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Analysis of the Geomorphometric Parameters in High Altitude Glacierised Terrain using SRTM DEM data in Central Himalaya, India

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ABSTRACT

The drainage and basin morphometric parameters were obtained from SRTM (Shuttle Radar Topographic Mission) DEM (Digital Elevation Model) of the Bhagirathi basin using automatic digital techniques. It has been observed that drainage morphometry derived from this technique fallows standard rules. The high density of stream frequency and high drainage texture on surface of big glaciers indicate that glacier surface is not uniform in lower altitude and these two parameters can be utilized in automatic mapping of the debris covered glaciers in Himalaya. Distribution of the relative relief along the major drainage at some location show asymmetrical distribution indicate active tectonic at such locations. Dissection index is low at high altitude and increase in downstream direction, it indicate that convex profile at higher altitude and concave at lower altitude. The convex profile does not help in active mobilization of the weathered material at higher altitude, while weathered material mobilization is quick at lower altitude. The whole of the valley is dominated by low value of Ruggedness index except few places at downstream at junction of the tributaries with main stream especially at lower altitude and main valley.

Keywords: *Geomorphology, Glacier, SRTM DEM, Himalaya.*

1. INTRODUCTION

The measurement of shapes or geometry of any natural geomorphological features is termed as geomorphometry. Natural geomorphological forms are formed by various surface natural agencies and their impact on considering area. Along with surface agencies the Tectonic forces originating deep below the surface of earth also change surface configuration, increase or reduce the rate of surface modification intensity. The role of orogenic and surface geological agents on surface features influences morphometric parameters. Hence, analyzing the characteristics of these parameters were utilized to differentiate the different environmental parameters i.e., rock type, climate erosional type, structure and texture of the rocks in various studies. The delineation of these environment further utilized in identifying the groundwater potential zone, selecting groundwater recharge sites, soil survey, suitability of land use and natural hazards and other information. Estimation of morphometric parameters for geomorphological features require topographic information such as length of the drainage, ordering of the drainage, basin boundaries, elevational information of various points etc.

Determination of these information need Topographic sheets, remote sensing images and geological/ geomorphological field investigations. The topographic sheets are not always available with good horizontal and vertical resolution especially in remote areas such as Himalaya. Hence, studies related to variation of spatial variation of morphometric parameters are very few[1],[2]&[3]. The advancement in the mapping and survey technology in last 10 years provided the opportunity for the better topographic information of any remote region through SRTM (Shuttle Radar Topographic Mission). Therefore numerous studies used topographic data to conduct the various earth science investigations [4],[5],[6],[7]&[8]. Along with availability of topographic data, the development of various morphometric software provides the opportunity to investigate morphometric analysis of such remote Himalaya within short time. In present study, morphometry analysis of drainage and basins in Bhagirathi valley using SRTM DEM is done.

2. GEOLOGY OF THE STUDY AREA

Most dominant rock types of the Bhagirathi valley are Garhwal group of rocks and the central Crystalline. The lower altitude Garhwal group rocks are represented by cream colored quartzite grading to talc – Chlorite schist along thrust passes through Maneri. Major portion of the basin fall under Central crystalline rocks composed of Pelitic and semi-pelitic meta-sediments with acid and basic intrusive. The area is situated north of Main Central Thrust (MCT), which separates the metamorphics from the underlying very low grades of unmetamorphosed sedimentary sequence of the lesser Himalaya. Mica schists are the predominant rock found over the MCT. Further, northeast of Gangotri, these schists are intruded by hard and massive granite known as Gangotri granite. From Gangotri town towards Gomukh, the Gangotri granite gradually changes into fine grained, well-foliated, garnetiferrous gneiss and augen gneiss intruded by fine-grained aplitic veins[9]&[10].

