

Sub-Watershed Prioritization Based on Stream Ordering Analysis Using RS and GIS of the Gori Ganga Watershed Kumaun Himalaya

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ABSTRACT

Present research paper is an attempt to analysis of the stream ordering in sub-watershed in the Gori Ganga watershed Kumaun Himalaya, Uttarakhand (India) where Gori Ganga watershed has 2191.63 km² area. For the study of detect stream order and delineation sub-watersheds used of Remote Sensing (RS) data Cartosat-1 of 2008. Using pour point technique for the Gori Ganga watershed is divisible in to 9 sub-watersheds these are varies between 83.97 km² (viz., Baram sub-watershed) and 794.97 km² (viz., Gori Ganga sub-watershed). Sub-watersheds of Gori Ganga watershed has total 2299 first order streams which contribute 47.37% (234 km), 1302 second order streams which contribute 26.11% (129 km), 430 third order streams which contribute 8.71% (43 km) and 893 fourth order streams which contribute 17.81% (88 km). Where Gori Ganga sub-watershed has the longest stream about 170 km (34.41%) and Raunits Gad sub-watershed has the smallest stream about 18 km (3.64%). Present study describes details of stream ordering pattern in 9 sub-watersheds based on remote sensing and GIS. A brief account of these results it's discussed in the following paragraphs.

KEYWORDS: Watershed Delineation, Sub-watershed, Stream Ordering, GIS and Remote Sensing

1. INTRODUCTION

Delineating catchment areas by employing GIS and DEM is being preferred to manual techniques due to the improved accuracy, less duplication, easier map storage, flexibility and simplicity in data sharing, timeliness, greater efficiency and higher product complicity. The delineated boundary helps in management efforts, analyzing and in drawn appropriate conclusions (Savant et al., 2002). GIS tools can be automated in the implementation of various practical applications of watershed delineation (Fattah et al., 2015). Arc GIS Hydrology tools could be used to describe the physical components of a surface by identifying sinks, calculating flow direction and accumulation, stream order, delineating watershed and creating stream network (Pareta et al., 2012; Woodrow et al., 2016). The various morphometric parameters like stream order, stream length, mean stream length, stream length ratio and areal aspect describes as stream frequency, drainage density, drainage texture, form factor circularity index, and length of the overland flow (Kumar et al., 2016). A geographical area

separated by surrounding ridges is a hydrological unit defined as a watershed within the basin all land areas contributed their runoff to a common point (Kumar et al., 2015). As water tends to move downwards by the forces of gravity, the common point is normally situated in a watercourse at the bottom of the basin (Wilson et al., 2012). The concept of stream order has been introduced by Horton (1932). The stream order is the first step in the drainage basin, which is based on the hierarchic ranking of streams and determines the stream orders. Stream classification of a river basin is derived from the stream ordering method (Strahler, 1964).

2. METHODOLOGY

The present study works out stream ordering analysis in sub-watersheds by using remote sensing data of Gori Ganga watershed of Kumaun Himalaya, Uttarakhand (India). To classification of sub-watershed and stream ordering, Cartosat-1 Satellite images (Digital Elevation Model- DEM) for the year 2008 were used from NRDMS- Natural Resource Data Management System, Department of

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Geography, S.S.J. Campus, Almora Uttarakhand. The study area, i.e., sub-watersheds of Gori Ganga watershed was clipped using its shape file from satellite images and the image was given the base map coordinates, i.e., UTM projection, 44 N zone for the purpose to identify the study area in the images. For stream ordering and sub-watershed delineations was using Arc GIS 10.2.2 software with hydrology tools.

3. STUDY AREA

The study area, viz., the Gori Ganga watershed (Kumaun Himalaya) extends between 29°45'0''N to 30°35'47''N latitudes and 79°59'33''E to 80°29'25''E longitude, and encompasses an area of 2191.93 km² in Figure 1. Figure 2 depicts the Digital Elevation Model altitude of the Gori Ganga watershed which is varies between 626 m and 6639 m. The Gori Ganga watershed has 168 villages and total population is about 40616 (2011).

4. RESULT AND DISCUSSION

Figure 3 depicts geographical distribution of stream numbers, stream orders and stream lengths in the sub-watersheds of the Gori Ganga watershed which is registered in Table- 1. Figure 4 depicts the geographical distribution of point based sub-watersheds and registered in Table- 2. Figure 5 depicts the distribution of the stream order in sub-watersheds which is registered in Table- 3 and these data diagrammatically presented in Figure 6. A detail of stream order in the sub-watersheds is presented in Table- 4 and diagrammatically presented in Figure 7. Figure 8 (A) to (I) depicts separately geographical distribution of stream orders, and stream lengths in sub-watersheds of Gori Ganga watershed which is registered in Table- 4. A brief account of these results it's discussed in the following paragraphs.

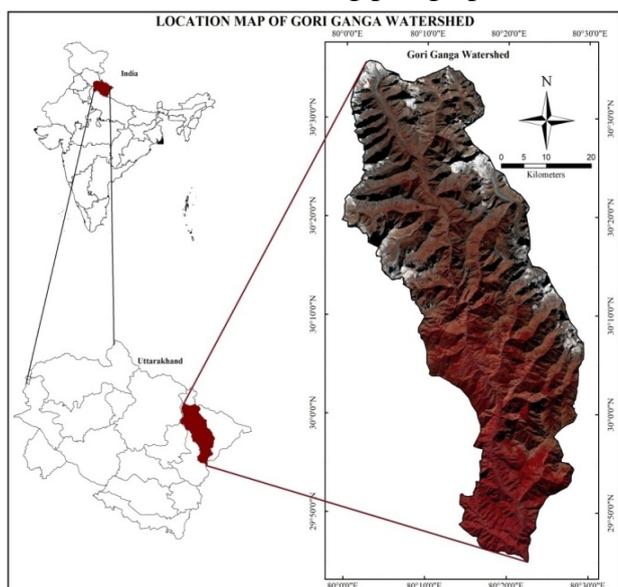


Figure 1: Geographical location and extension of the study area Viz. Gori Ganga watershed, Kumaun Higher Himalaya, Uttarakhand.

