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A Geographic Information System (GIS) based approach for drainage and morphometric characterization of Beki river basin, India

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सार — भू-आकृतिक जल संभर प्रबंधन के जल निकासी पैटर्न और विभिन्न ज्यामितीय पद्धतियों का पता लगाने के लिएभौगोलिक सूचना प्रणाली और सुदूर संवेदन उपकरण प्रभावीसाबित हुए हैं। यहां तक कि GIS का व्यापक रूप से कई बाढ़ प्रबंधन और पर्यावरणीय अनुप्रयोगों में उपयोग किया गया है। 19,354.35 sq.km^2 के क्षेत्र में बहने वाली बेकी नदी हिमालय के ग्लेशियर (भूटान में कुला कांगरी ग्लेशियर) से 26.18° उत्तरी अक्षांश और 90.53° पूर्वी देशांतर सेनिकलती है और असम के मैदानी इलाकों से होकर बहती हुई 26.48° उत्तरी अक्षांश और 91.02° पूर्वी देशांतर पर विशाल ब्रह्मपुत्र में मिलती है जिनका आकृतिक प्राचलों के विस्तृत विश्लेषण के लिए चयन गया है। आकृतिक प्राचलों के माध्यम से, धारा प्रवाह, धारा की लंबाई, द्विभाजन अनुपात, अपवाह घनत्व, अपवाह आवृत्ति, अपवाह की बनावट, स्वरूप गुणक, चक्रीय अनुपात, दीर्घीकरण अनुपात, संहतीय अनुपात, आदि को प्राथमिकता के लिए मापा गया और यौगिक प्राचल मानोंकी गणना की गई। इस अध्ययन से स्थानीय लोग द्रोणी क्षेत्र के सतत जल संसाधन विकास के लिए संसाधनों का सही तरीके से उपयोग करने में सक्षम होंगे। इसके अलावा, अध्ययन को जलवायु परिवर्तन के परिणामस्वरूप भू-आकृति विज्ञान में कालिक परिवर्तन पर अध्ययन के लिए एक निर्देश चिन्ह के रूप में भी संदर्भित किया जा सकता है। विभिन्न आकृतिक विश्लेषण जल संभर के भौतिक गुणों की व्याख्या करते हैं, जो भूमि उपयोग योजना, मृदा संरक्षण, भू-भाग की ऊंचाई और मिट्टी के कटाव के लिए महत्वपूर्ण हैं।

ABSTRACT. Geographic Information Systems and remote sensing have proved to be effective tools in delineation to find the drainage pattern and different geometric methodologies of geomorphologic watershed management. Even GIS has been widely used in several flood management, and environmental applications. The river Beki with an area of 19,354.35 sq. km^2 originates at the Himalayan glacier (Kula Kangri glacier in Bhutan) at 26.18°N latitudes and 90.53°E longitudes and flows through the plains of Assam and finally to the mighty Brahmaputra at 26.48°N latitudes and 91.02°E longitudes have been selected for a detail analysis morphometric parameters. Morphometric parameters via; Stream order, Stream length, Bifurcation ratio, Drainage density, Drainage frequency, Drainage texture, Form factor, Circularity ratio, Elongation ratio, Compactness ratio, etc. were measured for prioritization and compound parameter values were calculated. The local people from this study will be able to utilize the resources in the right manner for a sustainable water resource development of the basin area. Moreover, the study can also be referred to as a benchmark for studies on temporal change in geomorphology resulting from climate change. Various Morphometric analyses explain the physical properties of the watershed, which are important for land use planning, soil conservation, terrain elevation, and soil erosion.

Key words – Morphology, Satellite images, Remote sensing, Geographic Information Systems.

1. Introduction

Morphometry is measuring and studying quantitatively the earth's surface arrangement, shape, and size of the various landforms (Clarke, 1996; Agarwal, 1998). Morphometric study can be completed effectively by measuring the basin's linear, aerial, relief parameters, the gradient of the channel network, and contributing ground slope (Nag and Chakraborty, 2003; Nautiyal, 1994). According to a large number of morphometric research, drainage of river basin morphology reflects diverse geomorphological and geological processes across time which is a generally accepted principle of morphometry (Horton, 1945; Strahler, 1964; Mueller, 1968; Hurtrez, 1999).

It is generally known that drainage morphometry has a substantial impact on understanding landform processes, physical qualities of soil and erosional features. The drainage assessment does not appear to be complete if it does not involve a systematic approach to the establishment of drainage basins in the region (Singh, 1980). The drainage lines present in a place not only describe the region's actual three-dimensional geometry but also aid in describing its evolutionary path. Drainage basin gives a fundamental understanding of the drainage basin's or watershed's variation in rock resistance, geological and geomorphologic history, initial gradient and structural control. The evaluation of the morphometric characteristics necessitates the examination of numerous drainage parameters such as stream order, basin size and perimeter measurement, drainage channel length, bifurcation ratio (Rb), drainage density (Dd), relief ratio (Rr), and stream length ratio (RL). Also, a quantitative evaluation of the drainage system is an essential component of watershed characteristics. It is essential in any hydrological inquiry such as groundwater potential evaluation, groundwater management, basin management, and environmental assessment. Within the watershed, hydrological and geomorphic processes occur. Morphometric characterization at the watershed scale exposes information about the origin and evolution of the land surface. Using traditional approaches, the drainage features of various river basins and sub-basins from across the world have been examined. The surface runoff and flow intensity of the drainage system may be calculated using geomorphic characteristics linked with morphometric factors. According to Strahler's classification method, a stretch with no tributaries is classified as a first-order stream. A second-order stream segment is generated when two first-order stream segments meet, and so on. The purpose of the drainage basin morphometric research is to obtain trustworthy data on quantifiable characteristics of the drainage basin's stream network. Various hydrological phenomena, including as drainage area size, form, slope, drainage density, contributory size and length, and so on, can be linked to the physiographic features of a drainage basin. Remote sensing is a useful technique for morphometric study because satellite images provide a synoptic view of a large area and are particularly successful in the analysis of drainage basin morphometry (Rao *et al*., 2010). The combination of remote sensing satellite data with hydrological and spatial data in a GIS context makes it simple to identify and differentiate drainage areas. GIS-based analysis of Shuttle Radar Topographic Mission (SRTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data has provided an accurate, quick and low-cost method for analyzing hydrological systems(Smith and Sandwell, 2003; Grohmann, 2004). The processed DEM may successfully be utilized to generate the stream network and other supporting layers. (Mesa, 2006; Magesh *et al*., 2011). The