The lower portion of the basin is characterized by fluvial activity, but the upper portion of the basin is dominated by glacial –fluvial processes. A geological map of the area is shown in Figure 1. The Bhagirathi river valley is a broad U-shaped with high sidewalls, which is a characteristic of its glacial – fluvial origin. Morainic

VOL. 1, NO. 1, November 2011 ISSN XXXX-XXXX
ARPN Journal of Science and Technology

http://www.ejournalofscience.org

material present between Chirwasa and Gomukh in the form of tillite hillocks are considered as evidences of the

Figure 1: Location map of the Bhagirathi Basin, Garhwal Himalaya

extent of Gangotri Glacier. It is NW-SE trending valley within the granitic terrain. The prominent geomorphic landforms formed by the glacial environment are different levels of lateral and recessional moraines, U-shaped glacial troughs, terraces and outwash plains.

3. MORPHOMETRIC ANALYSIS

SRTM Digital Elevation Model (DEM) is downloaded from GLCF website (Global Land Cover Facility) Maryland, which is in Tiff format with 90 meter ground resolution. For morphometric analysis, contour intervals at 100 meters have been used in this study. However, comparison of contours are also generated at 30 meter intervals and verified and modified with Survey of India(SOI) toposheets. Based on this image, study area is divided into 6,392 square grids of 1km x 1km and detailed morphometric analysis is done for each grid using software like ArcGIS and River Tool.

4. RESULTS AND DISCUSSIONS

Based on the automatic morphometric analysis using SRTM DEM, the results are presented. In general drainage pattern of the Bhagirathi Basin shows interesting characteristics, the southern part shows parallel pattern, whereas the northern and central part shows dendritic pattern. Parallel pattern are usually found where there is structural controls which leads to regular spacing of parallel or near parallel streams. These parameters are classified as drainage and basin characteristics. The drainage properties are the linear parameters (stream order, bifurcation ratio, stream frequency, drainage density and texture) distribution pattern are described. The basin parameters (Absolute and Relative Relief, Dissection and Ruggedness index) are the aerial properties of basins and their distribution are discussed below.

4.1. Stream ordering

The number of streams of different orders in a watershed decreases with increasing order in a regular way. When the logarithm of the number of stream of given order are plotted against the order, the points lie on sub-straight line. The Figure 2 confirms the law of stream order with some reservation. A slight variation in stream order at the 4th order is due to change in from alpine to sub-alpine environment.

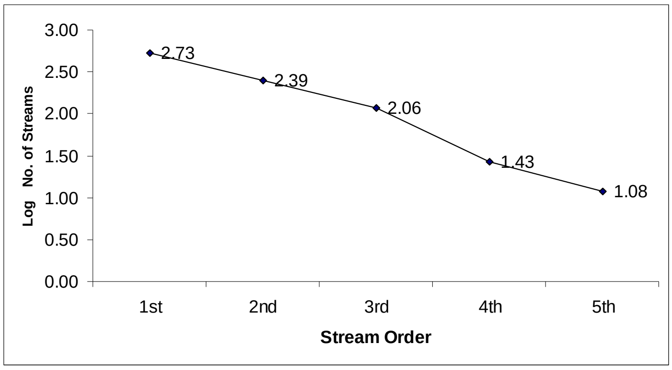


Figure 2: The distribution of stream numbers and stream order

4.2. Bifurcation Ratio

It shows the degree of integration prevailing between the streams of various orders in a drainage basin. The value of bifurcation ratio ranges from 2 to 4 and increases from 1st order to 2nd order and further increases as shown in Table 1. The increase in bifurcation ratio for 2nd and 3rd order is result of occurrences of more unsuitable geological conditions in downstream direction as structural change from Central Crystalline to thrust zone. High value of ratio indicates lower degree of drainage integration and vise versa.

