Morphometric Analysis of Shaliganga Sub Catchment, Kashmir Valley, India Using Geographical Information System

Mohd Iqbal[1], Haroon Sajjad[1], F.A. Bhat [2]

[1]Department of Geography, Faculty of Natural Sciences, Jamia Millia Islamia, New Delhi, India

[2]Department of Geology and Geophysics, University of Kashmir, India

[*]Corresponding Author: Mohd Iqbal

Abstract: The quantitative analysis of drainage system is an important aspect of characterization of watersheds. Using watershed as a basic unit in morphometric analysis is the most logical choice because all hydrologic and geomorphic processes occur within the watershed. Shaliganga Sub catchment comprises of two watersheds with a total area of 354 km² and has been selected for the present study. Various linear parameters (Stream order, Stream number, Stream length, stream length ratio, Bifurcation ratio, Drainage density, Texture ratio, Stream frequency) and shape factors (Compactness coefficient, Circularity ratio, Elongation ratio, Form factor) of the Sub catchment were computed at watershed level. This was achieved using GIS to provide digital data that can be used for different calculations

Keywords: Morphometric analysis, GIS, Shaliganga, linear parameters, areal aspects.

1. Introduction

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Obi Reddy et al., 2002). A major emphasis in geomorphology over the past several decades has been on the development of quantitative physiographic methods to describe the evolution and behavior of surface drainage networks (Horton, 1945; Leopold & Maddock, 1953; Abrahams, 1984). Most previous morphometric analyses were based on arbitrary areas or individual channel segments. Using watershed as a basic unit in morphometric analysis is the most logical choice. A watershed is the surface area drained by a part or the totality of one or several given water courses and can be taken as a basic erosional landscape element where land and water resources interact in a perceptible manner. In fact, they are the fundamental units of the fluvial landscape and a great amount of research has focused on their geometric characteristics, including the topology of the stream networks and quantitative description of drainage texture, pattern and shape (Abrahams, 1984). The morphometric characteristics at the watershed scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes occur within the watershed (Singh, 1998).

The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management at watershed level. quantitative description of the drainage system which is an important aspect of the characterization of watersheds (Trawler, 1964). The influence of drainage morphometry is very significant in understanding the landform processes, soil physical properties and erosional characteristics. Drainage characteristics of many river basins and sub basins in different parts of the globe have been studied using conventional methods (Horton, 1945; Strahler, 1957, 1964; Krishnamurthy et al., 1996). Geographical Information System (GIS) techniques are now a days used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. In the present study stream number, order, frequency, density, texture ratio, bifurcation ratio, compactness coefficient, circularity ratio, elongation ratio, and form factor are derived and tabulated on the basis of areal and linear properties of drainage channels using GIS based on drainage lines as represented over the topographical maps (scale 1:50,000).

2. Study Area

Shaliganga is the sub catchment of Dudhganga catchment of Kashmir valley (Figure 1), located in the northern part of India between 33^0 44′ to 34^0 40′ N and 74^0 28′ to 74^0 45′ E, and covers an area of 354

Morphometric analysis of a watershed provides a

km². The area supports a varied topography exhibiting altitudinal extremes of 1567 to 4663 m above mean sea level. The area consists of the lofty Pir-Panjal and flat-topped karewas as foothills and plains. The Pir-Panjal mountain range covers the Kashmir valley on the south and southwest, separating it from the Chenab valley and the Jammu region. The karewas formation is a unique physiographic feature of this area. These are lacustrine deposits of the Pleistocene age composed of clays, sands, and silts. The soils in the area are generally of three types, viz., loamy soil, karewas soil and poorly developed mountain soil (Raza *et al*, 1978). Climate of the area is temperate type with warm summers and cold winters. The mean annual temperature is 20^0C. Average annual rainfall in the area is 669 mm and maximum precipitation occurs during March to April when westerly winds strike the northern face of the Pir-Panjal Mountains. The geology of the area is quite diverse ranging from Archean to Recent; Pir-Panjal represents rocks of a wide range in age. The commonest of the rocks present in the area are Panjal traps, karewas and alluvium. Drainage of the area is quite significant as most of the drainage flows into river Jhelum. Shaliganga is the most important tributary of river Dudhganga. The Shaliganga originates below Ashdhar Gali near Tatakuti peak.

