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Estimation of Morphometric Parameters of Karatoya sub-River Basin in Bangladesh using GIS and Remote Sensing Techniques

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Abstract

Morphometric analysis identifies the relationship of various aspects in the basin area, and plays an important role for understanding the geo-hydrological characteristics of a basin. The Karatoya River is ecologically and economically significant for Dinajpur region of Bangladesh. In this study, the morphometry of a sub-portion of Karatoya River in Birganj upazila was assessed by using GIS and remote sensing. The secondary data from ASTER DEM data and DEM data of Bangladesh were used to represent the morphologic and geo-hydrologic nature of the basin. The study computed and assessed more than 31 morphometric parameters in all aspects of the river basin. Morphometric analysis of the river network and the basin revealed that the Karatoya sub-basin was in the 6th order river network (as Strahler's classification) with a dendritic and parallel drainage pattern and fine grain in drainage texture. This type of analysis will lead to develop the sustainable framework for agricultural and watershed management to be used by the local administration.

Keywords

Morphometric parameters, Karatoya sub-basin, GIS, Remote sensing, Watershed management

Introduction

Morphometry is the measurement and mathematical analysis of the configuration of the Earth's surface, shape and dimension of its landforms (Bates and Jackson, 1987; Clarke, 1966; Agarwal, 1998; Wagener *et al*., 2001; Rekha, George, and Rita, 2011). It also represents the topographical expression of land in terms of area, shape, length, etc., which affect the catchment stream flow patterns through their influence on concentration time (Jones, 2014). Morphometric studies were first initiated in the field of hydrology where the main idea behind this work was to ascertain complete stream properties from the quantification of various stream attributes (Horton, 1940; Strahler, 1950). Morphometric analysis for the evaluation of catchment basin, their characterization and classification are performed from the 1990s by the pioneer workers who studied linear, aerial and relief aspects with interpretation of its interrelationship to land and water management (Horton, 1945; Smith, 1950; Strahler, 1957) by using remote sensing and GIS methods (Krishnamurthy and Srinivas, 1995; Srtvastava and Mitra, 1995; Agarwal, 1998; Biswas, Sudhakar and Desai, 1999; Narendra and Rao, 2006). Morphometric analysis of the watershed is taken under consideration to be the foremost satisfactory method because it enables an understanding of the connection of various aspects within a catchment area. A comparative evaluation is made of different drainage basins evolved in several geomorphological and topographical regimes (Krishnamurthy *et al*., 1996).

Digital elevation model (DEM) is a major dataset for various applications including hydrology and morphometric studies (Patel, Katiyar and Prasad, 2016; Wise, 2000). Morphometric parameters can be readily determined from DEM using GIS (Samal, Gedam and Nagarajan, 2015). Nowadays, integration of remote sensing (RS) and geographical information system (GIS) is useful in planning and management of land and water resources. With the advancement of geospatial technologies like GIS and RS, geomorphological parameters can easily be extracted from the digitalized toposheets (Ratnam *et al*., 2005). Moreover, GIS tools are capable of handling spatial and temporal data, with the implication that morphometric parameters are often updated whenever any change occurs (Apaydin *et al*., 2006). In this study, the effort is made to investigate the influence of morphometric variables on drought-vulnerable zone and agricultural practice in the north-western part of Bangladesh, especially in the Dinajpur region. A morphometric analysis of the Karatoya sub-basin can answer the query, and to help in planning of this area for agricultural development. The GIS and image processing techniques were adopted for the identification of morphometric features to analyze the properties of the Karatoya sub-river basin in Birganj upazila. The objectives of the study were i) to formulate the management guideline for the Karatoya sub-basin, ii) to identify the drainage network and channel geometry, and iii) to analyze the drainage texture and relief characteristics of the sub-basin.

Materials and Methods

The Karatoya sub-basin is in the Birganj upazila of Dinajpur district located in the north-western corner of Bangladesh. The study area is located between 25°47' and 26°01' N latitudes and in between 88°42' and 88°51' E longitudes (Figure 1). The Karatoya River enters this upazila through Bherbheri union and gets out of this upazila through Bhabki union. The secondary data were collected from USGS (United States Geological Survey), GloVis (Global Visualization Viewer),

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published articles and Bangladesh Geological Survey (BGS). This study also used the ASTER DEM image with 30 m spatial resolution. The analysis for this research was conducted in different steps (Figure 2). The map of the study area was made by ArcMap software with the help of Google Earth image. The elevation map of the Karatoya sub-river basin was generated by 3D analyst tool of ArcMap using the DEM data of Bangladesh.