Table 1: Table of Bifurcation Ratio of streams in Bhagirathi basin

Stream Order	No. of Streams	Bifurcation Ratio
1st	353	2.50
2nd	141	2.17
3rd	65	3.10
4th	21	2.63
5th	8	--

4.3. Stream Frequency

Stream frequency is an important morphometric indicator and provides additional information concerning the response of drainage basin to runoff process. It is defined as the ratio of total number of streams to the drainage area. It is found that steam frequency bears a direct relationship to the degree of relief fragmentation and also reflects the number of valley segments per unit area[11]. He noticed that the spatial distribution of stream frequency is influenced by the resistance to erosion and the permeability, tectonics and the structure of the rock types in a basin [12]. Tributaries and rivulets have coarse texture, i.e. widely spaced in coarse grained rocks like sandstones. On the other hand, fine textured drainage systems are narrow and closely spaced, and indicative of fine grained rocks with lesser permeability. It is shown that major part of the basin is characterized by the low frequency class (Figure 3), moderate frequency found in other basins equally. Figure 4 shows that high to very high

VOL. 1, NO. 1, November 2011 ISSN XXXX-XXXX
ARPN Journal of Science and Technology

http://www.ejournalofscience.org

stream frequency found only in the Bhagirathi and Jahnvi sub-basins. The high densities of stream frequency on surface of big glaciers indicate that glacier surface is not uniform. The high stream frequency can be used as decisive factor for debris covered glaciers.

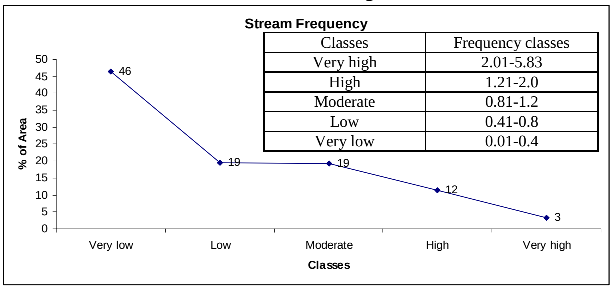


Figure 3: Relationship between area of percentage and corresponding Stream frequency classes

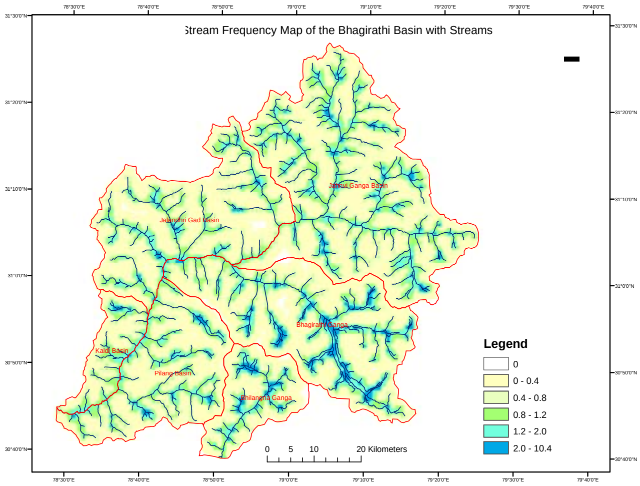


Figure 4: Spatial distribution of the Stream Frequency groups in Bhagirathi basin

4.4. Drainage Density

Drainage density is the length of stream channel per unit square area. It is generally influenced by several factors like geology, climate, permeability of soil etc.[13]. Drainage density is regarded as a fundamental concept in hydrological analysis and defined as the length of drainage per unit area[14]. A high drainage density reflects a highly dissected drainage basin with a rapid hydrological response to rainfall events, while a low drainage density means a slow hydrological response[15]. Thus higher drainage density is also supposed to cause a greater flood risk. [16] identified that drainage density varied according to type of substratum, surface gradient, plant cover and precipitation. Figure 5 and 6 show that the equal drainage density for all most in all the basins. However, the upper Bhagirathi sub-basins are dominated by higher drainage density. This is result of more coverage with more number of debris covered glaciers in this basin, which help in generate in high drainage density at those surfaces.