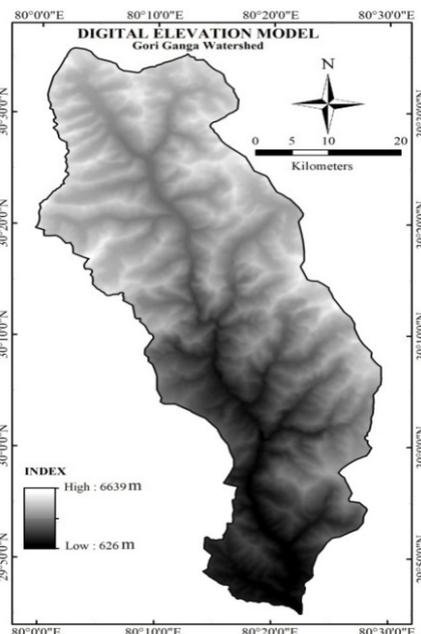


Figure 2: Digital Elevation Model (DEM) of the Gori Ganga watershed.

5. STREAM ORDERING AND LENGTH

Using DEM for stream ordering map was workout as presented in Figure 3 the number of each order were counted and the length of each stream order was measured in the sub-watershed of the Gori Ganga watershed by Arc GIS tool and the results are registered in Table 1. There are as means as number of 2299 first order stream, 1307 second order stream, 430 third stream order and 893 fourth order stream. The calculated length of the first order stream about 234 km, second order stream about 129 km, third order stream about 43 km and fourth order stream about 88 km. The total length of streams in the whole sub-watersheds of the Gori Ganga watershed studies at 494 km (Table 1).

6. SUB-WATERSHED DELINEATION

Preprocessing the Digital Elevation Model (DEM) is one of the important steps needed to be carries out as a first step in automatic extraction of drainage networks and delineation of sub-watersheds. A watershed describes an area of land that contains a common set of streams and rivers that all drain into a single larger body of water, such as a larger river, a lake or an ocean. A watershed can cover a small or large land area. A brief account of these results it's discussed in the following paragraphs.

Table 1: Stream Length of Gori Ganga Watershed (based on Cartosat-1 Satellite, 2008)

Stream Order	Stream Length		Number
	in km	In %	
First	234	47.37	2299
Second	129	26.11	1307
Third	43	8.71	430
Fourth	88	17.81	893
Total	494	100	4929

6.1. Point Base Sub-Watershed Delineation

The selection of pour points and sub-watershed delineation are the final steps. All of the water from within the watershed will flow through the pour point. The pour point defines the lowest point in watershed and must be located on a flow accumulation cell. The chosen pour points will be the basis for the watershed or sub-watershed delineation. Pour points chosen for

this analysis can be classified into major sub-watersheds. Using GIS techniques, the Gori Ganga watershed was divided into 9 sub-watersheds based on selected pour point. Plate 1 and Plate 2 depicts the Mandakini and Gori Ganga River vallies in the Gori Ganga watershed. Figure 4 depicts the geographical distribution of point based sub-watershed which is registered in Table 2.

Table 2: Area of point based sub-watershed in the Gori Ganga watershed (based on Cartosat-1 Satellite, 2008).

S. N.	Name of Sub-Watershed	Area		S. N.	Name of Sub-Watershed	Area	
		km ²	in %			km ²	in %
1	Goukha Gad	190.51	8.69	6	Bona Gad	215.15	9.82
2	Gori Gad	237.31	10.83	7	Baram Gad	83.97	3.83
3	Lwan Gad	162.53	7.42	8	Raunits Gad	85.91	3.92
4	Ralam Gad	227.82	10.39	9	Gori Ganga	794.97	36.27
5	Mandakini Gad	193.46	8.83	Total		2191.63	100

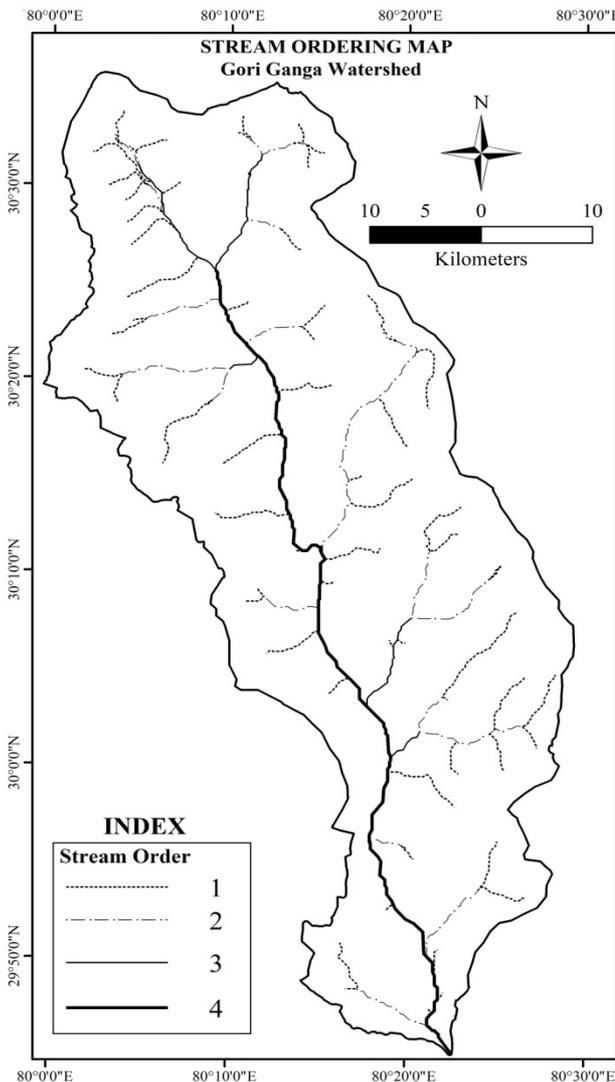


Figure 3: stream orders in the Gori Ganga watershed (based on Cartosat-1 Satellite, 2008).