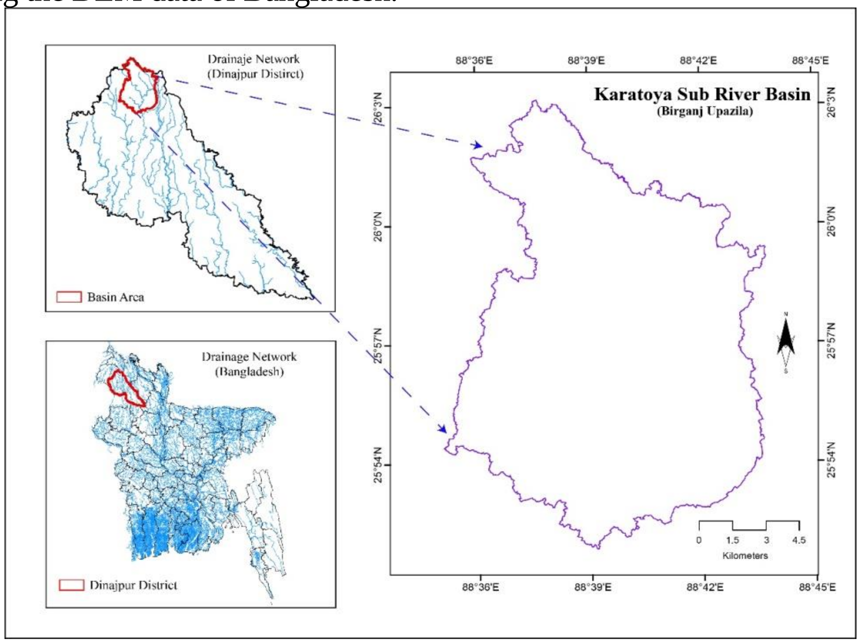

Figure 1: Geographical location of the Karatoya sub-river basin in Dinajpur district, Bangladesh

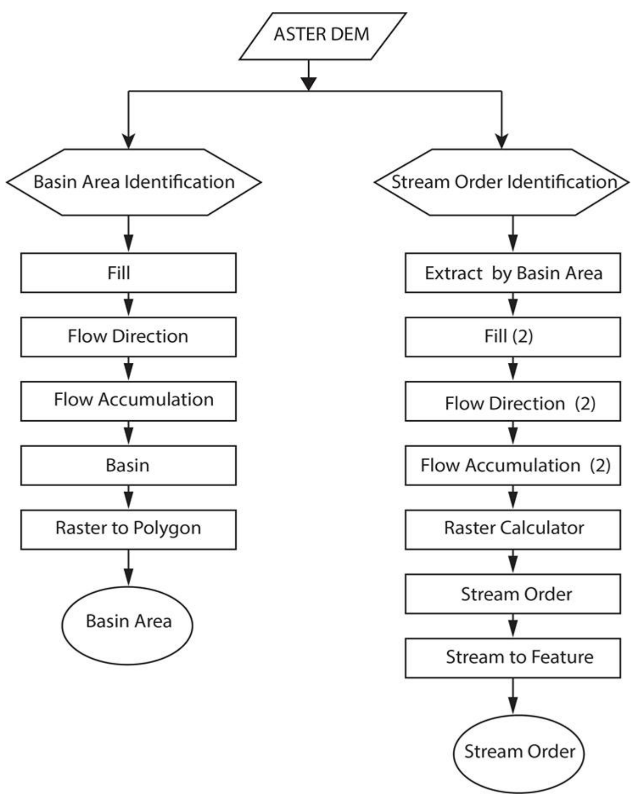

Figure 2: Methodological framework of the study in Dinajpur district, Bangladesh

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In the study, the morphometric parameters such as drainage network, basin geometry, drainage texture, and relief characteristics of the Karatoya sub-basin were computed from the following formula developed by different hydrologists, geomorphologists and researchers (Table 1).

Table 1: Morphometric parameters calculated for the Karatoya sub-basin from four aspects as drainage network, basin geometry, drainage texture and relief characteristics

Morphometric parameters	*Formula*	*Reference*
Drainage network		
Stream order (S_u)	Hierarchical rank	Strahler, 1952
Stream number (N_u)	$N_u = N_1+N_2+\ldots.+N_n$	Horton, 1945
Stream length (L_u)	$L_u = L_1+L_2+\ldots.+L_n$	Strahler, 1952
Bifurcation ratio (R_b)	$R_b = N_\mu/N_{\mu+1}$; where, R_b = Bifurcation ratio, N_μ = No. of stream segments of a given order, $N_{\mu+1}$= No. of stream segments of next higher order.	Strahler,1964
Weighted mean bifurcation ratio (R_{bwm})	Total of Rb*(N_{u-r})/Total of (N_{u-r})	Strahler, 1964
Mean stream length (L_{um})	$L_{sm} = L_\mu/N_\mu$; where, L_μ = Total stream length of order 'μ', N_μ = Total no. of stream segments of order 'μ'	Horton, 1945
Stream length ratio (L_{ur})	$L_{ur} = L_u/(L_{u-1})$; where, L_u = Total stream length of order 'μ', L_{u-1} = Stream length of next lower order	Horton, 1945
Length of main channel (C_l)	GIS software	-
Rho coefficient (ρ)	$\rho = L_{ur}/R_b$	Horton, 1945
Basin geometry		
Length of the basin (L_b)	GIS software	-
Basin area (A)	GIS software	-
Basin perimeter (P)	GIS software	-
Lemniscate's (k)	$K = L_b^2/A$; where, L_b = basin length, A = Area of basin	Chorley, 1957
Form factor (F_f)	$F_f = A/L_b^2$; where, A = Bain Area, L_b = Basin length	Horton, 1932
Circularity ratio (R_c)	$R_c = 12.57\times(A/P^2)$; where, A = Area of basin; P = Basin perimeter	Miller, 1953
Compactness coefficient (C_c)	$C_c = 0.2841\times P/A^{0.5}$; where, P = Basin perimeter, A = Basin area, 0.2821= Constant.	Gravelius, 1914
Fitness ratio (R_f)	$R_f = C_l/P$; where, C_L = Channel length; P = Basin perimeter.	Melton, 1957
Wandering ratio (Rw)	$Rw = C_l/L_b$; where, C_L= Main channel length; L_b = Length of the basin	Smart and Surkan, 1967
Sinuosity index (Si)	Si = Main channel length/air length	Pareta and Pareta, 2011
Drainage texture analysis		
Stream frequency (F_s)	$F_s = N_u/A$; where, N_u = No. of streams; A = Basin area	Horton, 1932

