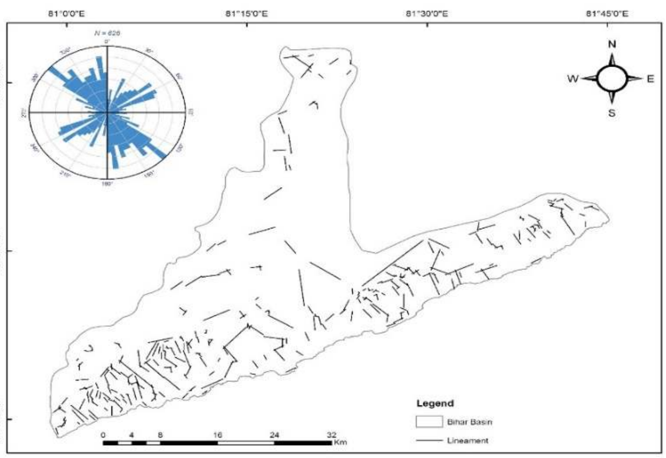

Fig. 5. Lineament Density Map of Bihar River Basin.

e) GRADIENT RATIO (RG)

Rg assesses channel variability, which helps to evaluate the volume of surface runoff. The elevated Rg values (0.004) observed within the Bihar watershed region suggest a steep and rugged topographic landscape.

f) MELTON RUGGEDNESS NUMBER (MRN)

MRn is a ratio of the basin's total relief to the total watershed area. The MRn value for the Bihar watershed basin was determined to be 0.008. According to the classification system developed by Wilford et al., this watershed can be characterized as a debris flood system, defined by the dominance of bed load sediment transport processes.

Table 3: Calculated Morphometric Analysis of Bihar River Basin

Linear aspects	**Bihar watershed(BW)**
Perimeter (P) (km)	270.41
Basin length (Lb) (km)	75.44
Stream order (Nu)	2170
Stream length (Lu) (km)	2401.71
Bifurcation ratio (Rb)	4.47
Stream length ratio (Rl)	0.63
Rho coefficient(R)	0.14
Areal aspects	
Area (A) (km2)	1597.91
Drainage density (Dd) (km km-2)	1.50
Stream frequency(Fs) (Km-2)	1.35
Drainage texture(T) (Km km-4)	2.04
Length of overland flow (Lg) (km)	0.75
Constant of Channel maintenance (C) (km)	0.66
Form factor (Ff)	0.28
Circularity ratio (Rc)	0.27
Shape index (Sw)	3.56
Relief aspects	
Basin relief (R) (km)	0.337
Relief ratio (Rr)	0.004
Ruggedness number (Rn)	0.006
Gradient ratio (Rg)	0.004
Meltonruggedness ratio (MRn)	0.008
Coarses Ratio (CR)	0.506

4. TECTONIC PARAMETER

a) Asymmetry Factor (AF)

The lateral tilt of a basin in relation to the primary watercourse can be assessed with greater ease by utilizing the Asymmetry Factor (Hare & Gardner, 1985; Cox, 1994; Cuong & Zuchiewicz, 2001; Mohan et al., 2007; Singh & Srivastava, 2011; Raj, 2012). These metrics exhibit sensitivity to the vertical movements of particular geological blocks rather than to extensive tilting while also considering potential orientations of differential tectonic (neo) activity (Pinter, 2005). In the realm of mathematics, AF = 100 (Ar/At), where Ar denotes the area to the right (downstream) of the mainstream and At signifies the overall area of the drainage basin. The findings of Molin et al. (2004) indicate that when AF decreases below 50, a transition to the downstream right side occurs. An AF exceeding 50 within the Bihar watersheds suggests a lateral shift of the channel towards the west (Fig 6a). The existence of meander cutoffs, meander scars, and paleochannels is evidence of this channel migration.

b) ELONGATION RATIO (RE)

Through a quantitative analysis of the planimetric configuration of the basin, this parameter indirectly provides insights into its maturity degree. The drainage basins located in areas with active plate movements are often longer and further change to circular when the uplift ceases (Bull & McFadden, 1977). According to Schumm (1956), the basin elongation ratio Re = 1.128vA/Lb, where A denotes the basin area, and Lb denotes the length of the basin in relation to the primary drainage axis. Basins with circular layouts and Re values close to 1 suggest low relief and developed terrain. The Bihar watershed exhibits notable topography and steep gradients, as indicated by the Re value of 0.597 (Table 4). The Bihar River Basin's elongation ratios indicate the existence of elongated basins, primarily in the southern and southwestern sections. While oval to circular basins are rather stable, elongated basins are a sign of increased tectonic activity (references there in). Based on this finding, it may be concluded that the Bihar Basin's southern and southwest portions have more tectonic activity than the other regions (Fig 6c).

c) HYPSOMETRIC INTEGRAL (HI)

The hypsometric integral (Strahler, 1952) is a crucial assessment tool that describes how elevation is distributed throughout a certain geographic region.