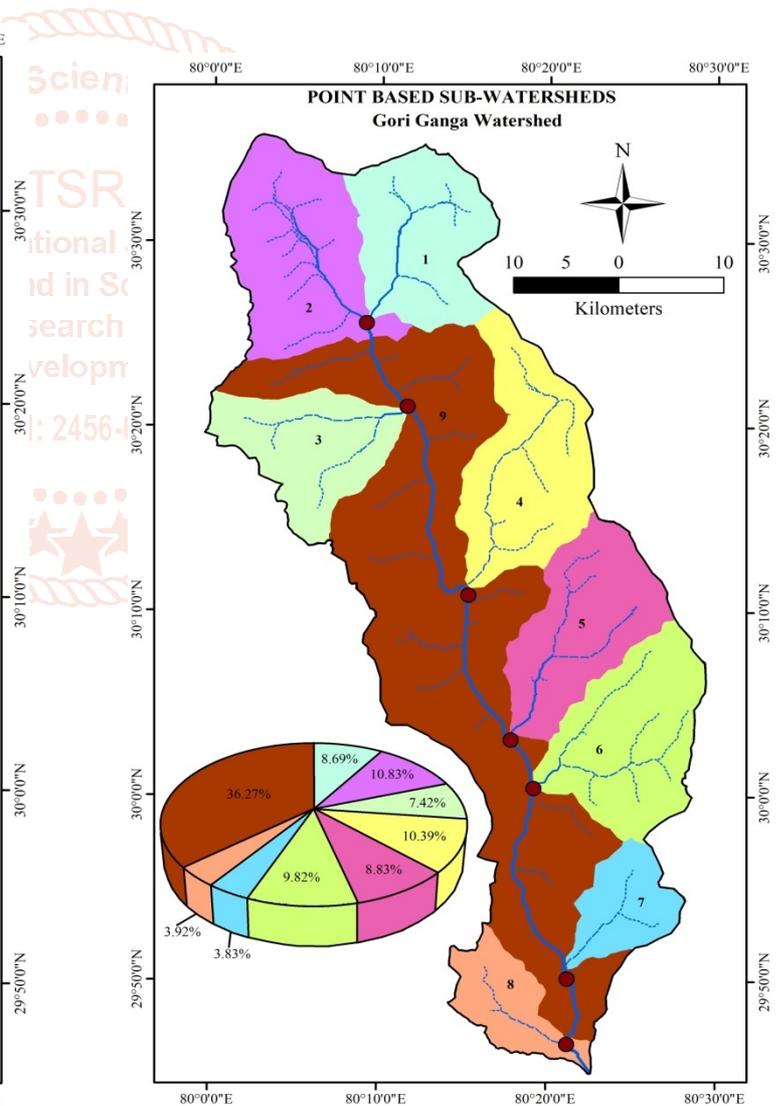


Figure 4: Geographical distribution of point-based sub-watersheds of Gori Ganga watershed (based on Cartosat-1 Satellite, 2008).

7. STREAM ORDERING AND LENGTH IN SUB-WATERSHEDS

Using RS and GIS techniques, the Gori Ganga watershed was divided into 9 sub watersheds based on selected pour point. Figure 8 (A) to (I) depicts the spatial distribution of stream orders in these sub-watersheds which is registered in Table 3 and Table 4. Table 3 presents Total stream lengths in the sub-watersheds which is diagrammatically presented in Figure 6. Table 4 presents details of stream order length in the sub-watershed which is diagrammatically presented in Figure 7. A brief account of the stream orders, stream lengths in the sub-watersheds of Gori Ganga watershed is presented in the following paragraphs.



Plate 1: Mandakini and Gori Ganga river valley view from Josha Village in the Gori Ganga watershed (based on field visit Dec, 2019).



Plate 2: Gori Ganga River Valley near Rilkote village in the Gori Ganga watershed (based on field visit May, 2018).

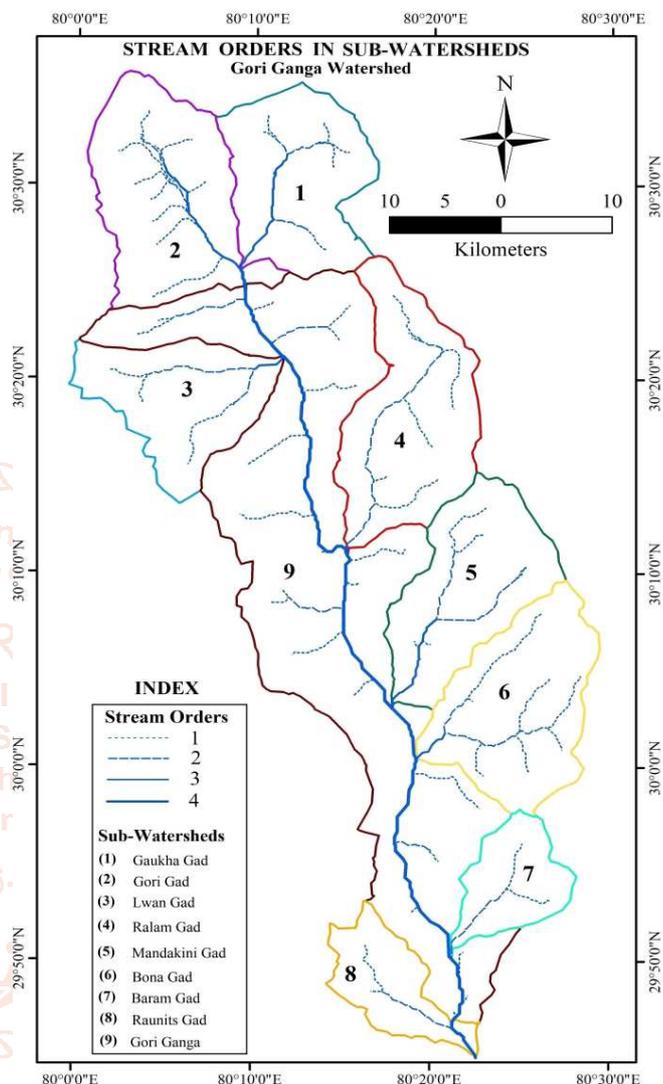


Figure 5: Distribution of sub-watersheds in Gori Ganga Watershed (based on cartosat-1 satellite, 2008).