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Drainage density (D_d)	$D_d = L_u/A$; where, L_u = Length of stream; A = Basin area.	Horton, 1932
Drainage texture (D_t)	$D_t = N_u/P$; where, Nu = Number of streams; P = Basin perimeter	Horton, 1945
Constant of channel maintenance ($1/D_d$)	$C = 1/D_d$	Schumm, 1956
Infiltration number (I_f)	$I_f = F_s \times D_d$	Faniran, 1968
Drainage pattern (D_p)	-	Horton, 1932
Length of overland flow (L_g)	$L_g = A/2 \times L_u$; where, A = Basin area; L_u = Length of stream	Horton, 1945
Relief characteristics		
Relief ratio (R_{hl})	$R_{hl} = H/L_b$; H = Difference in height between highest and lowest point of basin, L_b = Horizontal distance along longest dimension of basin parallel to main stream	Schumm, 1956
Relative relief (R_r)	$R_r = H/P$; where, H = Basin leminescate, P = Perimeter	Schumm, 1956
Absolute relief (R_{hp})	GIS software	-
Slope	GIS software	-

Results and Discussion

Drainage network

The drainage network for a river is simply the system of the considerable number of streams and water bodies that are feeding water to the stream. A drainage network incorporates all the stream channels that flow toward a reference point (Martz and Garbrecht, 1992). The parameter of the drainage network in the Karatoya sub-basin was shown in Table 2 with their calculated values and measured units.

Table 2: Drainage network aspect parameters of the Karatoya sub-basin

Parameters	*Calculated values*	*Measured units*
Stream order (S_u)	1 to 6	order
Stream number (N_u)	628	number
Stream length (L_u)	567	kilometer
Bifurcation ratio (R_b)	3.98	-
Weighted mean bifurcation ratio (R_{bwm})	3.29	-
Mean stream length (L_{um})	1.62	kilometer
Stream length ration (L_{ur})	8.1	-
Length of main channel (C_L)	92.97	kilometer
Rho coefficient (p)	0.48	-

Stream order (S_u): Stream order provides a clear idea about the hierarchy of the tributaries. The study counts the stream order of Karatoya sub-basin according to Strahler (1952) concept which is popularly known as stream segment method. Each subsequent stream order is considered to stretch out headwords to the tip of the longest tributary. The third order gets second and first-

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order channels as its tributaries (Strahler, 1952). According to GIS assessment, there are 6th orders of streams found in this basin area (Table 2 and 3).

Stream number (N_u): The count of stream in a provided order is known as stream number (Horton, 1945). Generally, with the increase of stream order, the number of the stream decreases. Karatoya sub-basin consists of 446 streams in the 1st order and in the last order, the number decreases to 1. A higher stream number indicates that there are lesser permeability and infiltration. Karatoya sub-basin shows a negative relationship among the stream orders and stream numbers as mentioned in Table 3. The total number of the stream in the sub-basin is 628 (Table 2).

Stream length (S_l): The sum of all stream lengths of a particular order is the stream length of that order. Stream length is demonstrative of sequential improvements of the stream sections including interlude structural tectonic influences (Hajam, Hamid and Bhat, 2013). The length of the various stream channels in a basin is counted from the underlying catchment, for example, from the part of the basin to discharge zone is estimated with the assistance of ArcMap software. In this research, the length of all stream order has computed, here the total length of the first-order stream is 288 km and the length of the last stream order is 7 km (Table 4).