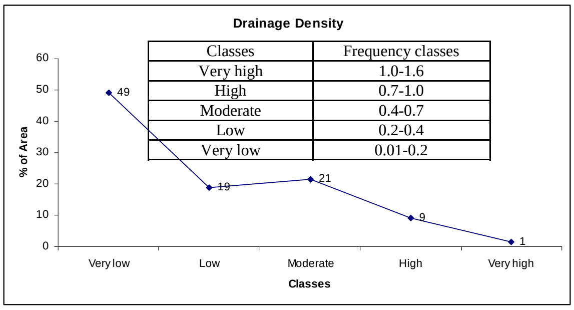


Figure 5: Relationship between area of percentage and corresponding Drainage Density groups

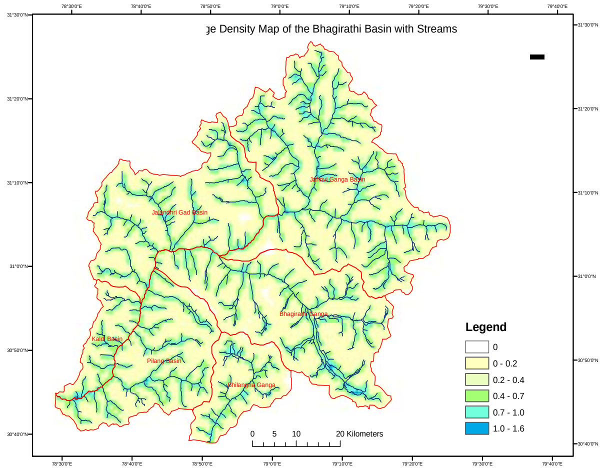


Figure 6: Spatial distribution of various Drainage Density groups in Bhagirathi basin (Length of Streams/Sq.km.)

4.5. Drainage Texture

An important geomorphic concept, drainage texture indicates relative spacing of streams in a unit area along a linear direction. [17] suggested that drainage texture is indicative to relative spacing of streams in a unit area along a linear direction. The various groups of the drainage texture classes are shown in Figure 7 and 8. Maximum area is covered by moderate to very low drainage texture. It shows that the high to very high drainage texture is found along Bhagirathi sub-basin (Figure 8). High drainage texture is maximum on the entire glaciers surfaces and also at few places along the valley at junction of the streams with main stream.

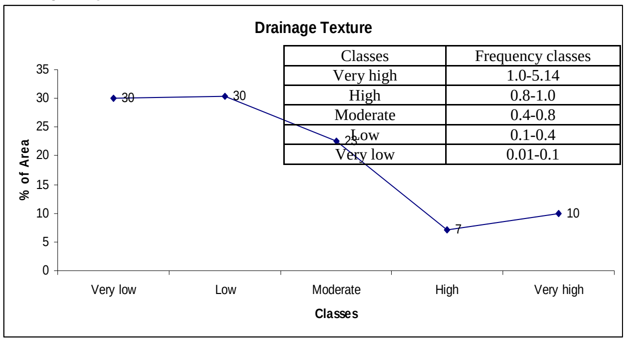


Figure 7: Relationship between area of percentage and corresponding Drainage Texture groups

VOL. 1, NO. 1, November 2011 ISSN XXXX-XXXX
ARPN Journal of Science and Technology

