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Comparative Study of Morphometric Characteristics of Arunachal Rivers and its Influence on Hydrology

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ABSTRACT

This study presents a comparative morphometric analysis of six major river basins in Arunachal Pradesh such as Kameng, Subansiri, Brahmaputra, Dibang, Lohit, and Noa Dihing to examine their hydrological dynamics and geomorphological behavior. Morphometric parameters including stream order, stream length, drainage density, bifurcation ratio, relief, and shape indices were analyzed to understand basin characteristics and their influence on water flow, erosion, flooding, and watershed stability. Results indicate significant variation across basins: Subansiri exhibits the largest drainage network with extensive stream counts and lengths, while Noa Dihing has the smallest and most compact system. The Brahmaputra Basin shows the highest average stream length, reflecting efficient runoff transport, whereas Kameng demonstrates compact drainage conducive to localized flooding. Relief and ruggedness values highlight the steep and erosion-prone landscapes of Subansiri and Dibang, while Noa Dihing's elongated shape suggests slower drainage and heightened flood susceptibility. The findings underscore the role of morphometric diversity in shaping hydrological responses, flood vulnerability, and watershed stability. These insights are critical for formulating region-specific water resource management, flood control, and disaster mitigation strategies in Arunachal Pradesh's complex riverine environment.

Keywords: Morphometric analysis, Arunachal Pradesh rivers, Hydrological response

Introduction

Arunachal Pradesh, located in the eastern Himalayas, is characterized by its diverse topography, steep slopes, and an extensive network of rivers that play a vital role in shaping the region's hydrology, ecology, and livelihoods. The river basins of this state, including Kameng, Subansiri, Brahmaputra, Dibang, Lohit, and Noa Dihing, exhibit remarkable variations in their morphometric characteristics owing to differences in geology, relief, and climatic conditions.

Morphometric analysis, which involves the quantitative study of basin geometry, drainage networks, and relief parameters, serves as an effective tool to understand the structural control, hydrological behavior, and environmental dynamics of river systems. Such an approach not only provides insights into runoff, infiltration, sediment transport, and flood susceptibility but also contributes to watershed management, land use planning, and disaster risk reduction. Comparing the morphometry of rivers in Arunachal Pradesh is crucial for gaining insights into their overall morphogenesis and understanding the variations in their characteristics. Arunachal Pradesh, known for its diverse topography and extensive river network, provides a unique opportunity to explore the distinct morphometric features that shape its watercourses. The comparison of river morphometry involves analyzing various parameters such as stream orders, stream lengths, drainage basin sizes, and relief characteristics across multiple rivers within the state. This comprehensive assessment can unveil patterns and trends, shedding light on the geological, climatic, and hydrological factors influencing the morphological diversity of Arunachal Pradesh's rivers.

Each river's morphometric profile contributes to its unique behavior, drainage patterns, and ecological significance. Factors such as the river's origin, geological formations it traverses, and the overall topography of the region play pivotal roles in shaping its morphometric characteristics. The comparison enables researchers, environmentalists, and policymakers to discern the factors influencing river systems across the state, aiding in effective water resource management, environmental conservation, and disaster preparedness. Given the region's vulnerability to floods, landslides, and erosion, a comparative study of morphometric parameters across multiple basins is essential for assessing hydrological responses and devising region-specific management strategies. This study, therefore, undertakes a detailed morphometric comparison of Arunachal Pradesh's major river basins to explore their geomorphological diversity and its influence on hydrological stability and flood vulnerability.

Methodology

The methodology of this study involved a systematic morphometric analysis of six major river basins in Arunachal Pradesh such as Kameng, Subansiri, Brahmaputra, Dibang, Lohit, and Noa Dihing using topographic maps, Shuttle Radar Topography Mission (SRTM) Digital Elevation Models (DEMs), and Survey of India toposheets. Basin boundaries were delineated with GIS-based hydrology tools, and morphometric parameters were computed following standard methods (Horton, 1945; Strahler, 1964), categorized into linear (stream order, stream length, bifurcation ratio), areal (drainage density, stream frequency, drainage texture), relief (basin relief, relief ratio, ruggedness number), and shape indices (circularity ratio, elongation ratio, form factor). Comparative analysis was carried out to identify variations across basins, with statistical tabulation and graphical representation used to interpret patterns. These morphometric characteristics were further evaluated to understand hydrological implications such as runoff, infiltration, erosion potential, flood vulnerability, and watershed stability, and the results were validated through existing literature and secondary hydrological data to ensure accuracy and reliability.