Bifurcation ratio (R_b): The term bifurcation ratio might be characterized as the proportion of various stream segments of a provided order to the number of portions of the following higher order (Schumm, 1956). The bifurcation ratio represents the branching pattern of the drainage network. The mean bifurcation ratio of the Karatoya sub-basin is 3.98 (Table 2). The high bifurcation ratio represents an early hydrograph top with a potential for flash flooding during the storm events in the territories in which these stream orders overrule (Rakesh *et al*., 2000).

Weighted mean bifurcation ratio (R_{bwm}): Weighted mean bifurcation ratio is closely related with bifurcation ratio. This ratio is calculated by multiplying the bifurcation ratio for each successive pair of orders by the total number of streams involved in the ratio and taking the sum of these values (Srivastava *et al*., 2014). It was observed that the weighted mean bifurcation ratio of Karatoya sub-basin is 3.29 (Table 2), which is very close to bifurcation ratio.

Table 3: Stream order, streams number and bifurcation ratio of Karatoya sub-basin

S_u	N_u	R_b	N_{u-r}	$R_b \times N_{u-r}$	R_{bwm}
i	446	-	-	-	
ii	127	3.51	573	2011.23	
iii	40	3.18	167	403.86	
iv	11	3.64	51	185.64	3.29
v	3	3.67	14	51.38	
vi	1	3	4	12	
Total	628	17	809	2664.11	
Mean		3.4			

Note: S_u = Stream order, N_u = Number of streams, R_b = Bifurcation ratio, N_{u-r} = Number of streams used in the ratio, R_{bwm} = Weighted mean bifurcation ratio.

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Table 4: Stream order and stream length ratio of Karatoya sub-basin

S_u	L_u	L_u/S_u	L_{ur}	L_{ur-r}	$L_{ur} \times L_{ur-r}$
i	288	0.65			
ii	140	1.10	1.69	428	723.32
iii	85	2.12	1.93	225	434.25
iv	34	3.09	1.46	119	173.74
v	13	4.33	1.40	47	65.8
vi	7	7	1.62	20	32.4
Total	567	18.29	8.1	839	1429.51

Note: S_u = Stream order, L_u = Stream length, L_{ur} = Stream length ratio, L_{ur-r} = Stream length used in the ratio.

Mean stream length (L_{um}): The mean stream length is the characteristic which is directly associated with the drainage network and its related surfaces (Strahler, 1964). Mean stream length indicates that the average stream length of a basin area. It is computed by dividing the total length of stream order by the total number of stream segments in the order (Table 4). The mean stream length varies from stream order to stream order. Karatoya sub-basin follows this principal concept.

Stream length ratio (L_{ur}): The ratio of the mean stream length of the given order to the mean stream length of next lower order is defined as stream length ratio. This helps determine the relationship with surface water flow and discharge (Horton, 1945). The total stream length ratio of Karatoya sub-basin is 8.1. The more the stream length ratio the more the surface water flow and discharge.

Length of the main channel (C_I): The main channel length is the longest watercourse from the outflow point of designated sub-watershed to the upper limit to the watershed boundary (Miller, 1953). Generally, it is the length principle flow of the watershed that is the destination of all tributaries (Heitmuller *et al.*, 2006). The main channel length of the Karatoya sub-basin is 92.97 km (Table 2), computed by ArcMap software.

Rho coefficient (P): Rho coefficient indicates the storage capability during the flood. This parameter is influenced by climatic, geologic, biologic, anthropogenic factors. This is a very important parameter that relates physiographic advancement of a watershed which leads to evaluate the storage capacity of a drainage network and also determinates the ultimate degree of drainage development in a given watershed (Horton, 1945). The higher the Rho coefficient value the higher the hydrologic storage during the flood. Rho coefficient of the Karatoya sub-basin is 0.48 (Table 2). This value suggests that lower hydrologic storage during the flood.

Basin geometry

Basin geometry demonstrates the size and shape of the channels in which water flows. Basin geometry and characteristics of the stream flow are naturally related. Changes in the geometry of the channel can affect stream velocity and discharge (Wohl and Wilcox, 2005). The parameters of channel geometry in Karatoya sub-basin are shown with results and measurement in Table 5.

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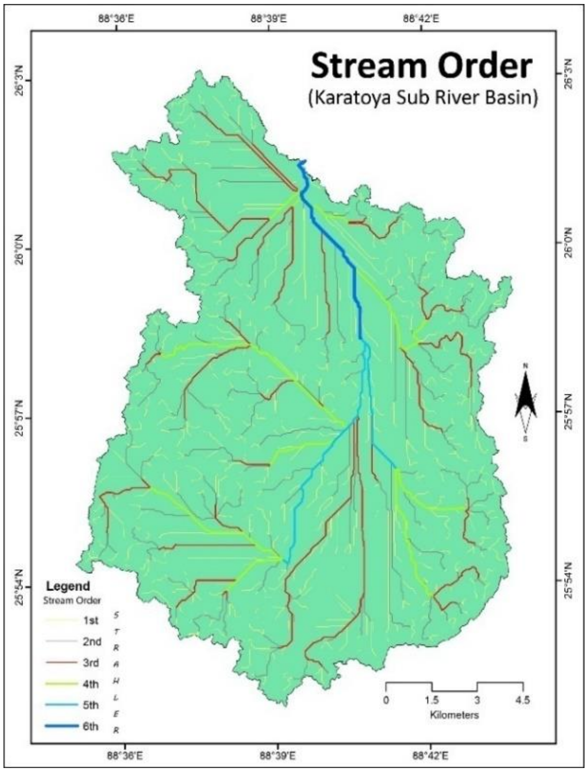