Table 3: Total stream lengths in the sub-watersheds of the Gori Ganga watershed (based on Cartosat-1 satellite, 2008)

S. N.	Name of Sub-watershed	Total		S. N.	Name of Sub-watershed	Total	
		in km	in %			in km	in %
1	Goukha Gad	37	7.49	6	Bona Gad	53	10.73
2	Gori Gad	68	13.77	7	Baram Gad	19	3.85
3	Lwan Gad	34	6.88	8	Raunits Gad	18	3.64
4	Ralam Gad	54	10.93	9	Gori Ganga	170	34.14
5	Mandakini Gad	41	8.30	Total		494	100

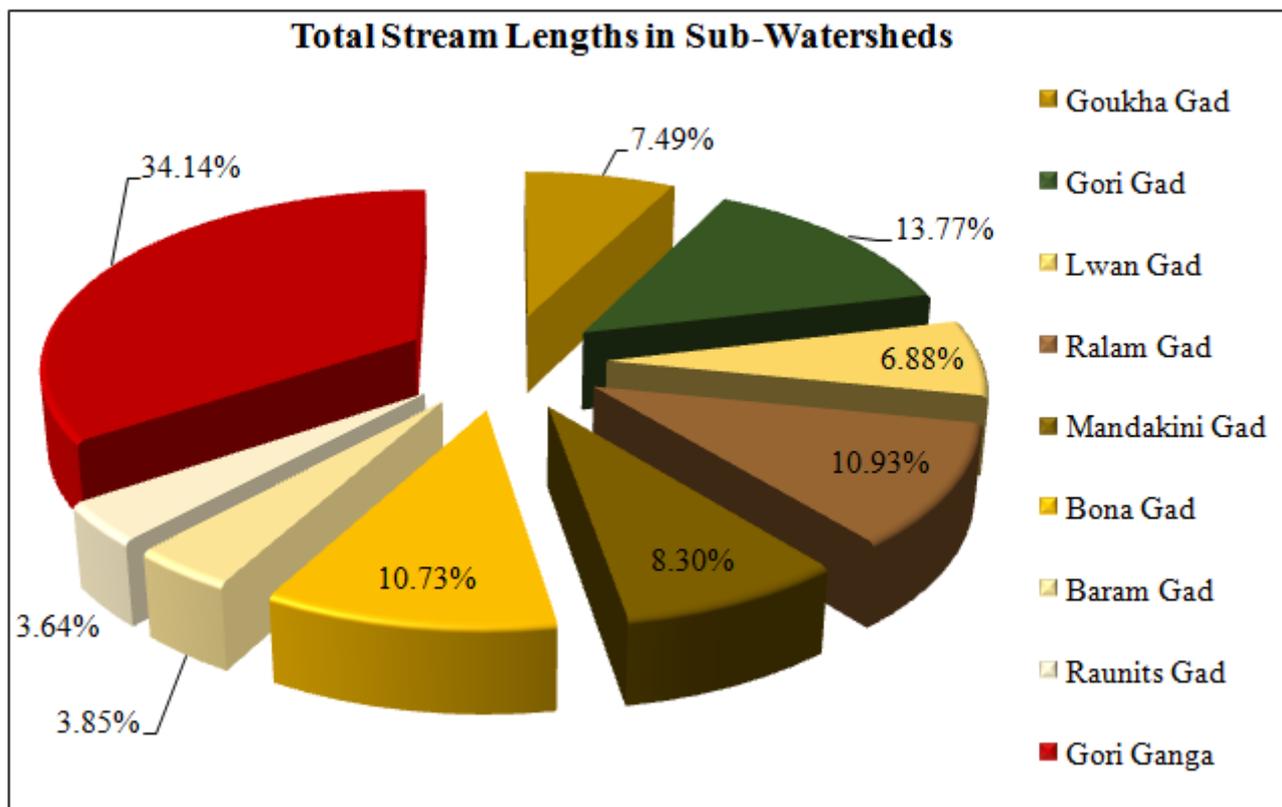


Figure 6: Diagrammatic presentation of total stream lengths in sub-watersheds of the Gori Ganga watershed.

Table 4: Details of stream order lengths in the sub-watersheds of the Gori Ganga watershed (based on Cartosat-1 satellite, 2008)

S. N.	Name of Sub-watershed	Stream Order Lengths (in km)							
		1 st Order		2 nd Order		3 rd Order		4 th Order	
		in km	in %	in km	in %	in km	in %	in km	in %
1	Goukha Gad	15	40.54	9	24.32	13	35.14	0	0
2	Gori Gad	45	66.18	7	10.29	13	19.12	3	4.41
3	Lwan Gad	17	50	14	41.18	3	8.82	0	0
4	Ralam Gad	27	50	27	50	0	0	0	0
5	Mandakini Gad	15	36.59	16	39.02	10	24.39	0	0
6	Bona Gad	34	64.15	15	28.30	4	7.55	0	0
7	Baram Gad	10	52.63	9	47.37	0	0	0	0
8	Raunits Gad	6	33.33	8	44.45	0	0	4	22.22
9	Gori Ganga	65	38.24	24	14.12	0	0	81	47.64
Total		234		129		43		88	