http://www.ejournalofscience.org

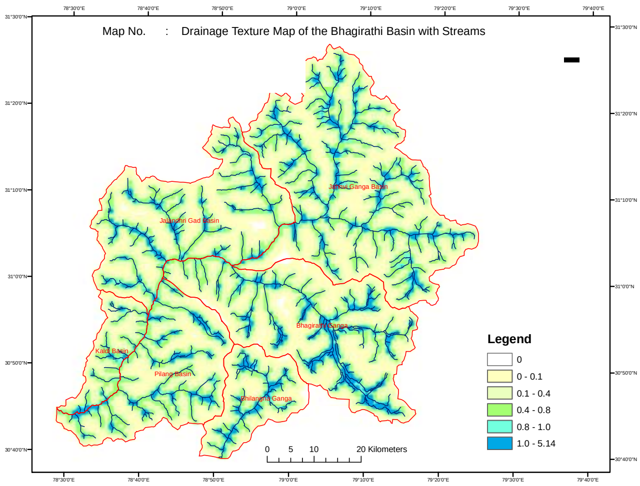
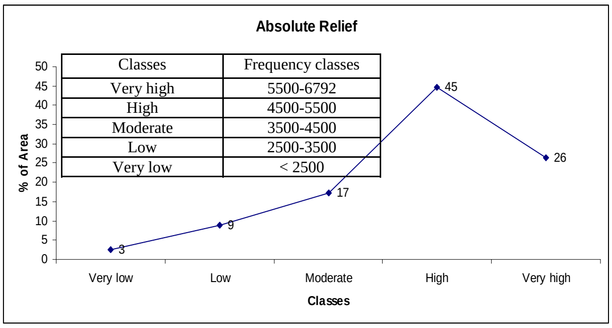


Figure 8: Spatial distribution of Drainage Texture (No. of Streams/km)

4.6. Absolute Relief

Absolute relief gives the elevation of any area above the sea level in exact figure. The very high and high relief classes constitute about 70 % of the total area. The high absolute relief area is dominated by cold temperature and provides the opportunity for accumulation of the snow in cirques and which further form the valley glaciers. It is shown in Figure 9 and 10 that the high absolute relief area is surrounded by very high absolute relief. The high relief provides the accumulation area for snow and move from here to lower relief area in glacier valley.



Classes	Frequency classes
Very high	5500-6792
High	4500-5500
Moderate	3500-4500
Low	2500-3500
Very low	< 2500

Figure 9: Relationship between area of percentage and corresponding absolute Relief in Bhagirathi basin

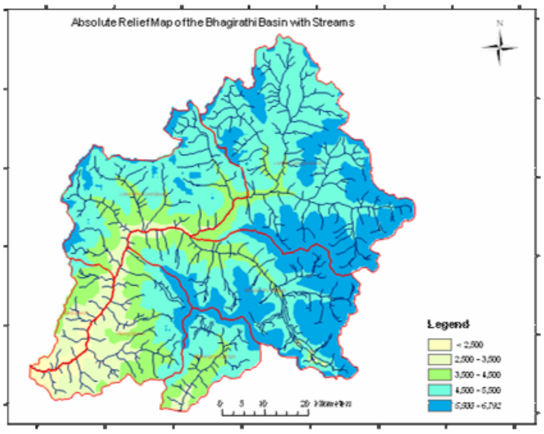
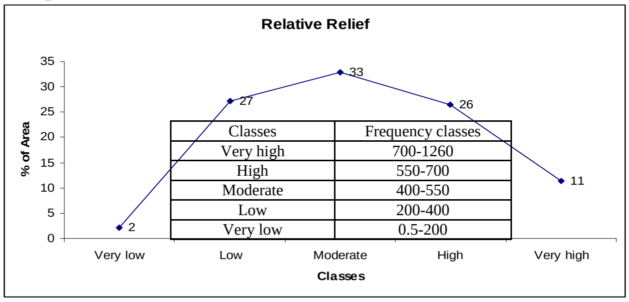


Figure 10: Spatial distribution of the absolute Relief (in Meters) in Bhagirathi basin

4.7. Relative Relief

Relative relief is also termed as amplitude of local relief. It is defined as the difference in height between the highest and lowest point heights in a unit area. Relative relief is defined as the difference in height between the highest and the lowest points in a unit area. Relative relief as an important morphometric variable is used for overall assessment of morphological characteristics of terrain and degree of dissection. More the degree of dissection greater is the relative relief. In the study area high, moderate and low relative relief constitute major area of the basin. The distribution of the relative relief along the major drainage at some location indicate asymmetrical distribution, it indicate the active tectonic at such location (Jalandhri gad) in the area in Figure 11 and 12. It also shows that high relative relief in Jalandhri basin and small patch in Jahnvi Basin. It is evident from this figure that the higher Relative Relief is mostly concentrated central part of the basin active tectonics in this part of the basin.