Figure 3: Stream order of the Karatoya sub-basin

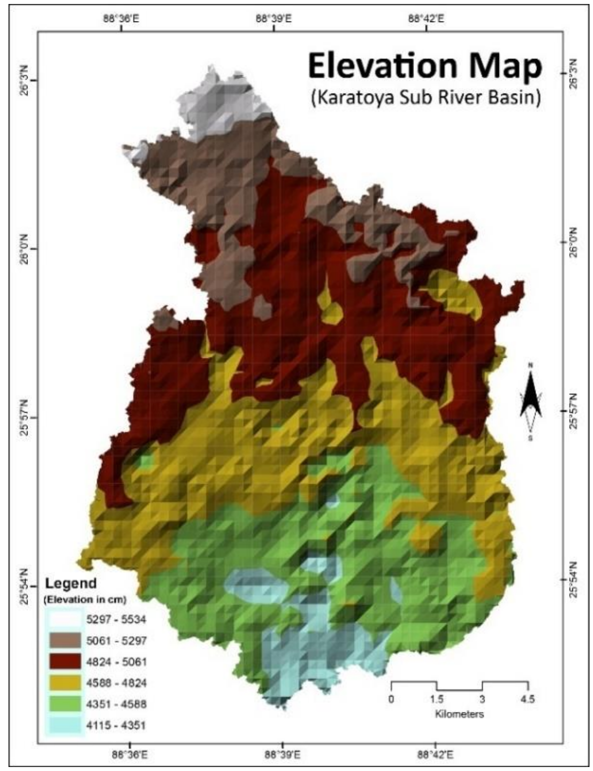

Figure 4: Elevation of the Karatoya sub-basin

Table 5: Channel geometry aspect parameters of the Karatoya sub-basin

Parameters	*Calculated values*	*Measured units*
Length of the basin (L_B)	16.57	km
Basin area (A)	185	km^2
Basin perimeter (P)	96	kms^{-1}
Lemniscate's (K)	1.48	-
Form factor (F_f)	0.67	-
Circularity ratio (R_c)	0.25	-
Compactness coefficient (C_c)	2.07	-
Fitness ratio (R_f)	0.23	-
Wandering ratio (R_w)	1.39	-
Sinuosity index (S_i)	1.36	-

Length of the basin (L_b): Several people defined basin length in different ways, such as Schumm (1956) defined the basin length as the longest dimension of the basin parallel to the principal drainage line. Gregory and Walling (1968) defined the basin lengths as the longest in the basin in which being the mouth to the end. A basin length is a calculated distance from where the water starts to flow towards a main channel and ends at the point of discharge (Heitmuller *et al*., 2006). The length of Karatoya sub-basin is 16.57 km and it is not so low or not very high and the basin is oval (Table 5).

Basin area (B_a): Basin area indicates a particular area where precipitation collects and drains

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them to a final outlet. The area of a basin usually delineates according to the collection of water and sediments from the sources and where it drains out into a large source such as large lakes, seas, oceans, etc. (Shreve, 1974). The sub-basin area of Karatoya river is 185 km^2 (Table 5).

Basin perimeter (P): Basin perimeter represents the outer boundary of a watershed that enclosed the area. It is the circumference of the drainage basin. The basin perimeter indicates the horizontal projection that divides the water flows. Basically, it is the representation that delimits the area of the basin that is always smaller than the real length of the water divide (Allan, 2003). The perimeter of the Karatoya sub-basin is 96 kms^{-1} (Table 5).

Lemniscate's (K): Chorley (1957) expressed the lemniscate's value to determine the slope of the basin. The lemniscate's (K) of Karatoya sub-basin is 1.48, which means the basin area is medium in size.

Form factor (F_f): According to Horton (1932), form factor may be defined as the ratio of basin area to the square of the basin length. If the watershed may be short or long usually measured by form factor. If the value of form factor is less than 0.75, the watershed will be elongated. The smaller the value the more the elongation. The form factor of the Karatoya sub-basin is 0.67 which indicates the basin is elongated with flow for a long duration (Table 5).

Circularity ratio (R_c): The circularity ratio is utilized as a quantitative measure picturing the state of the basin (Christopher, Idowu and Olugbenga, 2010). Circularity ratio is characterized as the proportion of watershed area to the territory of a circle having a similar border as the watershed and it is pretentious by the lithological character of the watershed (Khadri and Moharir, 2013). Circularity ratio relies upon the lithological qualities of the basin. This proportion is affected by length recurrence and radiant of streams of different orders instead of slope conditions and drainage patterns of the basin. According to the calculated value, the Karatoya sub-basin is moderately elongated and medium permeable.