The implementation of hypsometric analysis has facilitated the differentiation of erosional landforms corresponding to various stages of evolutionary development (Schumn et al., 1956; Strahler, 1952). Consequently, the hypsometric integral constitutes an indispensable instrument for elucidating the erosive processes that have transpired within the watershed over geological epochs, primarily due to hydrological processes and factors that contribute to land degradation. A principal advantage of the hypsometric integral lies in its capacity to compute and compare diverse basins of varying sizes, irrespective of scale. The calculation is executed as HI = (mean relief – minimum relief) / (maximum relief – minimum relief). The hypsometric integral for the Bihar watershed is determined to be 0.479 (Table 4), suggesting a nascent phase of basin development (Fig 6b). Furthermore, the hypsometric integral also quantifies the erosion cycle, encapsulating the total duration required to diminish a topographical unit of land to its minimal elevation.

d) CHANNEL SINUOSITY (S)

The ratio of the length of the river valley to the length of the channel is called the channel sinuosity (S) measure. The way a river flows can reveal information about the impact of tectonic movements (Singh, 2015). To calculate the index, the following formula is used: S is expressed as SL/VL, where S stands for channel sinuosity, VL for valley length, and SL for stream length. Channel sinuosity serves as a crucial quantitative parameter for comprehending the manner in which streams have influenced landscape evolution and is a resource that geologists, hydrologists, and geomorphologists frequently utilize. When the channel sinuosity value is 1, the river exhibits a linear course. Rivers with sinuosity values varying from 1 to 1.5 are categorized as sinuous; a sinuosity of more than 1.5 implies a meandering trajectory. The sinuosity value of the Bihar watershed (Table 4) is 1.5, indicating a transition in river characteristics from sinuous to meandering (Fig 6d).

Table 4: Calculated Tectonic parameter of Bihar River Basin

Tectonics Parameter	Bihar watershed(BW)
Asymmetry factor (AF)	72.41
Elongation ratio (Re)	0.597
Hypsometric Integral (Hi)	0.479
Channel Sinousity (S)	1.5

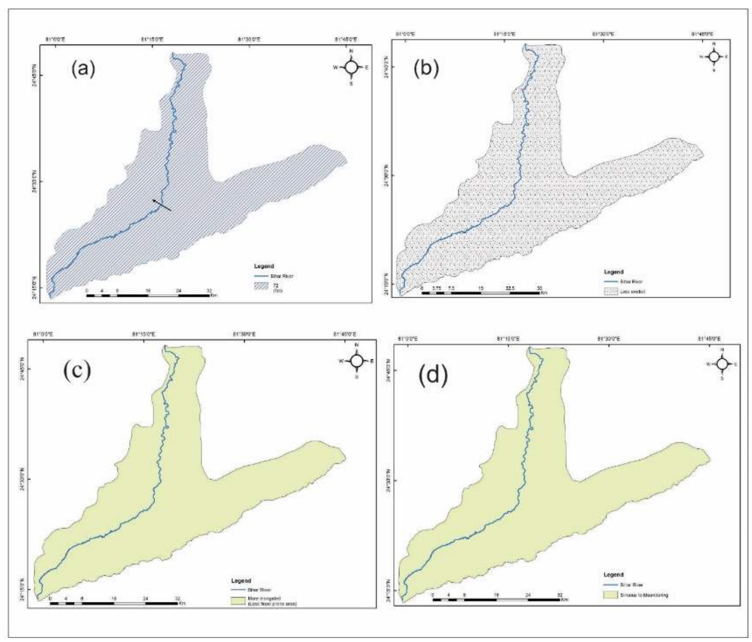

Fig. 6 (a) Lateral shift in the channel of Bihar River Basin. **(b)** Erosion cycle in the Bihar River Basin **(c)** The basin's southern and southwest portions are more prone to tectonic activity **(d)** The River shows a sinuous to meandering nature.