Study Area

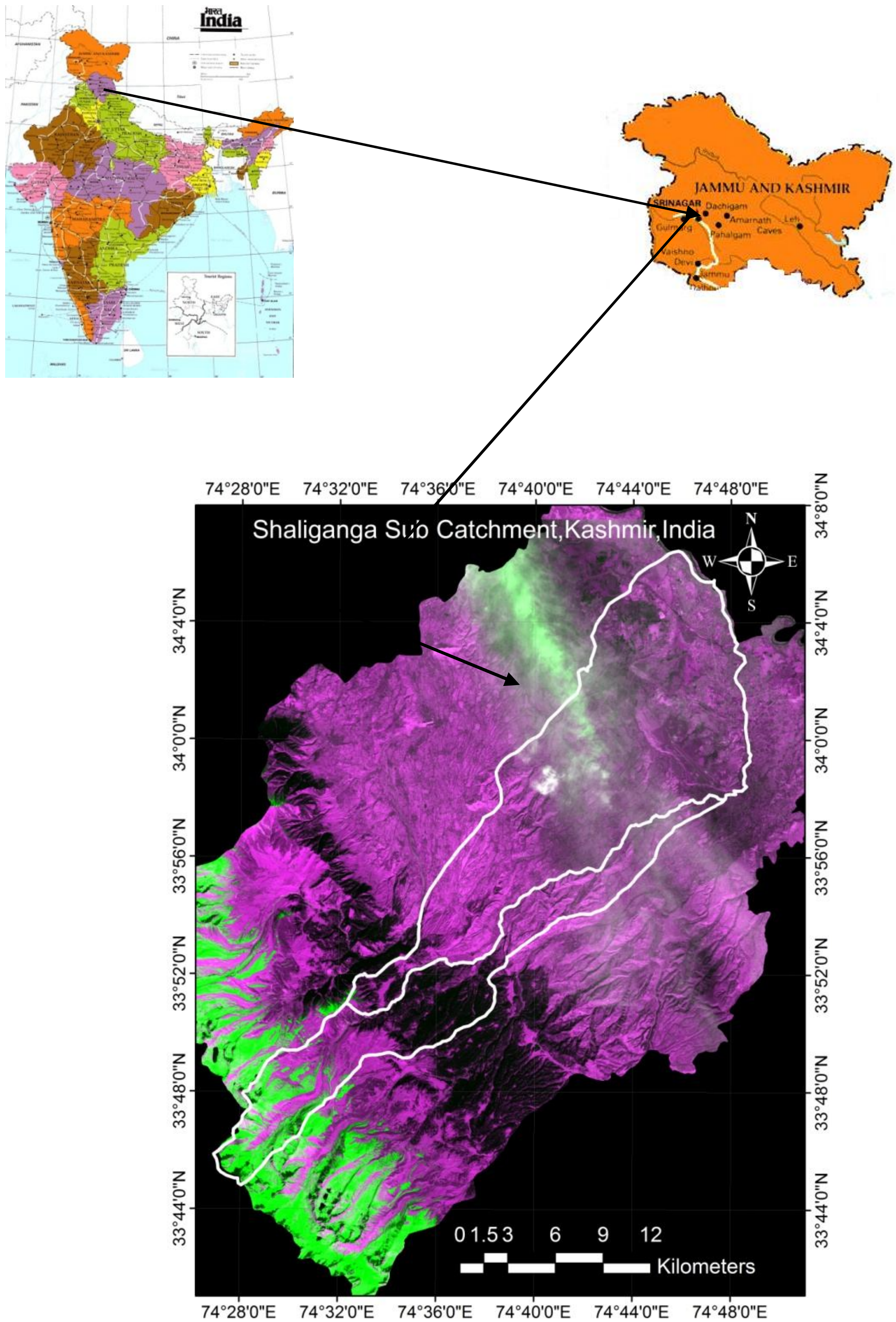


Figure1.Geographical location of Shaliganga Sub Catchment, Kashmir valley, India

3. Methodology

Morphometric analysis of a drainage system requires delineation of all existing streams. The stream delineation was done digitally in GIS (Arcview 3.2a) system. All tributaries of different extents and patterns were digitized from survey of India toposheets 1961 (1:50,000 scale) and the Sub catchment boundary was also determined for Shaliganga Subcatchment. Similarly, two watersheds (D2A and D2B) were also delineated and measured for intensive study. Digitization work was carried out for entire analysis of drainage morphometry. The different morphometric parameters have been determined as shown in table1.1.

Table 1: Formulae for computation of morphometric parameters.