Compactness coefficient (C_c): Compactness coefficient is used to express the relationship of a hydrological basin with that of a circular basin having the same area as the hydrologic basin. According to Gravelius (1914), compactness coefficient of a watershed is the ratio of perimeter of watershed to circumference of circular area, which equals the area of the watershed. The value of compactness coefficient of Karatoya sub-basin is 2.07 that means it is elongated in nature (Table 5).

Fitness ratio (R_f): The fitness ratio of a basin represents topographic fitness. It is the ratio of main channel length to the length of the watershed perimeter (Melton, 1957). The fitness ratio for this basin is 0.23 (Table 5).

Wandering ratio (R_w): The wandering ratio represents the ratio of the mainstream length to the valley length. The straight-line distance is between the basin outlet and the farthest point on the ridge of the valley length (Smart and Surkan, 1967). In this study, the wandering ratio is 1.39 (Table 5).

Sinuosity index (S_i): Sinuosity index indicates about the channel pattern of a basin. It is the ratio of the main channel length to the air distance of that channel. Basically, the sinuosity index is

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used to define the degree of meandering of a riverbed (Gregory and Walling, 1973). Generally, the sinuosity index value ranges between 1 to 4. The river having the sinuosity value of 1.5 is called sinuous, and more than 1.5 sinuosity value is called meandering (Leopold, Wolman and Miller, 1964). Sinuosity index value of Karatoya river-sub basin is 1.36, which means the main channel of Karatoya sub-basin is sinuous course. It is a noteworthy quantitative index for interpreting the essentialness of streams in the evolution of landscapes and helpful for geomorphologists, hydrologists and geologists (Hajam, Hamid and Bhat, 2013).

Drainage texture analysis

Drainage analysis is valuable in structural interpretation, especially in territories of low alleviation. The investigation incorporates thought of drainage patterns, drainage texture, individual stream patterns, and drainage irregularities (Howard, 1967). Table 6 represents the drainage texture analysis of the Karatoya sub-basin.

Table 6: Drainage texture aspect parameters of the Karatoya sub-basin

Parameters	*Calculated value*	*Measured units*
Stream frequency (F_s)	3.39	-
Drainage density (D_d)	3.06	kms^{-1}
Drainage texture	6.54	-
Constant of channel maintenance ($1/D_d$)	0.33	kms^2
Infiltration number (I_f)	10.37	-
Drainage pattern (D_p)	Dendritic and Parallel	-
Length of overland flow (L_g)	0.16	-

Stream frequency (F_s): Stream frequency is the number of stream segments per unit of area (Horton, 1932). It represents the topographic texture based on the number of stream segments per unit of area. Stream frequency is a good indicator of understanding drainage patterns. The more the value of stream frequency, the better drained a basin is. There is a positive correlation between the drainage density and the steam frequency. Where there is the lesser drainage density and stream frequency, there is the slow runoff in a basin, and subsequently, there is less probability to flood in this area. The stream frequency of the Karatoya sub-basin is 3.39, which means the basin is well-drained (Table 6).

Drainage density (D_d): Drainage density is the stream length per unit area in the region of the watershed (Horton, 1945). It can be estimated using the length of the stream and the total area of the basin. The drainage density decides the time travel by water (Schumm, 1956). High drainage density represents a highly dissected drainage basin with a moderately fast hydrological reaction to precipitation occasions, while a low drainage density implies an inadequately depleted basin with a moderate hydrologic reaction (Melton, 1957). The estimation of D_d is a valuable numerical measure of landscape dissection and runoff potential (Chorley, 1969). From one viewpoint, the D_d is a consequence of connecting factors controlling the surface runoff, and then again, it is itself affecting the yield of water and sediment from the drainage basin (Ozdemir and Bird, 2009). The drainage density of the Karatoya sub-basin area is 3.06 kms^{-1} (Figure 3).

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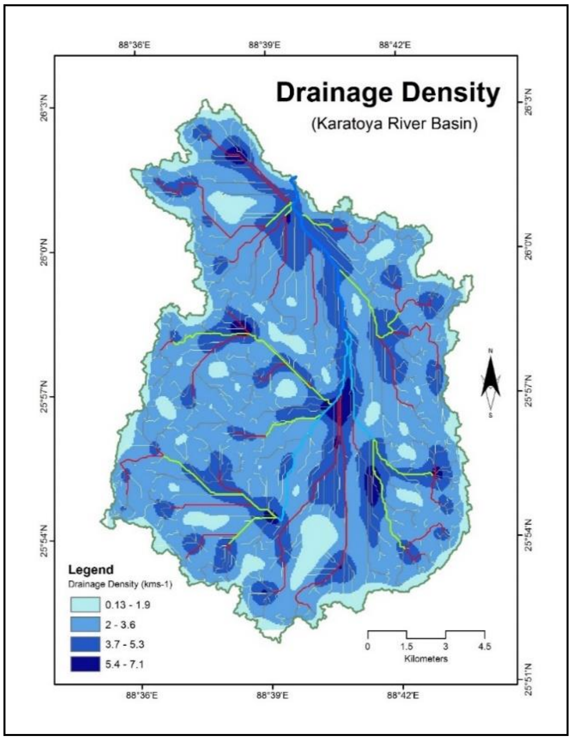