Result and Discussion

Morphometric Comparison and Hydrological Influence

Figure 1 shows the comparison of stream numbers of Arunachal Rivers.These six river basins' differences in stream counts and lengths offer important insights into the hydrological dynamics of the area.

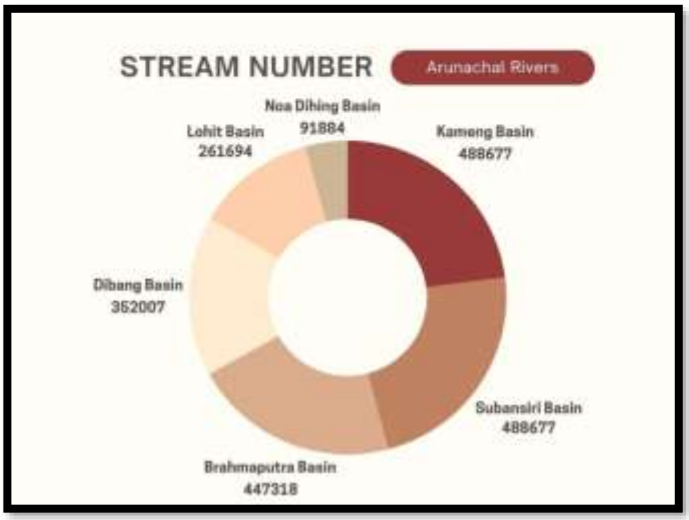

Figure 1. Comparison of stream numbers, Arunachal Rivers

Table 1 gives the comparison of Stream Numbers Across Basins. With 488,677 streams overall and a total length of 168,455.39 km, the Subansiri Basin is the largest basin. It is closely followed by the Brahmaputra Basin, which has 447,318 streams and a total length of 152,905.32 km. In terms of these parameters, Kameng Basin exhibits a notable stream count (286,365) and huge stream length, with Dibang trailing closely behind. On the other hand, the number of streams in the Lohit and Noa Dihing Basins is decreasing, with Noa Dihing having the lowest network of streams (91,884 streams) and the shortest total length of streams (27,971.73 km).

Table 1. Comparison of Stream Numbers Across Basins

Stream Order	Kameng Basin	Subansiri Basin	Brahmaputra Basin	Dibang Basin	Lohit Basin	Noa Dihing Basin
1	389,487	389,487	279,587	279,587	207,755	73,831
2	78,419	78,419	56,942	56,942	42,619	14,142
3	16,162	16,162	12,195	12,195	8,894	3,016
4	3,576	3,576	2,591	2,591	1,896	685
5	809	809	564	564	437	164
6	174	174	128	128	93	34
7	38	38	30	30	20	8
8	8	8	8	8	5	3

9	3	3	3	3	1	1
10	1	1	1	1	-	-
Total	**488,677**	**488,677**	**447,318**	**352,007**	**261,694**	**91,884**

Table 2. Comparison of Stream Length (Km) Across Basins

Stream Order	**Kameng Basin (Km)**	**Subansiri Basin (Km)**	**Brahmaputra Basin (Km)**	**Dibang Basin (Km)**	**Lohit Basin (Km)**	**Noa Dihing Basin (Km)**
1	120,257.54	120,257.54	90,904.97	90,904.97	68,335.37	19,090.68
2	28,320.17	28,320.17	21,829.19	21,829.19	16,485.53	4,921.79
3	10,313.27	10,313.27	7,562.73	7,562.73	5,659.82	1,969.83
4	4,803.26	4,803.26	3,513.51	3,513.51	2,559.83	1,011.68
5	2,489.96	2,489.96	1,784.04	1,784.04	1,320.49	469.23
6	1,201.04	1,201.04	887.67	887.67	682.17	224.20
7	525.93	525.93	413.84	413.84	405.44	97.41
8	329.53	329.53	205.31	205.31	125.26	79.05
9	140.48	140.48	113.99	113.99	158.78	107.86
10	74.21	74.21	93.56	93.56	-	-
Total	**92,270.52**	**168,455.39**	**152,905.32**	**126,482.11**	**95,043.22**	**27,971.73**