V. DISCUSSION

All the above-mentioned parameters of the Bihar River basin provide critical insights into its hydrological and geomorphological characteristics, influencing water flow, surface runoff, infiltration, and drainage patterns. These parameters suggest a basin with low surface runoff, a prominent infiltration rate, and a mature topography, indicating a stable hydrological regime.

A. Linear Parameters:

The linear parameters, including stream order and first-order streams (1607), indicate a dominant first-order stream network, which reflects the basin's gentle slope gradient and uniform lithology. The prominent infiltration rate and low surface runoff contribute to a mature landscape where the majority of precipitation infiltrates into the subsurface, enhancing groundwater recharge. This infiltration process, however, decreases over time, leading to increased surface runoff and the formation of additional first-order streams. The high infiltration and low surface runoff facilitate groundwater recharge, supporting a favorable hydraulic gradient for water retention (Shankar & Mohan, 2005).

B. Relief Parameters:

The basin exhibits a low relief (0.337 km) and relief ratio (0.004), which, in turn, suggests minimal surface runoff and a low erodibility by streams. This results in the dispersal of water through-out watershed, low water storability, and the maximum discharge towards mouth of the basin. These characteristics, along with the gentle slope and high infiltration rate, create a favorable environment for groundwater recharge and flood mitigation.

C. Areal Parameters:

Areal metrics indicate that the basin exhibits an elongated and skewed morphology oriented toward the northwest, characterized by a dendritic drainage configuration (Singh & Awasthi, 2011). The grater number of I stream orders indicates a uniform lithological composition and a minimal slope gradient, which aligns with observations that the majority of precipitation in this region flows as surface runoff. Stream size and order are closely linked to the basin’s physiography, climate, and precipitation patterns. In the monsoon season, initial precipitation enhances subsurface percolation, boosting the groundwater table. Over time, however, infiltration rates decline, leading to increased surface runoff and the formation of I-order streams. The gentle slope, reduced surface runoff, and prominent infiltration rate promote a positive hydraulic gradient conducive to groundwater recharge. This basin's stream network, slope, and relief adapt to accommodate the flow of water and sediment in response to climatic conditions, lithology, and other basin characteristics (Horton, 1945; Strahler, 1952; Mesa, 2006).

D. Hydrological Behavior and Flooding Risk:

Morphometric measurements are invaluable in predicting the watershed's hydrological response in high rainfall conditions, which might lead to unusual runoff and flooding (Perucca & Angilieri, 2010). The diminished metrics of Dd, Fs, and drainage intensity signify that surface runoff is not expeditiously evacuated from the watershed, rendering the downstream segments more vulnerable to inundation (Singh, 2020). Strategies such as rainwater harvesting, recharging ponds, and embankment construction to manage peak discharge should be implemented to mitigate flood risks.

River Basin Characteristics and Tectonic Influence:

The protracted configuration of the basin exerts a significant influence on hydrological and geomorphic phenomena, especially regarding the distribution and movement of water. In basins characterized by their elongated form, the temporal span for water dispersion is extended, resulting in postponed runoff and drainage (Angillieri, 2008). The stream length ratio and number of first-order streams within the basin serve as an indicator of advanced topographic evolution and the current stage of erosion. The HI value of 0.479 further suggests that the basin is in the youthful stage of landscape evolution (Singh, 2009). During this stage, rivers tend to narrow their valleys through vertical erosion, with lateral erosion being comparatively lower. Mean Rb, i.e., 4.47, points that the Bihar River basin is in a natural state, without significant influence from geological imprints like faults and lineaments (Mesa, 2006). Furthermore, an examination of the climatic conditions and tectonic activities indicates that the genesis of the river valley is not predominantly attributable to tectonic processes (Singh et al., 2009). However, the basin's (AF), i.e., 72, reveals that the left bank of the basin is tilted towards the right, reflecting tectonic influences on the river's alignment. The River is oriented in the northwest direction, aligning with the predominant lineaments in the Vindhyan Plateau, suggesting that tectonic forces play a major role in shaping the river's course.

VI. CONCLUSION

In conclusion, the geomorphic analysis of the Bihar River basin yields an essential understanding of its hydrological dynamics, erosion mechanisms, and potential inundation hazards. The basin's gentle slopes, low surface runoff, and high infiltration rates promote groundwater recharge, while its elongated shape and skewed drainage pattern reflect mature topography influenced by both climate and tectonics. Effective water management and flood mitigation tactics, such as rainwater harvesting and embankment construction, are essential for managing the basin's hydrological dynamics. In addition, on the basis of present investigation, this study infers that the north-western elongation of the river basin and partial tilting of its left bank may be the signature of neo-tectonic activity which may be established by further detail investigation.