Figure 5: Drainage density of Karatoya sub-basin

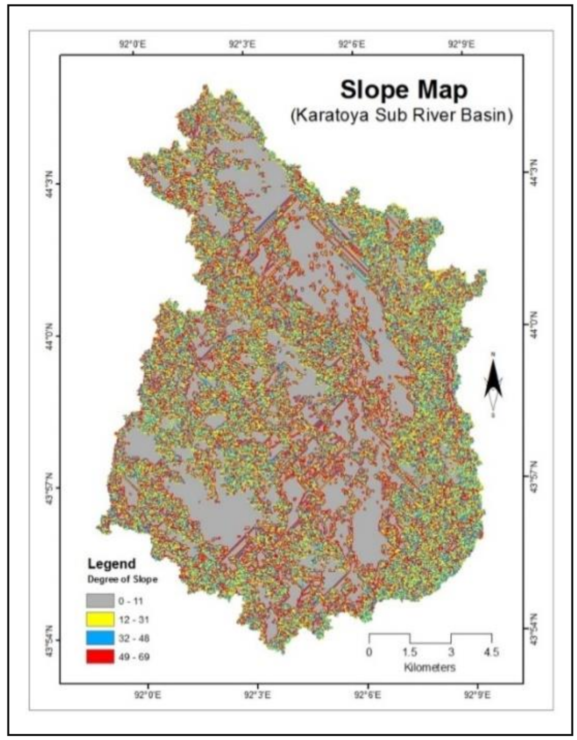

Figure 6: Slope of the Karatoya sub-basin

Drainage texture: In an area, the relative spacing of the total number of stream segments of a given length per unit area is considered as drainage texture (Horton, 1945). Drainage texture is on the underlying lithology, infiltration capacity, and relief aspect of the terrain (Pareta and Pareta, 2011). Smith (1950) has classified the drainage texture into five different classes. When the value is less than 2 shows very coarse, the value between 2 to 4 as coarse, 4 to 6 indicates moderate, somewhere in the range of 6 to 8 as fine and more than 8 very fine drainage textures. In this study, the calculated value of the Karatoya sub-drainage basin is 6.54 that indicates the texture of this basin is fine grain in nature (Table 6).

Constant of channel maintenance (C): Schumm (1956) utilized the opposite of drainage density or the consistent of channel maintenance as a property of landforms. The constant demonstrates the quantity of kms of the basin surface required to create and continue a channel 1 km long (Pareta and Pareta, 2011) Constant of channel maintenance gives a quantitative articulation of the base restricting territory required for the improvement of a length of the channel. The channel maintenance constant of the basin is 0.33 kms^2 (Table 6).

Infiltration number (I_f): The infiltration number assumes a noteworthy role in fostering the infiltration qualities of the basin. It is contrarily corresponding to the infiltration limit of the basin (Hajam, Hamid and Bhat, 2013). The infiltration number of a watershed is characterized as the product of drainage density and frequency that gives an idea about the infiltration characteristics of a watershed (Melton, 1957). The higher the infiltration number the lower will be the infiltration and the higher run-off. The infiltration number of Karatoya sub-basin is 10.37, which indicate moderate runoff and moderate infiltration (Table 6).

Drainage pattern (D_p): The drainage pattern indicates the distributional pattern of streams in a basin area. Basically, it represents how the stream networks are distributed with what pattern (Khadri and Moharir, 2013). The drainage pattern reflects the effects of slope, lithology, and structure. The investigation of drainage patterns also helps in recognizing the phase in the cycle of erosion. In the Karatoya sub-basin, most of the drainage pattern is dendritic and parallel (Figure 6). In the basin, the dendritic pattern is the most widely recognized pattern that is shaped in the drainage basin made from genuinely homogeneous stone without control by the underlying geologic structure. The more drawn out the time of the formation of a drainage basin is, the more effectively the dendritic pattern is formed (Pareta and Pareta, 2011).