Table 2 gives the comparison of Stream Length (Km) Across Basins. Since these metrics directly affect the drainage network's ability to convey water, manage surface runoff, and facilitate infiltration, they are essential for hydrological study. Greater numbers and lengths of streams indicate a more intricate drainage system, improving water distribution throughout the basin and influencing flood patterns, sedimentation, and water resource management. The capacity for both surface runoff and groundwater recharge is probably larger in basins with extensive stream networks, like Subansiri and Brahmaputra. This is important to understand the region's water supply, erosion, and landform change. On the other hand, basins like Noa Dihing may be more susceptible to localized floods due to their shorter stream lengths, which may signal faster runoff reaction times but less possibility for widespread water distribution. Planning for sustainable water resources, flood prevention, and efficient management of watersheds all depend on an understanding of these factors.

Table 3. Stream Length and Bifurcation ratio

Basin	**Average Stream Length (km)**	**Mean Bifurcation Ratio**
Kameng River Basin	17.72	4.39
Subansiri River Basin	18.43	4.62
Brahmaputra River Basin	27.39	4.48
Dibang River Basin	20.71	4.44
Lohit River Basin	24.35	4.57
Noa Dihing River Basin	18.01	4.46

Table 3 gives the Stream Length and Bifurcation ratio. Significant hydrological features are revealed by the table 33, which offers information on the mean bifurcation ratios and average stream lengths of six river basins. At 27.39 km, the average stream length in the Brahmaputra River Basin is the longest, showing substantial channel building and effective drainage, both of which can improve runoff and water transport during rainy events. The Kameng River Basin, on the other hand, appears to have a more compact drainage network, which could result in localized flooding, given its 17.72 km average stream length. The Subansiri River Basin has the greatest mean bifurcation ratio (4.62), suggesting a more intricate stream branching that may enhance water distribution and flood control. On the other hand, the simpler stream network in the Kameng River Basin, as evidenced by its lower bifurcation ratio of 4.39, may lead to direct flow pathways and a higher danger of flooding during heavy downpours. All things considered, these measures show how different the hydrological responses are in the different basins, highlighting the necessity of customized watershed management plans to deal with the distinct difficulties that each river system presents, especially when it comes to runoff control and flood resilience.

Table 4. Areal Characteristics of River Basins

Basin	**Drainage Density**	**Stream Frequency**	**Drainage Texture**	**Drainage Intensity**	**Length of Overland Flow**	**Constant of Channel Maintenance**
Kameng River Basin	10.59	32.87	709.57	3.1	0.047	0.09
Subansiri River Basin	10.78	31.26	823.89	2.9	0.05	0.09
Brahmaputra River Basin	10.77	31.51	878.38	2.93	0.05	0.09
Dibang River Basin	10.83	30.13	603.79	2.78	0.05	0.09
Lohit River Basin	10.79	29.52	596.58	2.73	0.05	0.09
Noa Dihing River Basin	9.68	31.79	259.53	3.39	0.05	0.10

Table 4 gives the Areal Characteristics of River Basins. The six river basins' hydrology and physiography are compared, and the results show some significant variations that may affect ecological health and water management plans (Table 34). The Noa Dihing River Basin has the lowest drainage density at 9.68, indicating a less intricate network that may cause localized flooding and slower water movement. Overall, drainage densities are quite high throughout all basins, indicating well-developed stream networks. Generally speaking, stream frequency is not too variable, with the Kameng River Basin showing the highest frequency at 32.87 streams per unit area. This could contribute to increased groundwater recharge and the maintenance of a variety of aquatic ecosystems. On the other hand, the Lohit River Basin, which has the lowest stream frequency (29.52), would have trouble preserving hydrological connectivity.