Classes	Frequency classes
Very high	700-1260
High	550-700
Moderate	400-550
Low	200-400
Very low	0.5-200

Figure 11: Relationship between area of percentage and corresponding Relative Relief groups

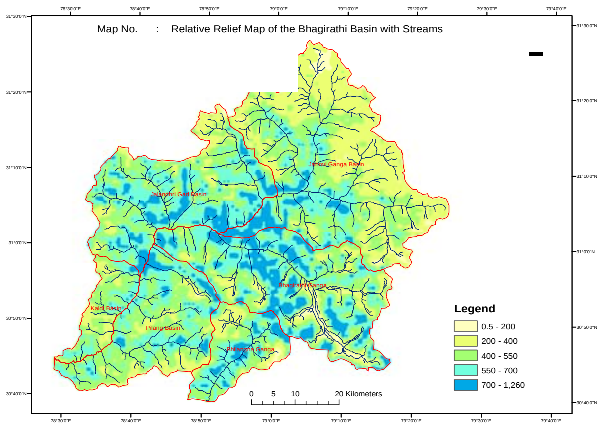


Figure 12: Spatial distribution of the Relative Relief (in Meters) in Bhagirathi basin

4.8. Dissection Index

Dissection Index(DI) is expressing a ratio of the maximum relative relief to maximum absolute relief. It is an important morphometric indicator of the nature and magnitude of dissection of terrain[17]. Equal relative altitudes are not always of equal importance since their absolute altitude may differ. On this basis, the relief in terms of the ratio between the two variables, absolute relief and relative relief is taken as Dissection Index. High value of DI shows young stage and low value shows old stage[18]. The value of dissection varies from zero (complete absence of dissection) to one (vertical cliff).

Figure 13 and 14 show that Dissection index mainly increase along the main drainage. This is related to active tectonics and concave drainage profile development along the profile at lower altitude and result in higher DI. However, the DI is low at high altitude because in glacier environment the valley longitudinal profile is convex. It does not help in active mobilization of the weathered material, while weathered material mobilization is quick at lower altitude.

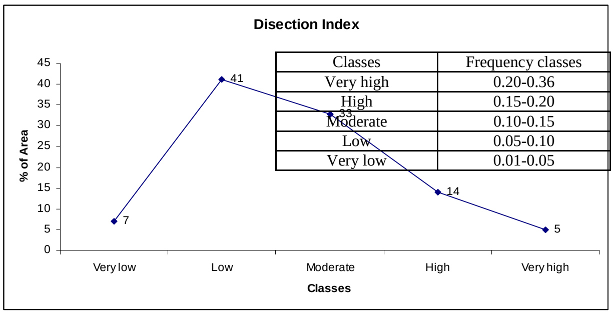


Figure 13: Relationship between area of percentage and corresponding Dissection Index classes in Bhagirathi basin

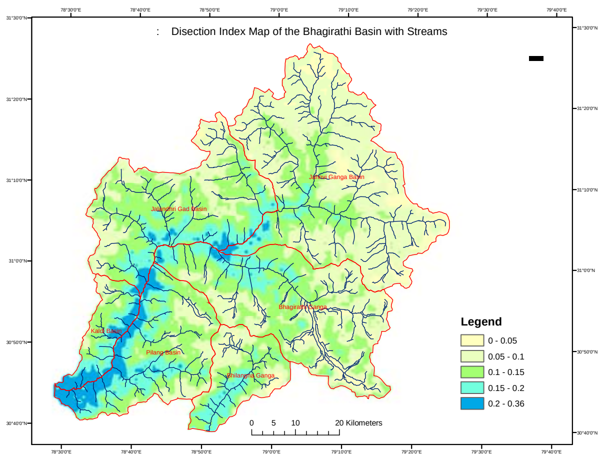


Figure 14: Spatial distribution of the Dissection Index (DI) in the Bhagirathi basin