VII. ACKNOWLEDGMENTS

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VIII. REFERENCES

Angillieri, E., (2008). Morphometric analysis of Colanguil river basin and flash flood hazard, San Juan, Argentina 55: 107-111.

Bull, W.B., & McFadden, L.D., (1977). Tectonic geomorphology north and south of the Garlock Fault, California. Doehring DO (ed) Geomorphology in arid regions. Geomorphology, State University of New York at Binghampton, Binghampton, 115–138.

Clarke, C., (1996). Morphometry from map, essay in geomorphology. Elsevier pub co, New York: 235–274.

Cox, R.T., (1994). Analysis of drainage-basins symmetry as rapid technique to identify areas of possible quaternary tilt-block tectonics: an example from Mississippi Embayment. Geological Society of America Bulletin 106: 571–581.

Cuong, N.Q., & Zuchiewicz, W.A., (2001). Morphotectonic properties of the Lo River fault near Tam Dao in North Vietnam. Natural Hazards and Earth System Sciences 1:15–22.

Dar, R.A., Chandra, R., & Romshoo, S.A., (2013). Morphotectonic and lithostratigraphic analysis of intermontane Karewa basin of Kashmir Himalayas. Journal of Mountain Science 10(1): 731-741.

Eze, E.B., Effiong, J., (2010). Morphometric Parameters of the Calabar River Basin: Implication for Hydrologic Processes. Journal of Geography and Geology, 1(2): 18-26.

Hare, P.W., & Gardner, T.W., (1985). Geomorphic indicators of vertical neotectonism along converging plate margins, Nicoya Peninsula, Costa Rica. In: Morisawa M, Hack JT (eds) Tectonic geomorphology: proceedings of the 15th annual binghamton geomorphology symposium. Allen @ Unwin, Boston 90–104.

Horton, R.E., (1945). Erosional development of streams and their drainage basins hydrophysical approach to quantitative morphology. Geophysical Society of American Bulletic 56(3):275–370.

Magesh, N.S., Jitheshlal, K.V., Chandrasekar, N., & Jini, K.V., (2012). GIS based morphometric evaluation of Chimmini and Mupily watersheds, parts of Western Ghats, Thrissur District, Kerala, India. Earth Science Informatics 5:111–121.

Mesa, L.M., (2006). Morphometric analysis of a subtropical Andean basin (Tucuma`n, Argentina). Environmental Geology 50:1235-1242.

Mohan, K., Srivastava, V., & Singh, C.K., (2007). Pattern and genesis of lineaments in and across Son-Narmada lineament lineament zone in a part of Central India around Renukoot District Sonbhadra, U.P. Journal of the Indian Society of Remote Sensing 35(2): 181–187.

Molin, P., Pazzaglia, F.J., & Dramis, F., (2004). Geomorphic expression of active tectonics in a rapidly-deforming forearc, Sila massif, Calabria, southern Italy. American Journal of Science 304(7):559–589.

Mustafa, A.S., (2016). Drainage Basin Morphometric Analysis of Galagu Valley. Journal of Applied and Industrial Science 4(1): 2320- 4609.

Nag, S.K., & Chakraborty, S., (2003). Influence of rock types and structures in the development of drainage network in hard rock area. Journal of the Indian Society of Remote Sensing 31(1): 25-35.

Nautiyal, M.D., (1994). Morphometric analysis of a drainage basin, district Dehradun, Uttar Pradesh. Journal of the Indian Society of Remote Sensing 22(4):251–261.

Pankaj, A., & Kumar, P., (2009). GIS-based Morphometric Analysis of five major-watersheds of Song river, Dehradun District, Uttarakhand with special reference to landslide incidences. Journal of the Indian Society of Remote Sensing 37:157–166.

Patel, D.P., Gajjar, C.A., & Srivastava, P.K., (2012b). Prioritization of malesari mini-watersheds through morphometric analysis: A remote sensing and GIS perspective. Environmental Earth Sciences 69: 2643-2656.

Pati, J.K., Malviya, V.P., & Prakash, K., (2006). Basement re-activation and its relation to Neotectonic activity in and around Allahabad, Ganga Plain. Journal of the Indian Society of Remote Sensing 34:47–56.