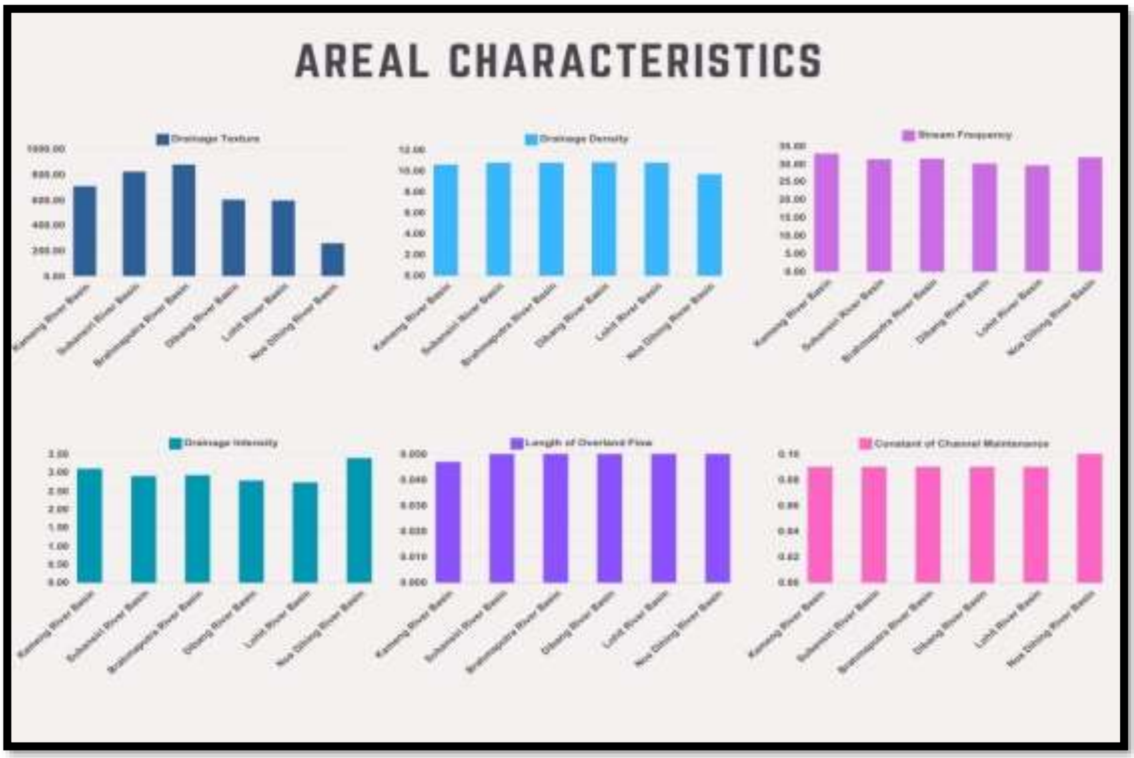

Figure 2. Aerial Characteristics of Arunachal Rivers

Figure 2 shows the Aerial Characteristics of Arunachal Rivers. With the highest texture value of 878.38, the Brahmaputra River Basin demonstrates the compactness of the drainage network and is a denser network that enables rapid runoff, which is crucial for mitigating flood risks, especially during monsoon seasons. So, the drainage texture further demonstrates the network's ability to manage flood risks. In comparison, the Noa Dihing River Basin has a much lower drainage texture of 259.53, which indicates more widely spaced drainage lines. This could indicate a lesser danger of flooding, but it could also mean insufficient drainage during periods of high rainfall. With a drainage intensity of 3.1, the Kameng River Basin stands out in terms of potential flooding because of increased runoff efficiency; somewhat surprisingly, the Noa Dihing River Basin also shows a higher drainage intensity of 3.39, indicating a relatively elevated flood risk despite its lower value. While the continuous channel maintenance reflects similar geological properties throughout these places, the length of overland flow is comparable across the basins, indicating similar water movement patterns prior to reaching the stream network.