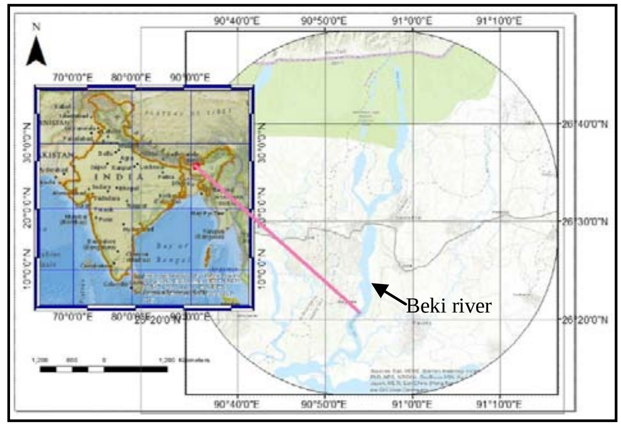

Fig. 1. Location of the study area

geographic and geomorphic qualities of a drainage basin are critical for hydrological research including the estimation of groundwater potential, among other things. This analysis of drainage and morphometric analysis of the Beki river basin, India is based on GIS and Remote Sensing approach.

2. Study area

The area of study lies in the geographical region of Assam, Bhutan, and Tibet. The river Beki (also known as the Kurissu River in Bhutan) is a north bank tributary of the Brahmaputra River. It flows through Bhutan and India. In India, it flows through the state of Assam. It originates in the upper reaches of Himalayas. In Assam, it originates from the Man as reserve forest at Mathanguri and outfalls at the Brahmaputra near Balajan. Extending between 26° 18' N - 26° 48'N latitude 90° 53'E - 91° 02' E longitude.

The present study attempts to analyze the various parameters of the Beki river basin along with morphometric analysis. Quantitative analysis of morphometric parameters for the present study is done using the Digital Elevation Model (DEM) from Shuttle Radar Topographic Mission (SRTM) of 90m resolution data. Arc GIS 10.3, spatial analyst tools, and Arc hydro tools were used for the sub-basin delineation and further analysis of the morphometric parameters of the sub basin like linear, relief, topographic and aerial aspects. Strahler (1952) stream ordering technique was followed for stream ordering Morphometry, the mathematical study of the configuration of the earth's surface shape and dimensions of its landform, serves as the foundation for the watershed investigation. (Clarke, 1996). The primary factors of analysis are the area, slope, volume, height, profile, and texture of landforms. Dury (1952). A systematic description of the geometry of the drainage basin and its