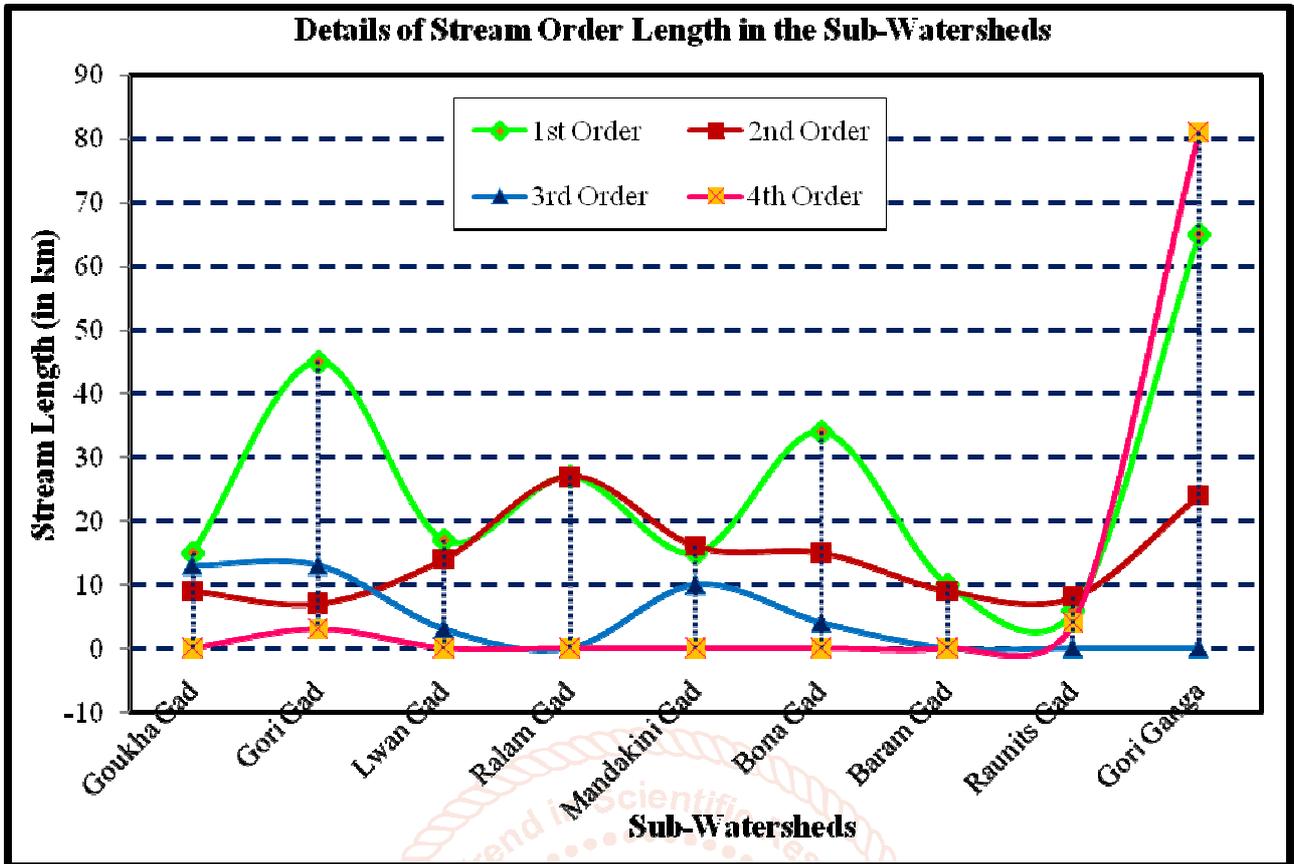
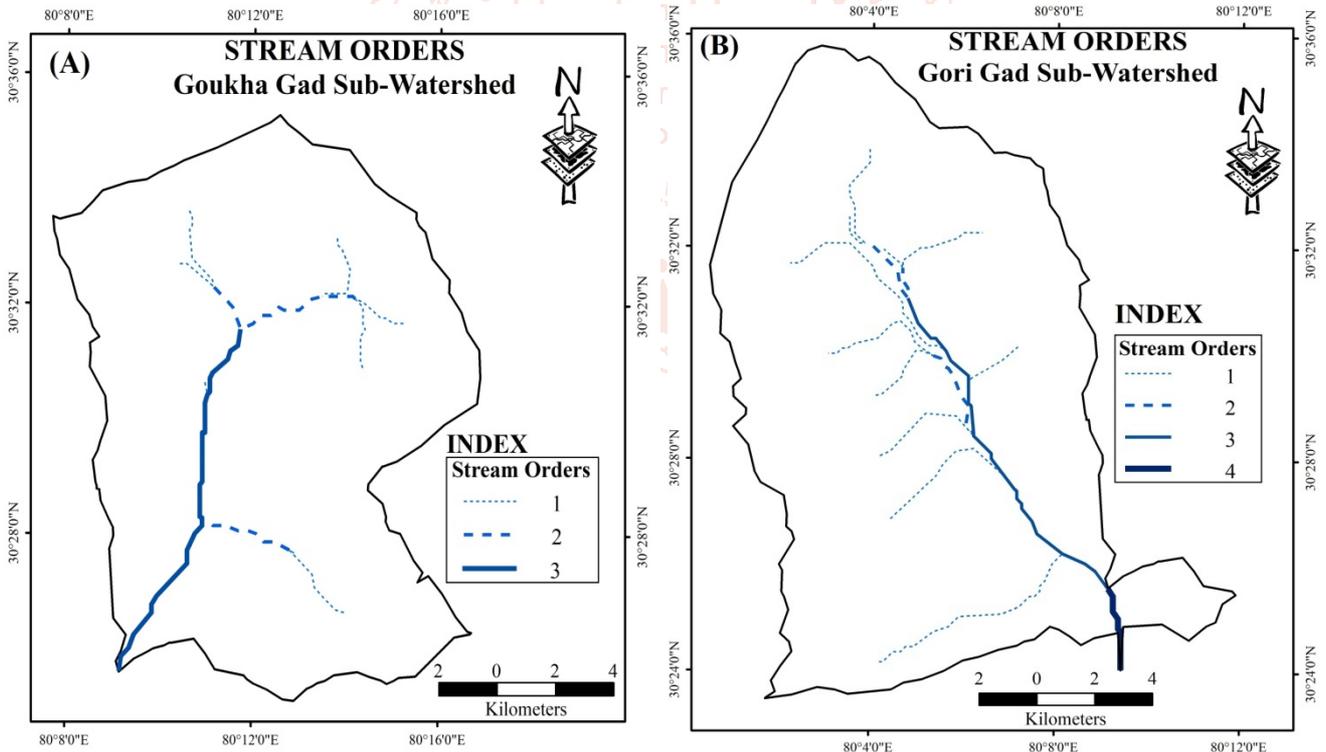
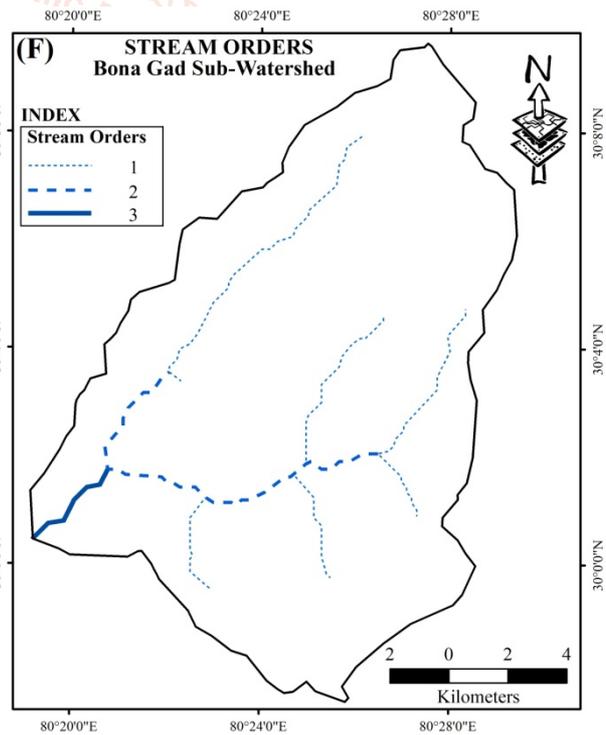