Table 5. Shape Indices of River Basins

Basin	**Circularity Ratio**	**Elongation Ratio**	**Form Factor**
Kameng River Basin	0.67	1.00	0.81
Subansiri River Basin	0.56	0.86	0.58
Brahmaputra River Basin	0.69	0.76	0.46
Dibang Basin	0.43	0.70	0.39
Lohit Basin	0.58	0.67	0.35
Noa Dihing River Basin	0.29	0.41	0.13

Table 5 gives the Shape Indices of River Basins. Considerable information on the hydrological behavior and landscape dynamics of the six river basins can be gained by comparing their circularity, elongation, and form factor ratios (Table 35). With a perfect elongation ratio of 1.00 and the maximum circularity ratio of 0.67, the Kameng River Basin appears to have a somewhat rounded form that may help with effective drainage and reduce the risk of flooding. The Noa Dihing River Basin, on the other hand, has the lowest ratios of circularity (0.29) and elongation (0.41), suggesting a more elongated shape that could cause slower drainage and a higher chance of localized flooding.

The Brahmaputra Basin's lower form factor (0.46) denotes a longer elongated basin profile that may have an impact on water retention and runoff patterns, while its circularity ratio of 0.69 indicates a well-rounded shape that promotes efficient water flow. With an elongation ratio of 0.86 and a circularity of 0.56, the Subansiri Basin exhibits a moderately effective drainage system that lowers surface runoff and promotes groundwater recharging. The Kameng River Basin has a higher value (0.81) than other basins in terms of form factor, which measures a basin's compactness. This suggests that the basin has a more favorable hydrological response, improving its capacity to control runoff during rainfall events. The lower form factors of the Dibang (0.39), Lohit (0.35), and Noa Dihing (0.13) basins show that these places may have longer transit periods for runoff, influencing flood control and soil erosion potential. Figure 3 shows the Comparison of shape index.