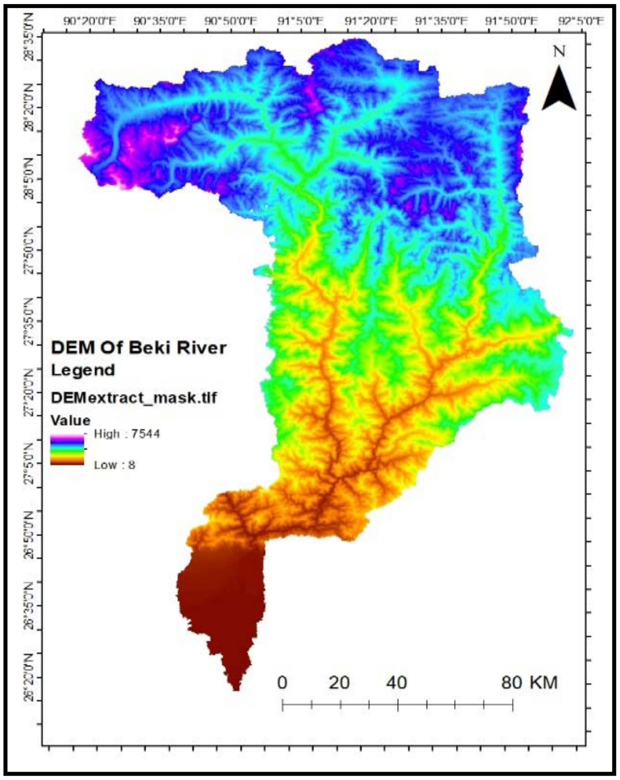

Fig. 2. DEM of Beki river basin

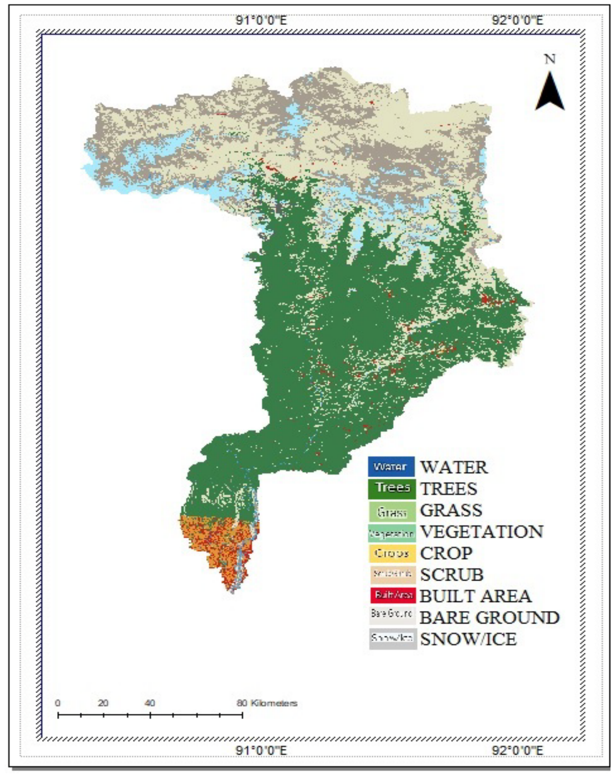

Fig. 4. LULC Map of Beki basin

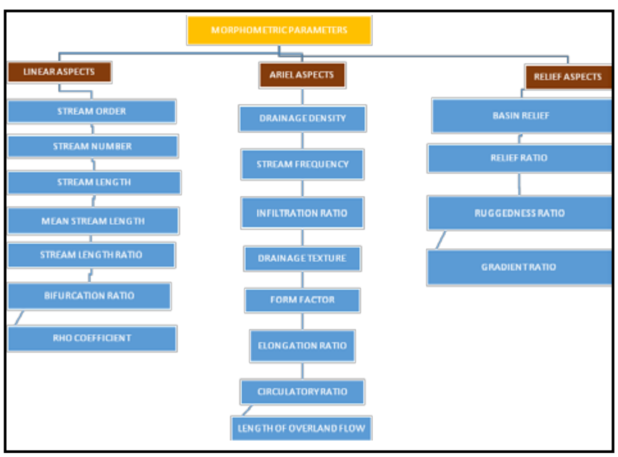

Fig. 3. Flowchart for Analysis of different Aspects

stream channel involves measurement of the drainage network's linear aspects, aerial aspects, relief (gradient) aspects of the channel network, and contributing ground slopes, Strahler (1964). The different features of the morphometric investigation of the Beki basin covered in this study are shown in the flowchart mentioned in Fig. 3.

Geomorphic indices are particularly useful in tectonic studies & may be used for rapid evaluation of large areas (Le Conte, J., 1909, Keller & Pinter, 2002). In this work, five active tectonics indices were generated in an ArcGIS context utilizing SRTM-DEM data. These include - sinuosity indices, the hypsometric integral (HI), stream length-gradient index (SL), valley width-height ratio (Vf) and the drainage basin asymmetry (Af).

3. Result and discussions

The Beki River basin's morphometric parameters have been computed, and the results are presented here. The Beki River basin has a total drainage area of 19354.35 km^2. The drainage pattern is dendritic, driven by the area's overall terrain, geology and rainfall conditions. The Aster DEM is used to generate slope, aspect, flow direction, stream network, Land use Land Cover (LULC), and contour maps.

3.1. *Basin Characteristics*

The Beki river basin has the highest elevation with about 7544 meters above msl in the north part and the lowest elevation is 8 meters above msl in the south partlies in the geographical territories of both Assam and Bhutanland use/land cover map (Fig. 4) of Beki riverbasin was prepared from satellite imagery of the study period to represent the land use/land cover conditions and the use of

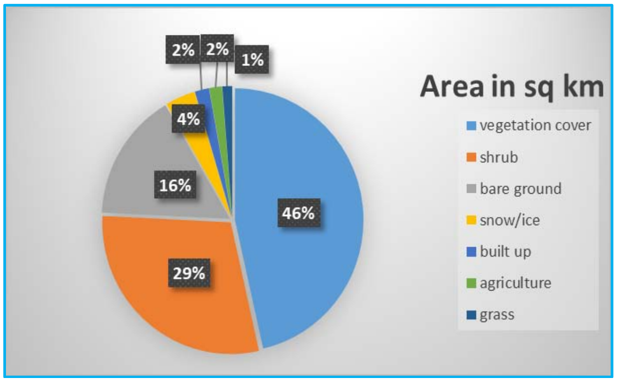

Fig. 5. Area in percentage covered by different main Land Use/Land Cover

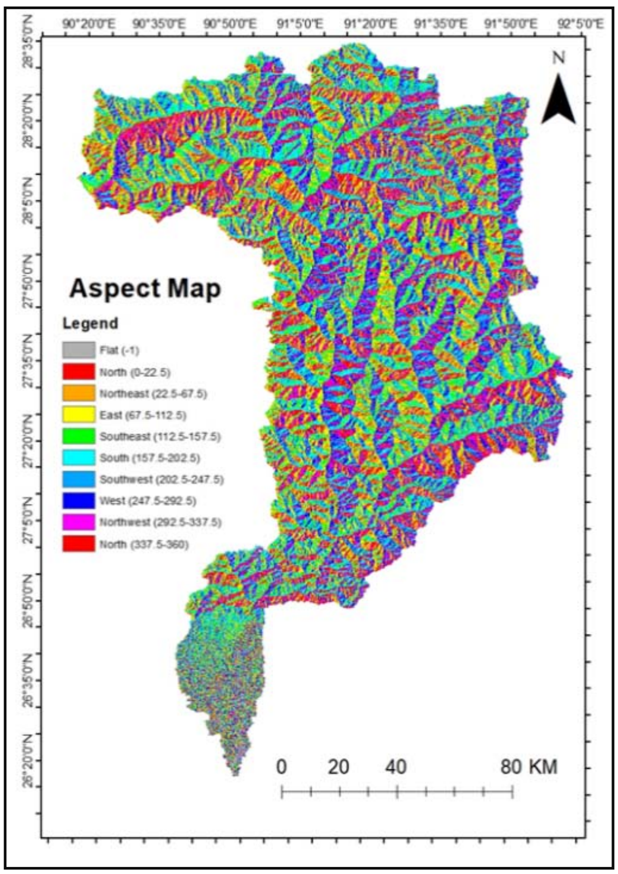

Fig. 6. Aspect Map of Beki Basin

land for various purposes. Nine major landuse/landcover types have been identified named water bodies, vegetation cover, flooded vegetation, agriculture, shrub, built-up area, bare ground, snow/ice and cloud.