Morphometric Parameters	Formula	Reference
Stream order	Hierarchical rank	Strahler (1964)
Stream length (Lu)	Length of the stream	Horton (1945)
Mean stream length (Lsm)	Lsm = Lu / Nu where Lu = Total stream length of order ‘u’ Nu = Total number of stream segments of order ‘u’	Strahler (1964)
Stream length ratio (Rl)	Rl = Lu / Lu1 where Lu = Total stream length of order ‘u’ Lu1= The total stream length of its next lower order	Horton (1945)
Bifurcation ratio (Rb)	Rb = Nu / Nu + 1 where Nu = Total no. of stream segments of order ‘u’ Nu + 1 = Number of segments of the next higher order	Schumm (1956)
Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders	Strahler (1957)
Drainage density (Dd)	Dd = Lu /A where Dd = drainage density Lu = total stream length of all orders A = area of the basin(km^2)	Horton (1945)
Stream frequency (Fs)	Fs = Nu/A where Fs = stream frequency Nu = total number of streams of streams of all orders A = area of the basin, km^2	Horton (1945)
Circulatory ratio (Rc)	$Rc = 4 * \pi * A/P^2$ where Rc = circularity ratio	Miller (1953)

	π = π value i.e., 3.141 A = area of the basin, km^2 P^2 = square of the perimeter, km	
Elongation ratio (Re)	Re = 2√A /π / Lb where Re = elongation ratio A = area of the basin, km^2 π = π value i.e., 3.141 Lb = basin length	Miller (1953)
Form factor (Ff)	Ff = A/Lb^2 where, Ff = form factor A = area of the basin, km^2 Lb = basin length	Schumm (1956)
Drainage texture (T)	T = Nu/P where Nu = total no. of streams of all orders P = basin perimeter, km	Horton (1945)
Compactness coefficient (Cc)	Cc = 0.2821 P/ A 0.5 where Cc = Compactness coefficient A = Area of the basin , km^2 P = basin perimeter, km	Horton (1945)

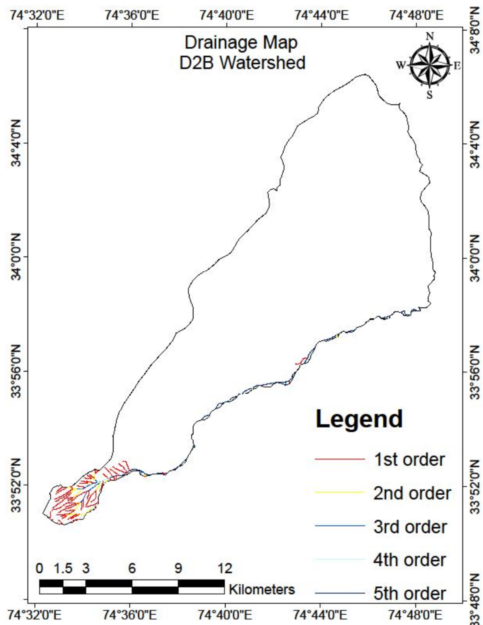
4. Results and discussion

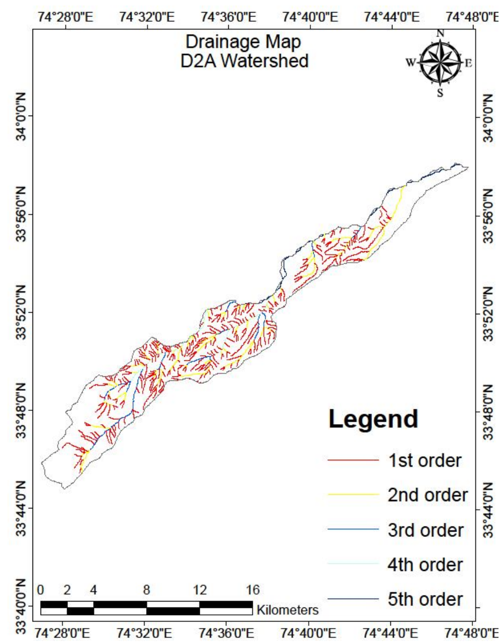
Drainage pattern is characterized by irregular branching of tributaries in many directions with an angle less than 90°. The Catchment is divided into two watersheds with codes, D2A, and D2B.