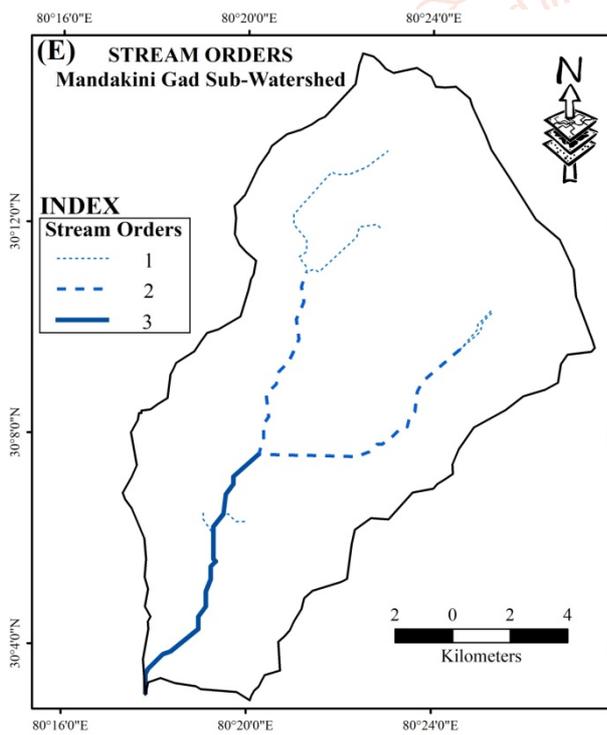
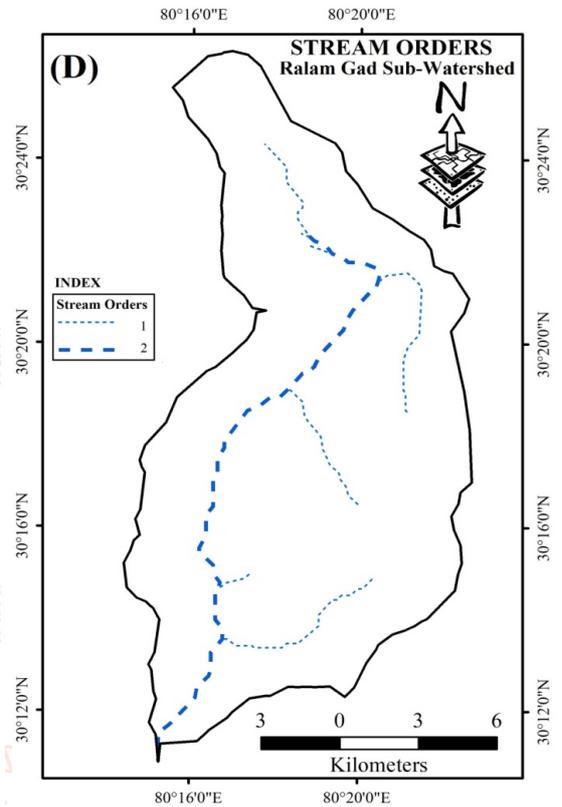
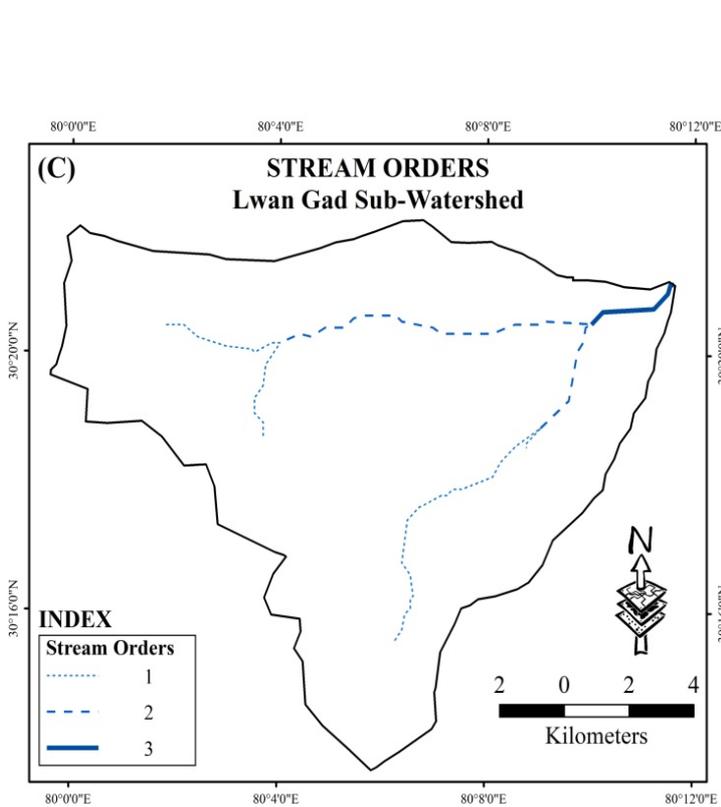