The different categories of land use and land cover in order of abundance can be represented as vegetation cover (includes trees, grass and vegetation) (46 %) > shrub

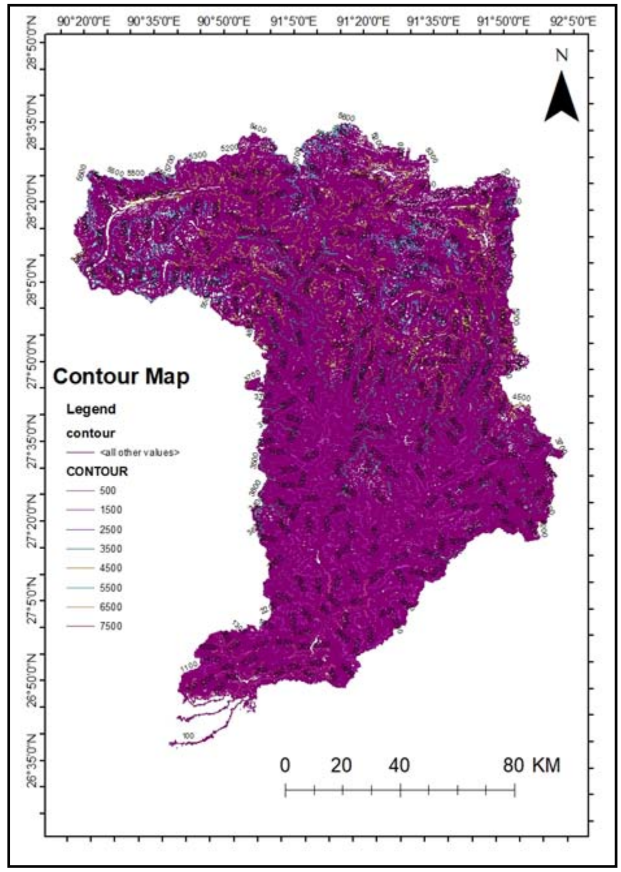

Fig. 7. Contour Map of Beki River Basin

(29%) > bare ground (15%) > built up area (1.76%) > ice or snow (3.7%) > agricultural area (1.58%) > grass cover (1.24%) > water bodies (0.67%) > vegetation (0.004%). (Fig. 5)

3.2. *Slope and Aspect Map*

Slope and aspect map of the basin were determined from the DEM and shown in Fig. 5 and Fig. 6. Slope map shows that the basin is characterized by variable slopes ranging from 78.6475 degrees to 0 degrees in certain locations. Aspect map has been generated to understand the direction of the mountain slope through DEM data.

3.3. *Contour and Flow Direction Map*

Contours are generated from the DEM, *i.e.*, the SRTM data downloaded from the USGS website (Fig. 7). The maximum contour value has been observed as 7500m in the basin's northern part while the minimum contour value is about 100 m in the southern part of the basin near the Brahmaputra.

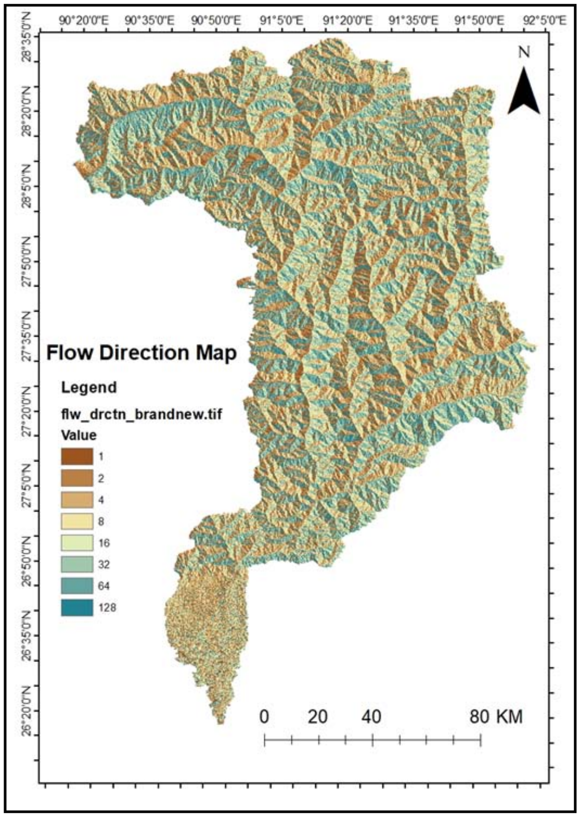

Fig. 8. Flow Direction Map of Beki River Basin

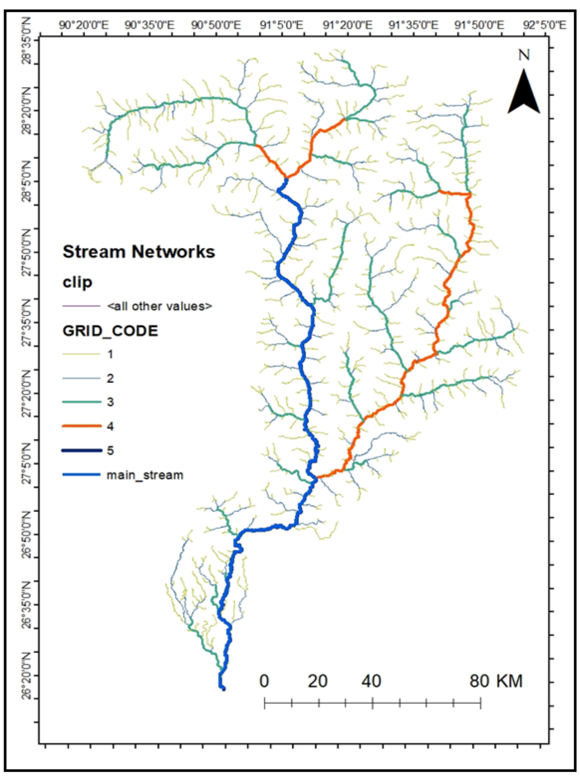

Fig. 9. Beki Basin with stream network

TABLE 1

Stream order and stream no. of different order streams of Beki basin

Stream Order	Stream No. (N_u)
1	612
2	104
3	20
4	3
5	1
Total	740

Flow direction map as shown in Fig. 8 is determined from the DEM and it shows that the drainage flows towards south and is connected together in one main stream in south.