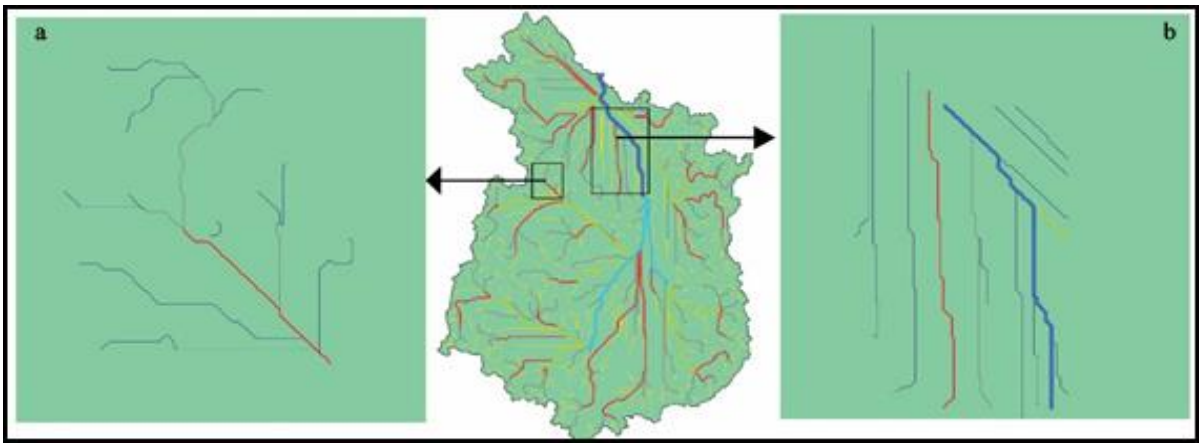

Figure 7: Drainage pattern of the Karatoya sub-basin: a) dendritic and b) parallel drainage pattern.

Length of overland flow (L_g): Overland flow is the horizontal movement of water over the land surface. It depends on soil type, slope, infiltration rate, saturation level, and other factors. The length of overland flow indicates the length where rainwater flows over the ground to reach into a channel (Pareta and Pareta, 2011). The length of overland flow of the Karatoya sub-basin is 0.16 km (Table 7), which shows gentler inclines in the valleys and thus low surface runoff and longer stream ways.

Relief characteristics

A relief aspect of a river basin traces the height of the surface from the encompassing the regular surface. It is always estimated regarding contrast in height of most elevated and least elevated in an aerial unit. Relief is the measure of the energy head from which potential energy can be determined (Pike, Evans and Hengl, 2009). The relief characteristics, parameters, their calculated values and measurement units have been shown in Table 7.

Relief ratio (R_{hl}): The relief ratio might be characterized as the proportion between the complete help of a basin and the longest component of the basin corresponding to the main drainage line (Schumm, 1956). There is a positive correlation between relief ratio and hydrological characteristics of a basin. The loss of sediment per unit of area is closely correlated with relief ratio. The relief proportion ordinarily increments with decreasing drainage area and size of sub-watersheds of a given drainage basin. The relief ratio of the Karatoya sub-basin is very low, which means relief between the highest and lowest point of this basin is extremely low (Table 7).

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Table 7: Relief characteristics of the Karatoya sub-basin

Parameters	*Calculated value*	*Measured units*
Relief ratio (R_{hl})	0.001	-
Relative relief (R_r)	0.02	meter
Absolute relief (R_{hp})	53.37	meter
Slope	Plain land	degree

Relative relief (R_r): The maximum basin relief was obtained from the highest point on the watershed perimeter to the mouth of the stream (Pareta and Pareta, 2011). By using the basin relief of the study area, the relative relief is calculated, according to Schumm (1956), which is 0.02 meter (Table 7).

Absolute relief (R_{hp}): Absolute relief is the difference in height between the highest point of the basin area and the sea level. The absolute relief of the Karatoya sub-basin is 53.37 meter (Table 7).

Slope: The slope of the landscape to the measure of the inclination of the physical feature, landform is the horizontal surface. Slope analysis is a significant boundary in morphometric considers (Pande and Moharir, 2017). The slope indicates the steepness or grade of the specific feature of the Earth's surface from the higher degree of slope indicates more steepness of an area. In Karatoya sub-basin, maximum areas are in low slope and a little portion is in high slope zone (Figure 7, Table 7) that means basin area is almost plain land.

Conclusions

The GIS based methodology is instrumental in investigating spatio temporal dynamics of various morphometric boundaries and the relationship among the drainage basin morphometry as well as geographical, lithological, structural, bio-geographical, pedological and hydrological parameters, which are very important for agricultural, structural, and hydrological management. The Karatoya sub-river basin is a very significant zone for agricultural production in the Dinajpur district. Six major stream orders flowing over this basin were identified of which total length 628 km with a basin area of 185 km^2 which indicates the basin size is medium. The main channel of this basin is known as Karatoya River with a length of 92.97 km that indicates moderately meandering in the flow characteristics. The tributaries and distributaries of the Karatoya river basin are mainly dendritic and some are parallel. Though this drainage basin is well-drained, it has low hydraulic storage capacity during flood. That's why this zone faces floods almost every year during the wet season and severe dry conditions during summer season. Examining morphometric dynamics of Karatoya sub-basin will help in the future watershed and hazard management in the region. This study is performed as a guideline to the local administration for the management and planning of soil erosion studies, groundwater potential assessment, and flood hazard risk reduction that can overcome the existing problem in the Birganj upazila.

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