Perucca, P., & Angilieri, E., (2010). Morphometric characterisation of del Molle Basin applied to the evaluation of flash floods hazards, Iglesias Department, San Juan, Argentina. Quaternary International 233(1): 81-86.

Prabu, P., & Baskaran, R., (2013). Drainage Morphometry of Upper Vaigai river Sub-basin, Western Ghats, South India Using Remote Sensing and GIS. Journal Geological Society of India 82: 519-528.

Prakash, K., Singh, S., & Shukla, U.K., (2016). Morphometric changes of the varuna river basin, Varanasi district, Uttar Pradesh. Journal of Geomatics 10: 48-54.

Prakash, K., Singh, S., & Shukla, U.K., (2016a). Morphometric changes of the varuna river basin, Varanasi district, Uttar Pradesh. J Geomatics 10:48–54.

Rai, P.K., (2017). A GIS-based approach in drainage morphometric analysis of Kanhar River Basin, India. Applied Water Science 7: 217-232.

Raj, R., (2012). Active tectonics of NE Gujarat (India) by morphometric and morphostructural studies of Vatrak River basin. Journal of Asian Earth Sciences 50: 66–78.
.
Sankar, M., & Mohan, G., (2005). Assesment of the groundwater potential and quality in Bhatsa and Kalu river basins of Thane district, western Deccan Volcanic Province of India. Environmental Geology 49: 990-998.

Sarmah, K., Jha, L.K., & Tiwari, B.K., (2012). Morphometric analysis of a high- land micro watershed in East Khasi Hills District of Meghalaya, India: using remote sensing and geographic information system (GIS) techniques. Journal of Geography and Regional Planning 5: 142–150.

Schumm, S.A., (1956). Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. Geological Society of American Bulletin 67: 597–646.

Singh, A.P., Arya, A.K., & Singh, D.S., (2020). Morphometric Analysis of Ghaghara River Basin, India, Using SRTM Data and GIS. *J Geol Soc India* **95**, 169–178.

Singh, C.K., (2014). Active deformations extracted from drainage geomorphology; a case study from Southern Sonbhadra district, Central India. Journal of the Geological Society of India 84: 569–578.

Singh, C. K. (2015). Middle Ganga Plain; May be on the Verge of Seismic Shock. Journal Geological Society of India, VOL.85, 511-513.

Singh, C.K., & Srivastava, V., (2011). Morphotectonics of the Area Around Renukoot, district Sonbhadra, U.P. using remote sensing and GIS techniques. Journal of the Indian Society of Remote Sensing 39(2): 235–240.

Singh, D.S., & Awasthi, A., (2011). Implication of drainage basin parameters of Chhoti Gandak River, Ganga Plain, India. *J Geol Soc India* **78**, 370–378.

Singh, P., Thakur, J., & Singh, U.C., (2013). Morphometric analysis of morar river basin, madhya pradesh, India, using remote sensing and GIS techniques. Environmental Earth Sciences 68: 1967-1977.

Singh, S., (1992). Quantitative Geomorphology of the Drainage Basin, Readings on Remote Sensing Applications, T. S. Chouhan and K. N. Joshi, Eds., Scientific Publishers, Jodhpur, India.

Strahler, A.N., (1952). Hypsometric—area–altitude. Analysis of erosional topography. Geological Society of American Bulletin 63: 1117–1142.

Strahler, A.N., (1964). Quantitative geomorphology of drainage basin and channel networks. Chow VT (ed) Handbook of applied hydrology. McGraw Hill Book, New York 4–76.

Vandana, M., (2013). Morphometric analysis and watershed prioritization: a case study of Kabani river basin, Wayanad district, Kerala, India. Indian Journal of Geo-Mar Sciences 42: 211–222.

Waikar, M., & Nilawar, A., (2014). Morphometric analysis of a drainage basin using Geographical Information System: A case study. International Journal of Multidisciplinary and Current Research 2: 179:184.

Withanage, W., Dayawansa, N.D.K., & DeSilva, R.P., (2014). Morphometric Analysis of the Gal Oya River Basin Using Spatial Data Derived from GIS. Tropical Agriculture Research 26(1):175–188.

Yadav, S.K., (2013). Morphometric analysis of Upper Tons basin from Northern Foreland of Peninsular India using CARTOSAT satellite and GIS. Geocarto International 29(8): 895-914.