3.3. *Stream Order (u) and Stream number (Nu)*

According to Strahler (1964), the smallest fingertip tributaries are designated as order 1. Where two first order channels join, a channel segment of order 2 is formed, where two of order 2 joins, a segment of order 3 is formed, and so forth.

Following the Strahler (1964) order, the study area is of a 5th order drainage basin (Fig. 9).

During the analysis, it was observed that the number of streams gradually reduces as the stream order increases (Table 1); the variance in stream order and size of tributary basins is heavily influenced by the region's physiographic, geomorphological and geological conditions. In the whole basin, 740 stream lines, including the Beki River, are identified, with 82.7 percent of them being navigable. (612) is of 1^{st} order, 14.05 % (104) 2^{nd} order, 2.7 % (20) 3^{rd} order, 0.405 % (3) 4^{th} order and 0.0013 % comprises 5^{th} order stream.

3.4. *Stream length (L_u) and Mean Stream Length (L_{um})*

The result of order-wise stream length of the Beki basin is shown in Table 2. It is identified that the cumulative stream length is higher in the first-order of the streams and eventually decreases as the stream order increases. The highest stream order (*i.e.*, 5^{th}) for Beki River has a length of 278.26 km.

The Mean Stream Length (Lum) values for the Beki basin range from 4.04 to 278.26 km (Table 3) with a mean L_{um} value of 80.84 km.

TABLE 2

Stream length of different order streams of Beki basin

Stream Order	Length (L_u) (km)
I	2474.53
II	1080.37
III	644.84
IV	237.84
V	278.26
Total Length	4715.84

TABLE 3

Mean Stream Length of different stream order

Stream Order	Mean Stream Length (Lum) = (L_u/N_u)
1st	4.04
2nd	10.388
3rd	32.24
4th	79.28
5th	278.26

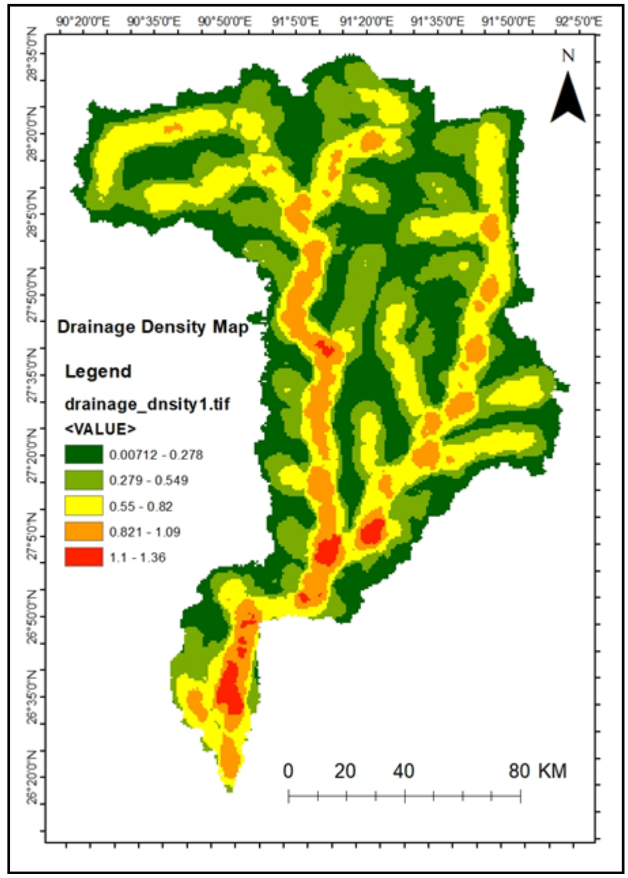

Fig. 10. Drainage Density Map

3.5. *RHO Coefficient (ρ)*

RHO is the ratio between stream length ratio and bifurcation ratio. It describe a relationship between drainage density (Dd) and physiographic development of the basin, evaluates the water storage capacity of the basin during flood periods. If RHO (>0.50) = basin has greater storage capacity and RHO (<0.50) = basin has less storage capacity. The Rho Coefficient for the Basin is 0.56 which is greater than 0.50. It defines that the water storage capacity of the basin is greater. It attenuates the effects of erosion during elevated discharge. Basin can hold water for a long time.

3.6. *Ariel aspects*

Ariel aspects consist of form factor, elongation ratio, circulatory ratio, stream frequency, drainage density, drainage texture, infiltration ratio, length of overflow and compactness coefficient.

3.6.1. *Basin Area (A)*

The basin area of the Beki river is 19354.35 km^2.

3.6.2. Perimeter (P)

The Beki river basin perimeter is about 1248.3 km.

3.6.3. *Basin Length (L)*

The basin length of the Beki river basin is about 265.96 km.

3.6.4. Total Streams (N)

The total streams of the Beki river basin are about 740 numbers.

3.6.5 *Total Streams Length (L_u)*

The total streams length of the Beki river along with its tributaries is about 4715.8 km.

3.6.6. *Form factor (F_f)*

Horton (1932), defined form factor as the ratio of basin area to square of the basin length. The form factor

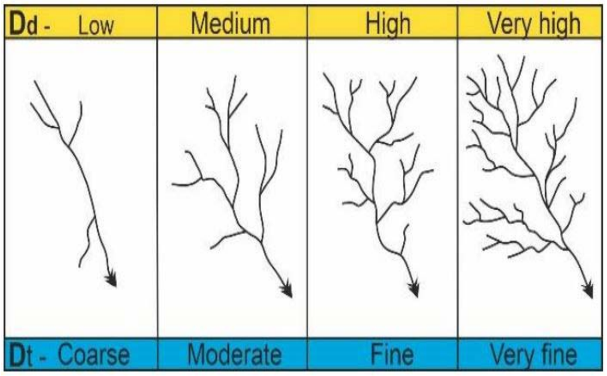

Fig. 11. Relationship between Drainage density (D_d) & Drainage Texture (D_t)

(F_f) value of the Beki basin is low, *i.e.*, 0.27. Thus, the Beki basin is an elongated one with low pick flow and longer duration.