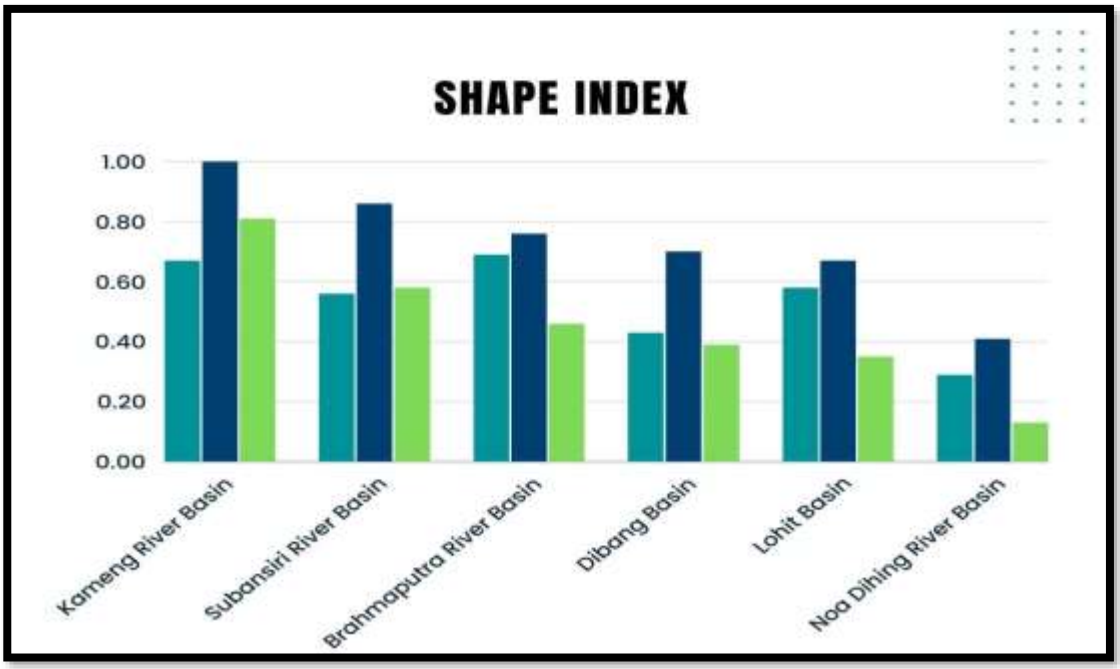

Figure 3. Comparison of shape index

Table 6. Relief Characteristics of River Basins

Basin	Basin Relief (m)	Relief Ratio	Relative Relief Index	Ruggedness Number
Kameng River Basin	5500	40.97	1362.82	58251.7
Subansiri River Basin	6680	50.54	1126.22	71975.91
Brahmaputra River Basin	5390	48.93	1034.84	56761.17
Dibang River Basin	5280	46.95	905.66	57161.11
Lohit River Basin	5000	50.85	1139.73	53595.9
Noa Dihing River Basin	4120	96.9	1163.69	39467.15

Table 6 gives the Relief Characteristics of River Basins. The examination of relief characteristics throughout the river basins reveals diverse geomorphological elements that have a substantial impact on biological dynamics and hydrology. With the largest basin relief (6680 m) and a noteworthy roughness number (71975.91), the Subansiri River Basin is distinguished by its steep and varied terrain, which can cause significant erosion and improve runoff efficiency. Because of its moderately steep terrain, as indicated by its relief ratio of 50.54, the area experiences a dynamic hydrological response during monsoon seasons.