Figure 7: Diagrammatic presentation of stream order lengths in sub-watersheds of the Gori Ganga watershed.





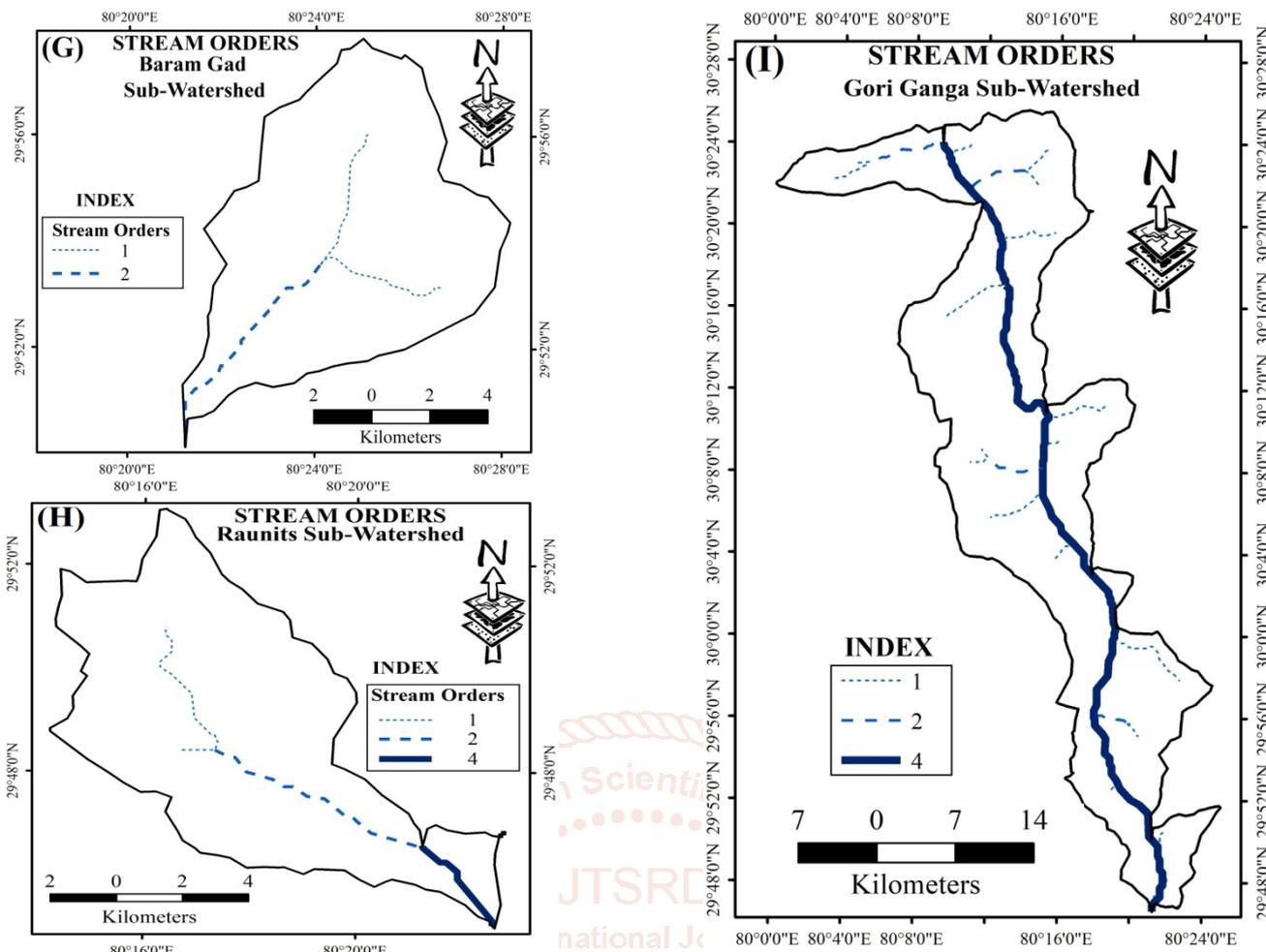


Figure 8: Geographical distribution of stream order classification in sub-watersheds of the Gori Ganga watershed (A) Goukha Gad, (B) Gori Gad, (C) Lwan Gad, (D) Ralam Gad, (E) Mandakini Gad, (F) Bona Gad, (G) Baram Gad, (H) Raunits Gad and (I) Gori Ganga Gad (based on Cartosat-1 Satellite, 2008).

7.1. Goukha Gad Sub-Watershed:

This watershed is part of Goukha River, which drains eastern part of Milam village. This watershed encompasses an area about 190.51 km² which accounts for 8.69% in the total study area (Table- 2, Figure 4). The total length of the streams in this sub-watershed about 37 km which is contributed 7.49% in the Gori Ganga watershed (Table-3, Figure 5). Where total stream lengths distributed 40.54% (15 km) in 1st order, 24.32% (9 km) in 2nd order and 35.14% (13 km) in 3rd order (Table- 4, Figure 8, A).