3.6.7. *Elongation Ratio (R_e)*

Elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. Strahler states that this ratio runs between 0.6 and 1.0 over a wide variety of climatic and geologic types. Beki basin has a R_e value of 0.59, indicating considerable relief with a steep slope and an elongated form. Higher elongation ratio values indicate good infiltration capacity and little runoff, whereas lower Re values indicate high sensitivity to erosion and sediment load (Reddy *et al.*, 2004). Elongation ratio (R_e) for Beki river, *i.e.*, 0.59 (for elongated basin) is susceptible to headwater erosion, high relief and steep ground slope indicating an increase in elongation.

3.6.8. *Circulatory ratio (R_c)*

Circularity ratio is defined as the ratio of watershed area to the area of a circle having the same perimeter as the watershed and it is pretentious by the lithological character of the watershed. R_c value of the Beki basin is 0.15. Low R_c value leads to elongated basin shape, low flood risk and longer lag times. Since the value of R_c is low it indicates the late Young stage.

3.6.9. *Drainage Density (D_d)*

The Beki basin has a drainage density of 0.24, indicating that the basin region has a highly resistant permeable underlying material with intermediate drainage and low to moderate relief. Low drainage density results in coarse drainage texture, whereas high drainage density results in fine drainage texture, high runoff, and the basin area's erosion potential. Strahler (1964). A low drainage density suggests porous subsurface strata and is a trait of coarse drainage, with values less than 5.0 being typical. The Beki basin has a drainage density of 0.24, indicating that the research region has a weak or porous subsurface material with intermediate drainage and low relief, as well as a drop in flood level.

3.6.10. *Drainage Texture (D_t)*

For the whole basin, the drainage texture (D_t) is 0.59 and it comes under coarse texture, as the values are less than 4.0 according to Smith classification but in the hilly areas, the drainage texture is fine with less infiltration and more runoff.

3.6.11. *Stream frequency (F_s)*

The channel segment numbers for unit areas are difficult to count (Singh 1980) however, an attempt has been made to quantify Beki basin stream frequency. The Beki basin has a stream frequency of 0.038. The value of stream frequency (Fs) for the basin has a positive association with the drainage density value of the region, showing an increase in stream population as drainage density increases. A low Fs results in a low Dd, a low slope, a permeable nature, and low surface runoff.

3.6.12. *Length of overflow (L_g)*

The length of overflow (L_g) of the Beki basin is 2.05 km. A higher value of L_g that is found in the valley area indicates gentle slopes & less susceptibility to erosion (sheet erosion) whereas lower values in the terrain or hilly areas indicate steep slopes with more susceptibility to erosion.

3.6.13. *Gravelius Index (K_g) or Compactness coefficient*

The compactness coefficient of the Beki basin is 2.51. A higher value of the Gravelius index indicated a more elongated basin.

3.7. *Relief Parameters*

Relief aspect refers to a three-dimensional feature involving area, volume and altitude. The highest and lowest elevation of the watershed is 7500 m and 100m respectively.

3.7.1. *Total basin relief (R)*

The total basin relief of the Beki basin is 5.493 km. It determines the slope, runoff and sediment transport. Its

TABLE 4

Sinuosity indices of the Beki River

Section	Channel length	Direct length	Sinuosity
Section 01	28.67	20.52	1.397
Section 02	28.67	21.63	1.325
Section 03	28.67	22.39	1.280
Section 04	28.67	25.16	1.139
Section 05	28.67	21.39	1.340
Section 06	28.67	21.04	1.362
Section 07	28.67	20.94	1.368
Section 08	28.67	19.68	1.456
Section 09	28.67	23.47	1.221
Section 10	28.67	20.71	1.384
		Average	1.32

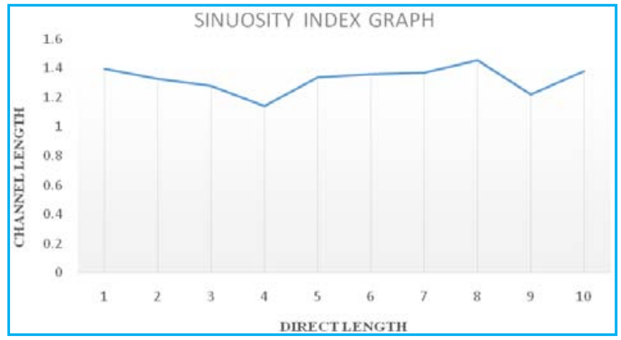

Fig. 12. Sinuosity graph at different sections of the Beki River

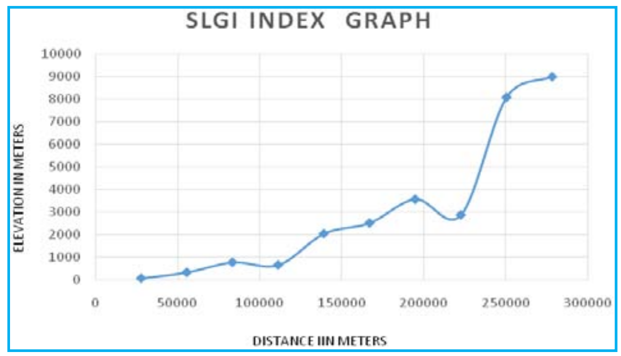

Fig. 13. SLGI Index graph of Beki Basin

high value suggests higher water flow gravity, little infiltration, and high runoff conditions.