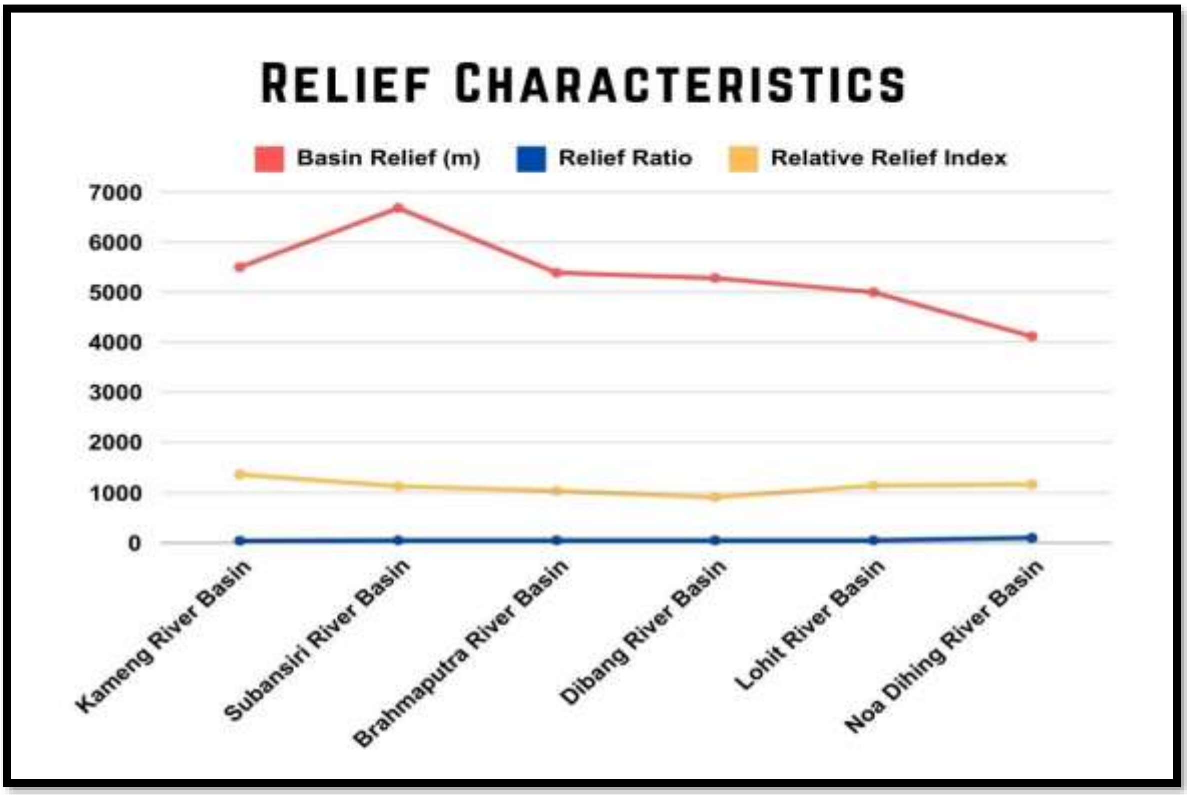

Figure 4. Comparison of relief characteristics

Figure 4 shows the Comparison of relief characteristicsOn the other hand, the Noa Dihing River Basin has the highest relief ratio (96.9) and the lowest basin relief (4120 m). Its profile is uncommon and could suggest large flat sections or depressions that could have an impact on flood control and drainage. Although a less difficult landscape may lessen the likelihood of severe erosion, it can still affect runoff speed, as indicated by its lower toughness value (39467.15). The Kameng Basin's high relative relief index (1362.82), which denotes noticeable elevation variations, may increase its ability to absorb surface runoff and recharge groundwater during periods of intense precipitation. Comparably, the Lohit River Basin's relief ratio of 50.85 denotes a steep terrain, but it has a lower ruggedness number (53595.9) than the Subansiri Basin's, suggesting a less complex topography.

Stability of The Region

Analyzing morphometric data, which is summarized in the master tables containing important parameters for the Kameng, Subansiri, Brahmaputra, Dibang, Lohit, and Noa Dihing river basins, significantly enhances the assessment of river basin stability. First, high stream orders indicate a mature and well-developed river network, and they are present in all basins. This is critical because improved hydrological functions and environmental resilience are frequently linked to higher stream orders. The average bifurcation ratios, which are constantly higher than 4, also show that these river systems have a strong branching network that helps distribute water efficiently and lessens the chance of floods.

The Kameng and Subansiri basins have the highest drainage densities (10.59 and 10.78, respectively), which suggests a compact and connected stream network when drainage parameters are examined. This density enables effective water movement, which can maintain the watershed by limiting the impact of intense weather events. In a similar vein, the Kameng Basin's stream frequency of 32.87 indicates a large number of minor tributaries that improve groundwater recharge and sustain a variety of aquatic habitats. On the other hand, the Lohit Basin, which has a lower stream frequency (29.52), may have difficulties preserving hydrological connectivity, which could have an impact on the health of the ecosystem and flood control.

The majority of basins consistently report a channel maintenance constant of 0.09, indicating comparable geomorphological conditions that support stable channel features. The Noa Dihing Basin, on the other hand, might go through more active maintenance procedures due to its somewhat higher constant (0.10), which could indicate a possible stronger resilience against destabilizing factors. Conversely, variables suggesting possible instability need to be carefully taken into account. With the greatest roughness number (71,975.91) and basin relief (6680 m), the Subansiri Basin is thought to have a terrain that is prone to erosion, which might cause problems with sediment movement and undermine riverbanks. Similar dangers are indicated by the considerable roughness (57,161.11) observed in the Dibang Basin. Conversely, the Noa Dihing Basin exhibits a high relief ratio (96.9), suggesting a steep terrain that may worsen erosion, even though it has the lowest basin relief (4120 m).

High drainage intensities (2.9 and 2.93, respectively) in the Subansiri and Brahmaputra basins imply active drainage patterns that may exacerbate erosion and instability, especially during monsoon seasons. This further complicates the stability narrative. Lastly, more information about basin stability and shape can be gleaned from the circularity ratios. The Kameng Basin's circularity ratio of 0.67 indicates that its shape is reasonably stable and favors effective water movement. As an example, the Noa Dihing Basin's lower circularity ratio (0.29) suggests a more elongated shape and may render it more susceptible to issues related to sediment transport and hydrological changes.