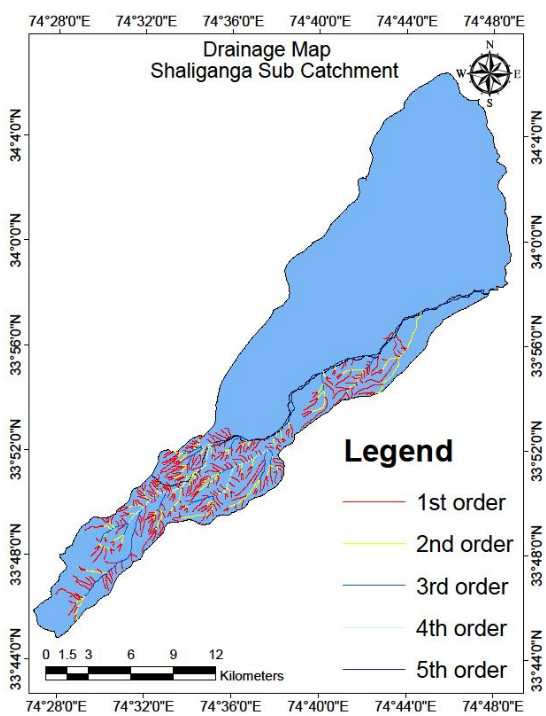
4.1 Linear Aspects of Shaliganga River:

4.1.1 Stream order (U)

The designation of stream order is the first step in morphometric analysis of a drainage basin, based on the hierarchic making of streams proposed by Strahler (1964). It is defined as a measure of the position of a stream in the hierarchy of tributaries. There are 428 streams linked with 5th order of streams sprawled over an area of 354 km^2. A perusal of table 2 indicates that the Shaliganga river which is the trunk stream in Shaliganga Sub Catchment is of the fifth order. The watersheds D2A and D2B having 5th order streams covering an area of 111 Km^2 and 243Km^2 respectively. The highest number of stream segments is found in watershed D2A (350 stream segments) while the lowest number of stream segments is found in watershed D2B (81 stream segments). In whole Shaliganga Sub Catchment the first order streams constitute 78.03 per cent while second order streams constitute 17.05 per cent of the total number of streams. Third and fourth order streams constitute 4.20 per







Figures. 2, 3, 4, respectively showing Drainage map of watersheds of Shaliganga sub catchment.

cent and 0.47 per cent of the total number of streams respectively while fifth order streams constitute only 0.23 per cent of the total number of streams. Thus the law of lower the order higher the number of streams is implied throughout the catchment. It is observed that the variation in order and size of the watersheds is largely due to physiographic, structural conditions of the region and infiltration capacity of the soil

Table 2: Stream analysis

Watersheds	Stream number in different orders					Total number of streams	Percentage of streams by different stream orders to total number of streams				
	1th	2nd	3rd	4th	5th		1th	2nd	3rd	4th	5th
D2A	278	57	12	2	1	350	79.42	16.28	3.42	0.57	0.28
D2B	56	16	6	2	1	81	69.13	19.75	7.40	2.46	1.23
Shaliganga Sub Catchment	**334**	**73**	**18**	**2**	**1**	**428**	**78.03**	**17.05**	**4.20**	**0.47**	**0.23**

4.1.2 Stream length (Lu)

The stream length was computed on the basis of the law proposed by (Horton, 1945), for the two watersheds. Generally, the total length of stream segments decrease as the stream order increase. In watershed D2A, the stream length followed Horton's law. But in watershed D2B, the stream segments of various orders showed variation from general observation. It is evident in the (Table 3) that in Shaliganga Sub Catchment the length of first order streams constitute 61.46 per cent of the total stream length with second order (17.61per cent), third order (8.23 per cent), fourth order (4.98per cent), fifth order (7.71per cent). The total length of 1st and 2nd order streams constitutes 79.07 per cent of the total stream length of the Shaliganga Sub Catchment. It can be in the length ratio from lower order to higher order indicating their mature geomorphic stage in Catchment, whereas in the D2B watersheds there was a change from one order to another order indicating the late youth stage of geomorphic development of streams in the inter basin area.

inferred that the total length of stream segments is maximum in first order streams and decreases as the stream order increases. However fifth order is an exception in Sub Catchment where the total stream length (7.71kms) is more than that of the fourth order (4.98 kms). This change may indicate flowing of streams from high altitude, lithological variations and moderately steep slopes. (Singh and Singh, 1997; Vittala et al., 2004).