4.9. Ruggedness Index

Ruggedness Index(RI) is a measure of surface unevenness. It is derivative of long-standing interaction between available sharpness of local relief and the amplitude of available drainage density and other environmental parameters such as slope, precipitation, weathering, soil texture, natural vegetation etc. Ruggedness index is measured by taking into account both relief and drainage[19]. The results shown in Figure 15 and 16, show moderate to very high frequency classes of ruggedness index at the region where it has high relative relief and dissection index. But moderate value of frequency classes also occurs towards valley area. It clearly shows that high values of dissection index are found in Jahnvi and Jalandhri Basins. Frequency classes of dissection index shows very low value is found in almost whole valley except few places at down stream. In the figure it is shown that at the junction of the tributaries with main stream RI is maximum and concentrated mainly at lower elevation.

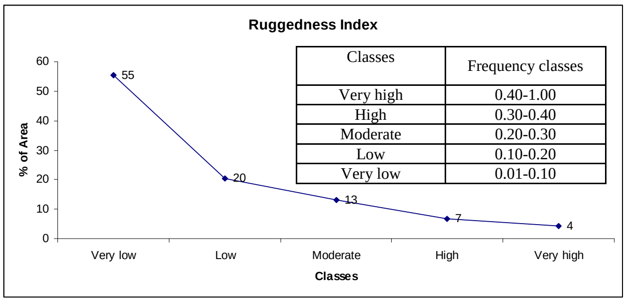


Figure 15: Relationship between area of percentage and corresponding Ruggedness Index classes in Bhagirathi basin

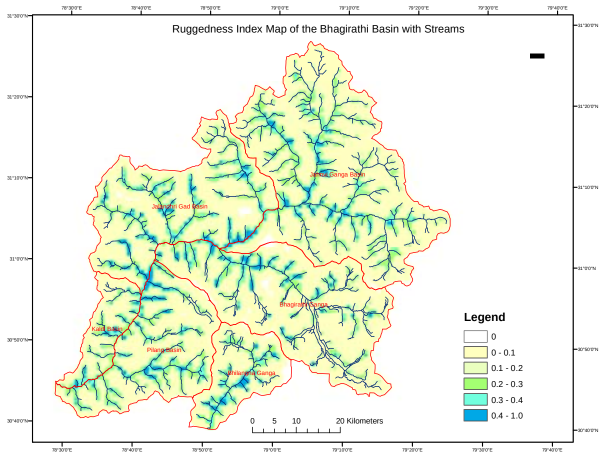


Figure 16: Spatial distribution of the Ruggedness Index in Bhagirathi basin

5. CONCLUSIONS

Based on the automatic morphometric analysis using SRTM DEM, the results show that drainage is follows stream ordering law with some reservation of change in structural nature of the rock type. The stream frequency is found very high in the Bhagirathi and Jahnvi sub-basins dominated by glacier activity. The high density of stream frequency on surface of big glaciers suggests that glacier surface is much uneven. Drainage texture is high to very high drainage along Bhagirathi sub-basin due to dip-controlled slope.

It is shown that the high absolute relief area is surrounded by very high absolute relief. The high relief provides the accumulation of snow and moves from here to lower relief area and form the big composite valley glaciers. Spatial distribution of the relative relief along the major drainage at some location indicates asymmetrical distribution, which indicates the active tectonic at such location in the area.

Dissection index mainly increase along the main drainage. The DI is low at high altitude because in glacier environment and valley longitudinal profile is convex in these locations. It does not help in active mobilization of the weathered material at higher altitude, while weathered material mobilization is quick at lower altitude and results in higher DI values. Low value of dissection index is found in almost whole valley except few places at down stream and at junction of the tributaries with main stream. Ruggedness Index is maximum and concentrated mainly at lower elevation at junction between main stream and joining streams.