7.2. Gori Gad Sub-Watershed:

This watershed is part of Milam glacier and the Gori Ganga River originating from the sub-watershed near Milam village. This watershed encompasses an area about 237.31 km² which accounts for 10.83% in the total study area (Table- 2, Figure 4). The total length of the streams in this sub-watershed about 68 km which is contributed 13.77% in the Gori Ganga watershed (Table-3, Figure 5). Where total stream lengths distributed 66.18% (45 km) in 1st order, 10.29% (9 km) in 2nd order, 19.12% (13 km) in 3rd order and 4.41% (3 km) in 4th order (Table- 4, Figure 8, B).

7.3. Lwan Gad Sub-Watershed:

The Lwan Gad is the western side tributary of Gori Ganga River. This watershed encompasses an area of 162.53 km² which accounts for 7.42% in the total study area (Table- 2, Figure 4). The total length of the streams in this sub-watershed about 34 km which is contributed 6.88% in the Gori Ganga watershed (Table-3, Figure 5). Where total stream lengths distributed 50% (17 km) in 1st order, 41.18% (14 km) in 2nd order and 8.82% (3 km) in 3rd order (Table- 4, Figure 8, C).

7.4. Ralam Gad Sub-Watershed:

This watershed lies in the eastern part of the Gori Ganga River. This watershed encompasses an area of 227.82 km² which accounts for 10.39% in the total study area (Table- 2, Figure 4). The total length of the streams in this sub-watershed about 54 km which is contributed 10.93% in the Gori Ganga watershed (Table-3, Figure 5). Where total stream lengths distributed 50% (27 km) in 1st order and 50% (27 km) in 2nd order (Table- 4, Figure 8, D).

7.5. Mandakini Sub-Watershed:

This watershed also lies in the eastern part of the Gori Ganga River. This watershed encompasses an area of 193.46 km² which accounts for 8.83% in the total study area (Table- 2, Figure 4). The total length of the streams in this sub-watershed about 41 km which is contributed 8.30% in the Gori Ganga watershed (Table-3, Figure 5). Where total stream lengths distributed 36.59% (15 km) in 1st order, 39.02% (16 km) in 2nd order and 24.39% (10 km) in 3rd order (Table- 4, Figure 8 E). In this watershed there are four watermills which are located at Ropar, Dobari, Rapti and Khata villages.

7.6. Bona Gad Sub-Watershed:

This watershed encompasses an area of 215.15 km² which accounts for 9.81% in the total study area (Table- 2, Figure 4). The total length of the streams in this sub-watershed about 53 km which is contributed 10.73% in the Gori Ganga watershed (Table-3, Figure 5). Where total stream lengths distributed 64.15% (34 km) in 1st order, 28.30% (15 km) in 2nd order and 7.55% (4 km) in 3rd order (Table- 4, Figure 8, F). In this watershed there are four watermills which are located at Pharwakot, Bindi, Bona Gad and Bona.

7.7. Baram Gad Sub-Watershed:

This watershed encompasses an area of 83.97 km² which accounts for 3.83% in the total study area (Table- 2, Figure 4). The total length of the streams in this sub-watershed about 19 km which is contributed 3.85% in the Gori Ganga watershed (Table-3, Figure 5). Where total stream lengths distributed 52.63% (10 km) in 1st order and 47.37% (9 km) in 2nd order (Table- 4, Figure 8, G). There are two watermills in the study area which is located at Baram and Kanar.

7.8. Raunits Gad Sub-Watershed:

This watershed lies in the Western part of the Gori Ganga River. This watershed encompasses an area of 85.91 km² which accounts for 3.91% in the total study area (Table- 2, Figure 4). The total length of the streams in this sub-watershed about 18 km which is contributed 3.64% in the Gori Ganga watershed (Table-3, Figure 5). Where total stream lengths distributed 33.33% (6 km) in 1st order, 44.44% (8 km) in 2nd order and 2.22% (4 km) in 3rd order (Table- 4, Figure 8, H). In this watershed there is one watermill which is located at Bari Gaun.

7.9. Gori Ganga Sub-Watershed:

This watershed encompasses an area of 794.97 km² which accounts for 36.27% in the total study area (Table- 2, figure 4). The total length of the streams in this sub-watershed about 170 km which is contributed 34.41% in the Gori Ganga watershed (Table-3, Figure 5). Where total stream lengths distributed 38.24% (65 km) in 1st order, 14.12% (24 km) in 2nd order and

47.64% (81 km) in 4th order (Table- 4, Figure 8, I). In this watershed there is 21 watermills which is located at Garali, Umargada, Sera, Dhoonamani, Golma, Imla, Josha, Mtyani, Harkote, Talla Ghorpatta, Dhapa, Syannar, Sain, Quiry, Sain Polu, Jimighat, Gopal Bara, Basantkote, Bachchepur, Jara Jibli and Jara.

CONCLUSION

The fundamental objectives of the present study is to analysis of stream ordering in sub-watersheds by using remote sensing and GIS techniques in the Gori Ganga watershed of Kumaun Himalaya, Uttarakhand (India). Based on the previous study following can be concluded.

1. Using pour point technique for the Gori Ganga watershed is divisible in to 9 sub-watersheds. Present study describes details of stream ordering in the 9 sub-watersheds based on remote sensing and GIS techniques. Which reveals that the sub-watershed size in the study area varies in between 83.97 km² (viz., Baram sub-watershed) and 794.97 km² (viz., Gori Ganga sub-watershed).
2. Their are total 4929 streams in the study area which accounts total length is about 494 km which is devided in first order streams about 2299 which is contribute 47.37% (234 km), in second order streams about 1302 which is contribute 26.11% (129 km), in third order streams 430 which is contribute 8.71% (43 km) and in fourth order streams 893 which is contribute 17.81% (88 km).
3. The Gori Ganga sub-watershed has longest stream lengths which are about 170 km (34.41%) and Raunits Gad sub-watershed has smallest stream lengths which is about 18 km (3.64%).
4. Remote sensing and GIS are very useful techniques for sub-watershed delineation and geographical distribution of stream ordering and analysis through DEM.

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