4.1.3 Stream Length ratio (Rl)

Horton's law of stream length states that mean stream length segments of each of the successive orders of a basin tends to approximate a direct geometric series with stream length increasing towards higher order of streams. The stream length ratio of D2A watersheds showed an increasing trend

4.1.4 Bifurcation Ratios (Rb)

Horton (1945) considered Rb as an index of reliefs and dissections. Strahler (1957) demonstrated that Rb shows only a small variation for different regions with different environments except

Table 3: Order wise total stream length

Watersheds	Order wise total stream length (km)					Total length of streams (km)	Percentage of stream length by different stream order to total length of streams (km)				
	1th	2nd	3rd	4th	5th		1th	2nd	3rd	4th	5th
D2A	170.93	51.92	23.29	14.24	9.63	270.01	63.30	19.22	8.62	5.27	3.56
D2B	32.40	6.35	3.94	2.26	15.88	60.83	53.26	10.43	6.47	3.71	26.10
Shaliganga Sub Catchment	**203.33**	**58.27**	**27.23**	**16.5**	**25.51**	**330.84**	**61.46**	**17.61**	**8.23**	**4.98**	**7.71**

Table 4: Order wise mean stream length & Stream length ratio

Watersheds	Order wise mean stream length (km)					Total mean length of streams (km)	Stream length ratio			
	1th	2nd	3rd	4th	5th		**2/1**	**3/2**	**4/3**	**5/4**
D2A	0.61	0.91	1.94	7.12	9.63	0.77	0.30	0.44	0.61	0.67
D2B	0.57	0.39	0.65	1.13	15.88	0.75	0.19	0.62	0.57	7.02
Shaliganga Sub Catchment	**0.60**	**0.79**	**1.51**	**8.25**	**25.51**	**0.77**	**0.28**	**0.47**	**0.60**	**1.54**

where powerful geological control dominates. Lower Rb values are the characteristics of structurally less disturbed watersheds without any distortion in drainage pattern (Nag, 1998). Bifurcation ratio is related to the branching pattern of a drainage network and is defined as the ratio between the total number of stream segments of one order to that of the next higher order in a drainage basin (Schumn, 1956). The mean bifurcation ratio values of different watersheds of Shaliganga Sub catchment (Table 6) shown variation from 2.79 to 4.90 indicates less structural control on the drainage development.

4.2 Areal Aspects of the Drainage Basin

4.2.1 Stream frequency (Fs)

Stream frequency is the total number of stream segments of all orders per unit area (Horton, 1932). Fs valves indicate positive correlation with the Dd of two watersheds of Shaliganga Sub Catchment. The stream frequencies of all the watersheds are mentioned in Table 5. The study revealed that the D2A watershed have high stream frequency because of the fact that it falls in the zone of fluvial channels and the presence of ridges on both sides of the valley which results in highest Fs. The watershed D2B has poor stream frequency because of low relief.

4.2.2 Form factor (Ff)

Form factor is defined as the ratio of basin area to the square of the basin length (Horton, 1932). The values of form factor would always be less than 0.7854 (perfectly for a circular basin). Smaller the value of

(Ff) more elongated will be the basin. The form factor for all watersheds varies from 0.06 to 0.23, But the whole Shaliganga sub catchment have 0.19 Ff (Table5). The values of Ff for Shaliganga Sub catchment indicates that the whole catchment is elongated. The elongated watershed with low value of Ff indicates that the basin will have a flatter peak flow for longer duration. Flood flows of such elongated basins are easier to manage than from the circular basin.

4.2.3 Elongation Ratio (Re)

Schumn (1956) defined elongation ratio as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. Analysis of elongation ratio indicates that the areas with higher elongation ratio values have high infiltration capacity and low runoff. A circular basin is more efficient in the discharge of runoff than an elongated basin (Singh and Singh, 1997). The values of elongation ratio generally vary from 0.6 to 1.0 over a wide variety of climate and geologic types. Values close to 1.0 are typical of regions of very low relief, whereas values in the range 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964). These values can be grouped in to three categories namely (a) circular (>0.9), (b) oval (0.9 to 0.8), (c) less elongated (<0.7). The values of Re in present study area varies from 0.28 to 0.54 indicates that the catchment falls accordingly in the less elongated category. The analysis reveals that D2B watershed has high infiltration capacity and low runoff then D2A watershed. The analysis suggests that D2B watershed has high ground water potential in the Sub Catchment of Shaliganga.

4.2.4 Circularity Ratio (Rc)

Circularity ratio is the ratio of the area of the basin to the area of a circle having the same circumference as the perimeter of the basin (Miller, 1953). It is influenced by the length and frequency of streams, geological structures, land use/ land cover, climate, relief and slope of the watershed. In the present study (Table 5), the Rc values for two watersheds vary from 0.16 to 0.36 which shows that the watersheds are almost elongated. This anomaly is due to diversity of slope, relief and structural conditions prevailing in these watersheds.