3.7.2. *Relief ratio (R_r)*

The Beki Basin has a relief ratio of 1.34. While high values are typical in hilly areas, low values are typical in plains and valleys. The inclinations of the land surface with respect to stream slope are closely linked with its channel gradients and relief. In the field, there is a strong association between high relief and high drainage frequency, high stream frequency, and high stream channel slopes, all of which produce significant discharges in a short period of time. Lower Re values indicate greater sensitivity to erosion and sediment load. This indicates that the watershed's discharge capability is quite high but the groundwater potential is modest.

3.7.3. *Ruggedness number (R_n)*

The ruggedness number (R_n) of the Beki river basin is 1.38 which is a lower value. The lower value of R_n indicates less prone to soil erosion.

3.7.4. *Gradient ratio (G_r)*

The gradient ratio of the Beki basin is 11.33. A higher value of gradient ratio indicates more surface runoff.

3.8. *Geomorphic Indices*

In this work, five active tectonics indices were generated in an ArcGIS context utilizing SRTM-DEM data. The hypsometric integral (Hi), stream length-gradient index (SLGI), valley width-height ratio (Vf), Sinuosity indices, and drainage basin asymmetry are among the indicators (Af).

3.8.1. *Sinuosity indices*

Sinuosity defines the degree of meandering of a river bed, which can be used to establish geomorphological river types. The sinuosity at the different sections of the river has been further discussed in the table below. When the straight-line slope of the valley is too steep; for equilibrium- the sinuous path of the meanders reduces the channel slope. The average Sinuosity index is 1.32 (>1) which indicates that river Beki is meandering.

3.8.2. *Stream Length-Gradient Index (SLGI)*

In the hilly terrain, *i.e.*, in the upper basin the SLGI index is high indicating that the river is flowing through tectonically active rock and the lower values are observed in the valley areas in the lower part of the basin. The

TABLE 5

Stream length-Gradient index (SLGI) at a different section of the Beki River

Section	Elv Upper (m)	Elv Lower (m)	Ls (m)	Total Length (m)	SLGI = (ΔH/ΔL) × L
Section 1	3,016	2,116.08	27,825.98	278259.7517	9,003
Section 2	2,116.08	1,307.11	27,825.98	278259.7517	8,090
Section 3	1,307.11	1,020.54	27,825.98	278259.7517	2,866
Section 4	1,020.54	664.95	27,825.98	278259.7517	3,556
Section 5	664.95	414.657	27,825.98	278259.7517	2,503
Section 6	414.657	211.254	27,825.98	278259.7517	2,034
Section 7	211.254	147.505	27,825.98	278259.7517	637
Section 8	147.505	71.947	27,825.98	278259.7517	756
Section 9	71.947	41	27,825.98	278259.7517	309
Section 10	41	36	27,825.98	278259.7517	50

TABLE 6

Hypsometric Integral (Hi) at a different section of the Beki River

Min Elv	Max Elv	Elv Class	h(relative relief) = Elv class -Min Elv	Relative Height (h/H)	Area	Cumulative Area (a)	Relative Area (a/A)
8	755	8	0	0	1716.001	19354.05673	1
755	1510	755	747	0.099124204	1760.433	17638.05593	0.911336377
1510	2265	1510	1502	0.199309979	2060.076	15877.62282	0.820376991
2265	3020	2265	2257	0.299495754	2192.411	13817.54658	0.713935418
3020	3775	3020	3012	0.399681529	2020.437	11625.13547	0.600656267
3775	4530	3775	3767	0.499867304	2970.569	9604.698017	0.496262781
4530	5285	4530	4522	0.600053079	4656.473	6634.128778	0.342777169
5285	6040	5285	5277	0.700238854	1764.159	1977.655461	0.102182994
6040	6795	6040	6032	0.800424628	198.2052	213.496336	0.01103109
6795	7544	6795	6787	0.900610403	15.29118	15.291175	0.000790076
		7544	7536	1			0
				0.449755958		1.742381767	0.842869851

higher value in the upper reaches indicates that the river is flowing through the tectonically active soft rock. The lower values in the valley region indicate more or less stability.

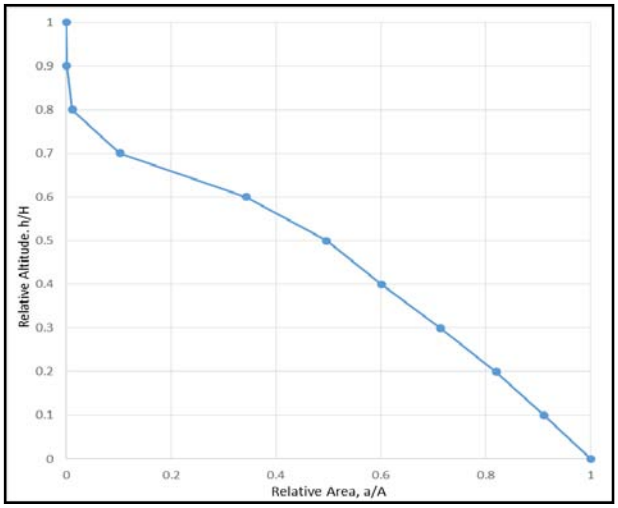

Fig. 14. Hi curve showing the Middle stage of the river

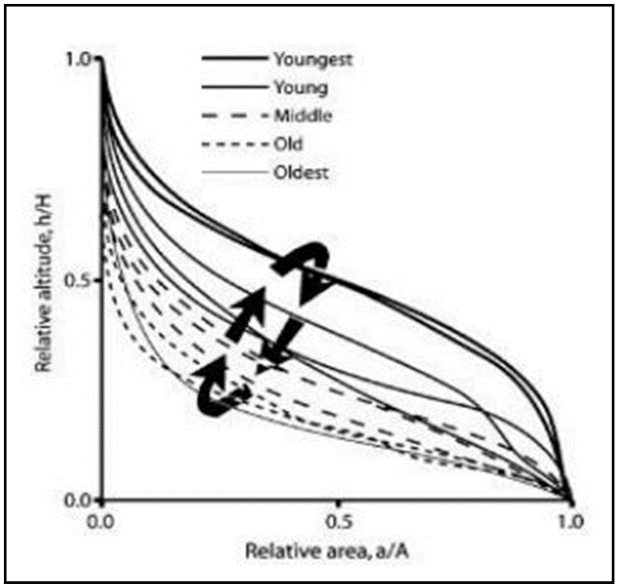

Fig. 15. Hi curve for different stages of the river

3.8.3. *Hypsometric curve & Hypsometric Integral (Hi)*

The Hi value of the basin is 0.45. Since the value is between 0.35 to 0.6, then defines the mature stage of the river.