Because of their distinct morphometric and hydrological features, the river basins of Arunachal Pradesh have differing degrees of landslide risk. With the highest relief (6680 m) and roughness number (71975.91), the Subansiri River Basin is notable for having steep topography. This, together with its high drainage density (10.78), increases the likelihood of slope failure during periods of severe rainfall. Closely behind, the elongated shape and steep slopes of the Kameng River Basin, which has a drainage density of 10.59 and a significant relief of 5500 m, provide comparable dangers. Although the Brahmaputra River Basin has a slightly lower relief (5390 m), it still has a roughness number (56761.17) and a strong drainage density (10.77), which means that under extreme hydrological stress, landslides could occur.

The Dibang River Basin is particularly vulnerable due to its high drainage density (10.83) and 5280 m of relief, which allow for quick runoff that might cause landslides. Due to effective water flow in steep regions, the Lohit River Basin, which has a drainage density of 10.79 and a relief of 5000 meters, shares comparable vulnerabilities. Finally, the Noa Dihing River Basin presents hazards because to its roughness number of 39467.15 and drainage density of 9.68, which could result in localized flooding and instability, even though it has the lowest relief (4120 m). All basins are at risk, but because of their distinct terrain and drainage features, the Subansiri and Kameng River Basins stand out as the most susceptible to landslide incidents.

Potential Vulnerability to Flooding

The distinct morphometric features of the river basins in Arunachal Pradesh determine how vulnerable they are to flooding. Due to its high stream order and elongated structure (elongation ratio of 1.00), the Kameng River Basin raises the possibility of flooding, especially during periods of severe precipitation. Its drainage intensity of 3.1 and drainage density of 10.59 show that water is effectively channeled, but there is also a chance of quick runoff, which increases vulnerability.

The Subansiri River Basin, in contrast, has a high order and number of streams, improving hydrological connection and potentially producing significant runoff. Its substantial elevation fluctuations and intricate drainage system, combined with a relief of 6680 meters and a drainage texture of 823.89, point to a higher danger of floods during monsoon season. These features are mirrored in the Brahmaputra River Basin, which has a roughness number of 56761.17, indicating steep topography that might increase the risk of floods, as well as a high stream order and significant stream length.

Additionally, the Dibang River Basin has substantial relief (5280 m) and high stream order, which increase its vulnerability to flooding caused by rapid runoff in higher locations. Similar flood dangers exist in the Lohit River Basin, which has a high stream order and a modest relief of 5000 m. Its elongation ratio of 0.67 indicates a reasonably fast runoff during periods of strong rainfall. Finally, the Noa Dihing River Basin is notable for having a comparatively lower drainage density of 9.68 and an extended shape with a circularity ratio of 0.29. With a relief of 4120 meters and a high drainage intensity of 3.39, although having a lower density, this area is highly vulnerable to flooding during periods of intense precipitation.

Although all basins exhibit features that may result in floods, the forms and drainage characteristics of the Kameng and Noa Dihing basins may put them at higher risk. Significant flood threats are also prevalent in the Subansiri, Brahmaputra, Dibang, and Lohit basins because to their high stream orders, significant relief, and drainage patterns. To successfully limit potential flood impacts throughout the region, a complete flood control strategy needs to take these morphometric parameters into account.

Conclusion

In conclusion, the morphometric analysis of the rivers in Arunachal Pradesh reveals a tapestry of diverse hydrological features, showcasing the intricate complexities inherent in each basin. The high stream order of 10 across all rivers signifies a mature and well-developed river network, with Subansiri standing out for its extensive stream number and length. The varying basin perimeters and areas, along with distinct circularity ratios, highlight the unique shapes and geographical extents of the basins. Drainage density and stream frequency provide insights into the intricate drainage patterns, with Subansiri, Kameng, and Brahmaputra exhibiting higher values. The relief characteristics and ruggedness numbers underscore the diverse topographies, with Subansiri and Dibang portraying more rugged landscapes. Each river basin, whether characterized by expansive dimensions or compact shapes, contributes to the rich mosaic of Arunachal Pradesh's hydrological landscape. The morphometric comparisons offer a nuanced understanding of the distinct features shaping these river systems, laying the foundation for further detailed studies and informed water resource management strategies in the region

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