4.2.5 Drainage density (Dd)

It indicates the closeness of spacing between channels and is a measure of the total length of the stream segment of all orders per unit area. Drainage density in all the watersheds varies from 0.25 to 2.43 respectively (Table 6). In general it has been observed over a wide range of geologic and climatic types, that low drainage density is more likely to occur in regions of highly permeable subsoil material under dense vegetative cover, and where relief is low. In contrast, high Dd is favored in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief (Nag, 1998). Hence in this study high drainage density was found in D2A because of weak and impermeable sub surface material and mountainous relief. Low Dd value for watershed D2B indicates that it has highly permeable sub surface material and low relief. It has been observed that low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture.

Table 5: Morphometric parameters of Dudhganga catchment

Watersheds	Area (km^2)	Stream Frequency (km/km^2)	Basin Length (km)	Form Factor	Elongation Ratio	Circularity Ratio	Compactness constant
D2A	111	3.15	42.65	0.06	0.28	0.16	0.47
D2B	243	0.33	32.55	0.23	0.54	0.36	0.21
Shaliganga Sub Catchment	**354**	**1.20**	**42.65**	**0.19**	**0.49**	**0.32**	**0.18**

Table 6: Values of drainage density, texture and bifurcation ratios for Dudhganga catchment.

Watersheds	Perimeter (km^2)	Drainage Density	Drainage Texture	Bifurcation Ratios					Mean Rb
				Rb1	Rb2	Rb3	Rb4	Rb5	
D2A	92.35	2.43	3.79	4.87	4.75	6	2	-	4.40
D2B	91.53	0.25	0.88	3.5	2.66	3	2	-	2.79
Shaliganga Sub Catchment	**118**	**0.93**	**3.63**	**4.57**	**4.05**	**9**	**2**	**-**	**4.90**

4.2.6 Drainage texture (Rt)

The drainage texture depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development (Smith, 1950). The soft or weak rocks unprotected by vegetation produce a fine texture, whereas massive and resistant rocks cause coarse texture. Sparse vegetation of arid climate causes finer textures than those developed on similar rocks in a humid climate. Drainage texture is defined as the total number of stream segments of all orders per perimeter of the area (Horton). Smith (1950) classified drainage into five classes i.e., very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). Horton (1945) recognized infiltration capacity as the single important factor which influences drainage texture and considered drainage texture which includes drainage density and stream frequency. The drainage density values of watersheds range from 0.25 to 2.43 indicating very coarse to coarse drainage texture for Shaliganga Sub catchment.

4.2.7 Compactness coefficient (Cc)

Compactness coefficient is used to express the relationship of a hydrologic basin with that of a circular basin having the same area as the hydrologic basin. A circular basin is the most hazardous from a drainage stand point because it will yield the shortest time of concentration before peak flow occurs in the basin. The values of Cc in the two watersheds of Shaliganga Sub catchment vary from 0.21 to 0.47 showing variations across the watersheds. But the overall value of Cc of Shaliganga Sub catchment is 0.18.

5. Conclusion

The drainage basin is being frequently selected as an ideal geomorphological unit. Watershed as a basic unit of morphometric analysis has gained importance because of its topographic and hydrological unity. GIS techniques characterized by very high accuracy of mapping and measurement prove to be a competent tool in morphometric analysis. Linear as well as shape factors are the most useful criterion for the morphometric classification of drainage basins which certainly control the runoff pattern, sediment yield and other hydrological parameters of the drainage basin. Linear parameters have direct relationship with erodability. Higher the value more is the erodability while as Shape parameters have an inverse relation with erodability, lower their value more is the erodability. Hence the present study demonstrates the usefulness of GIS for morphometric analysis and prioritization of the watersheds of Shaliganga Sub catchment. The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation, and natural resources management at micro level.

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Mohd Iqbal is working as a Research Scholar in the Department of Geography, Jamia Millia Islamia, New Delhi. He published more than 6 Research papers in various International Journals. His main research interest is Land use/ Land Cover Studies.

Dr. Haroon Sajjad is working as an Associate Professor in the Department of Geography, Jamia Millia Islamia, New Delhi. He published more than 3 dozen of Research papers in various International and National Journals. His main research interests are Agricultural geography. Remote Sensing and GIS and Land use/ Land Cover Studies.

F. A. Bhat is working as contractual Lecturer, in the Department of Earth Sciences, University of Kashmir (J&K). He published more than 7 Research papers in various International Journals. His main research interests are Hydrology and Remote Sensing and GIS.