3.8.4. *Asymmetry factor (A_f)*

The Asymmetry factor of the Beki river is 42.65. Since this value is less than 50, it means that the river slopes down to the right of the basin (looking downstream).

where,

A_r= area of the basin to the right of the trunk stream

A_t = the total area of the drainage basin

TABLE 7

Asymmetry factor (AF) of the Beki River

Ar	At	Af= 100 (Ar/At)
8255.931	19354.06	42.65736882

In the study the digital elevation models generated from SRTM data for the Beki Basin area are used as an elevation reference. From the digital elevation model, it is observed that the northern parts of the basin have higher elevations than the middle and southern parts have the lowest elevation. The basin elevation varies from 7544 m to 8 m. Slope and aspect maps of the river basin are generated from the DEM. Slope map shows that the basin is characterized by variable slopes ranging from 78.64 degrees to 0 degrees in certain locations. Aspect maps which are very important for determining water flow in the basin show that the basin mostly faces towards the south. The drainages flow in a different direction and are connected together in one main stream. The drainage network is characterized by dendritic patterns. The contour map shows that the northern section of the basin has the greatest elevation, while the southern and southwestern parts of the basin have the lowest. The contour value ranges between 7544m to 8m. The land-use and land-cover map is also generated using DEM. The morphometric examination of the basin's drainage network reveals a mostly dendritic type, indicating uniformity in texture and a lack of structural control and it aids in understanding many terrain aspects. According to the findings, the general architecture of the Beki River Basin is elongated and dendritic. It has been noticed that when the stream order lowers, the total number of streams progressively increases, and *vice versa*. It should also be mentioned that the basin's drainage region is transitioning from an early mature to an elderly age stage of the fluvial geomorphic cycle. Lower order streams predominate in the basin. Rainfall influences the development of stream segments in the basin region to varying degrees. Lower Rb values are features of watersheds that have had fewer structural disturbances (Strahler, 1964) and the drainage pattern has not been changed as a result of the structural disturbances (Nag, 1998). The watershed's stream frequency value has a positive association with drainage density, indicating that as drainage density increases, so does stream population. The drainage texture of the basin was defined as quite coarse by the drainage density. The drainage basin was defined as elongated with high relief, steep ground slope, increased headwater erosion, longer lag time, and highly permeable subsurface condition based on the elongation and circularity ratio value.

The drainage density in the area of study is low and characteristic of the texture of coarse drainage. The circularity ratio shows that the watershed is having low relief of terrain and is elongated in shape. A bifurcation ratio of 5.18 reveals that the drainage network in the study area is in a well-developed stage. The study reveals that the basin drainage area is passing through an early maturing stage to the old age stage of fluvial geomorphic cycle. Form factor (F_f) is computed out to be 0.27 which indicates an elongated basin with low pick flow and longer duration. The total area of the basin is 19354.35 km^2 and the perimeter is 1248.3 km. The length of the main stream is calculated as 265.96 km. The total length of the streams and number of streams is 4715.8 km and 740 numbers respectively.

In this study, greater Rb values imply substantial structural control on the drainage pattern, whereas lower values indicate watersheds that are unaffected by structural disturbances. This method to determine the mean bifurcation ratio value is 5.18 in the Beki Basin. The infiltration ratio is higher which indicates low infiltration and high runoff in the hilly terrain areas. The length of overflow (L_g) of the Beki basin is 2.05 km. A higher value of L_g that is found in the valley area indicates gentle slopes & less susceptibility to erosion (sheet erosion) whereas lower values in the terrain or hilly areas indicate steep slopes with more susceptibility to erosion. The ruggedness number is 1.38 which indicates that the area is rugged with high relief and high stream density, making the area vulnerable to flood. The gradient ratio of the Beki basin is 11.33 which indicates more surface runoff. The relief ratio of the basin is 1.34 in the field, there is a strong association between high relief and high drainage frequency, high stream frequency and high stream channel slopes, all of which produce significant discharges in a short period of time. Lower Re values indicate greater sensitivity to erosion and sediment load. These indicate that the water-discharge shed's capability is quite great while the groundwater potential is modest. The average Sinuosity index is 1.32 (>1) which indicates that the river Beki is meandering. In the hilly terrain, *i.e*., in the upper part of the basin the Stream Length Gradient Index (SLGI) index is high indicating that the river is flowing through tectonically active rock and lower values are seen in the valley sections of the basin's lower reaches. The Hi value of the basin is 0.45. Since the value is between 0.35 to 0.6, then defines the stage of maturity of the river**.** The Asymmetry factor of the Beki river is 42.65. Since the value is less than 50 and it implies that the river tilts down to the right of the basin (looking downstream).

4. Conclusion

According to the above discussion, the catchment region has strong drainage characteristics for water conservation which can be complied by analysing the satellite data. These information, on one hand, provides a better understanding of land utilization aspects and on the other hand, it plays an important role in the formation of policies and programme required for development planning.

As a result, the basin may implement appropriate water conservation practices. It is beneficial for natural water resource management which includes management and planning for stopping river bank erosion, land loss and economic loss etc. and the establishment of sustainable watersheds.

Disclaimer : The contents and views expressed in this study are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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