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REFERENCES

[1] NAITHANI, N.P. AND RAWAT, G.S., 1990, Morphometric Analysis of Bhagirathi Valley between Maneri and Gangnani area, district Uttarkashi, Garhwal Himalaya. In *Ecology of the Mountain Waters*, SD Bhatt and RK Pande(Eds.), pp. 33-40 (New Delhi: Ashish Publishing House).

[2] GARDINER, V., 1982, Drainage basin morphometry: quantitative analysis of drainage basin form. In *Perspectives in Geomorphology*, H.S. Sharma(Ed.), pp. 107-142 (New Delhi, Concept Publishing Company).

[3] SINGH, S., 1972, Altimetric analysis, A morphometric technique of land form study, *National Geographer*, Vol. VII, Allahabad.

[4] TOBIAS BOLCH, 2004, Using ASTER and SRTM DEMS for Studying Glaciers and Rock glaciers in Northern Tien Shan. In: *Proceedings Part I of the Conference "Theoretical and applied problems of geography on a boundary of centuries*", 8-9 June 2004, Almaty, Kasakhstan, pp. 254- 258.

[5] TOBIAS BOLCH, ULRICH KAMP and JEFFREY OLSENHOLLER, 2005, Using ASTER and SRTM DEMs for studying geomorphology and glaciation in high mountain areas. In: *New Strategies for European Remote Sensing*, Olui(ed.) (Rotterdam: Millpress).

[6] WANG, Y., LIAO, M., SUN, G. and GONG, J., 2005, Analysis of the water volume, length, total area and inundated area of the Three Gorges Reservoir, China using the SRTM DEM data. *International Journal of Remote Sensing*. **26** (18), pp. 4001–4012.

[7] MEEI LING LIN and KUO LUNG WANG, 2005, Assessment of Landslides Caused by Earthquake-Case Study of Chi-Chi Earthquake in Taiwan, 1999. *Geophysical Research Abstracts*, **7:** 08654.

[8] MARC LEBLANC and GUILLAUME FAVREAU, 2006, Reconstruction of Megalake Chad using Shuttle Radar Topographic Mission data. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **12**, pp. 213-216.

[9] HEIM, A. and GANSSER, A., 1939, Central Himalaya; geological observations of the Swiss expedition 1936. *Schweizer. Naturf. Ges., Denksch.* **73 (1)**, p. 245.

[10] GUPTA, H.K., RAO, V.D. and SINGH, J., 1982, Continental collision tectonics: Evidence from the Himalaya and the neighbouring regions. *Tectonophysics*, **81**, pp. 213-238.

[11] ZAVOIANU, I., 1985, *Morphometry of drainage basins, Developments in Water Science 20*, pages 251 (Bucharest: Editura Academiei).

[12] CHRISTOFOLETTI, A. and OKA- FIORI, C., 1980, O uso da densidade de rios como element para caracterizar as farmacoes superficials, *Not. Geomorfol.*, **20 (39&40)**, pp. 73-85.

[13] MORISAWA, M.F., 1968, *Streams their Dynamics and Morphology*, pp. 153 – 154 (New York: McGraw Hill).

[14] YILDIZ, O., 2004, An investigation of the effect of drainage density on hydrologic response, *Turkish J. Eng. Env. Sci.*, **28**, pp. 85-94.

[15] MELTON, M.A., 1957, An Analysis of the Relations among the Elements of Climate, Surface Properties and Geomorphology, In: *Technical Report 11*, New York Department of Geology, Columbia University.

[16] MORARIU, T., PISOTA, I. and BUTA, I., 1962, *General hydrology*, (Bucharest: Ed. Didactica si pedagogica), (in Romanian).

[17] SINGH, S. (Ed.), 2000, *Geomorphology*, (Allahabad: Prayag Pustak Bhawan), p 642.

[18] DEEN, M., 1982, Geomorphology and Land use: A Case Study of Mewat, thesis submitted to the center for the study of regional development, JNU, New Delhi.

[19] CHORLEY R.J. and KENNEDY, B.A.(Eds.), 1971, *Physical Geography, A systematic approach*, p 370 (London, Prentice Hall).