A Morphometric Analysis of Ravi River Basin in Himachal Pradesh

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Abstract:

Morphometric analysis of Ravi River basin in Himachal Pradesh is located in Kangra and Chamba Districts of State of Himachal Pradesh. Analysis of various morphometric attributes are done to understand the geomorphologic evolutionary stages of this basin. From the analysis it wasinferred that this basin in a matured stage. The morphometric analysis is carried out through measurement of linear, aerial and relief aspects of the basin and slope contribution to understand the run-off characteristics of the area and potentiality of basin corrosion. The measurement of various morphometric parameters namely stream order, stream length (Lu), mean stream length, bifurcation ratio, mean bifurcation ratio, drainage density, stream frequency and elongation ratio has been carried out. Structural and geomorphological features control the directions of flow of the tributaries. Drainage morphometric analysis gives overall view of the terrain information like hydrological, lithological, slope, relief, variations in the watershed, ground water recharge, porosity, soil characteristics, flood peak, rock resistant, permeability and runoff intensity and is useful for geological, hydrological, ground water prospects, civil engineering and environmental studies.

Keywords: Basin, stream order, stream number, stream length, Bifurcation Ratio, stream length ratio, drainage density, stream frequency.

1. Introduction:

Morphometric analysis of Ravi River basin in Himachal Pradesh in highland region of Ravi basin is carried out. This basin is located at Chamba and Kangra Districts of Himachal Pradesh. Analyses of various Morphometric attributes are done to understand the geomorphologic evolutionary stages of basin. From the analysis it was inferred that this basin is in matured stage. Geographically Ravi River (H.P.) Basin area is located between 32° 11' 30″ to 33° 01' 5″ North latitudes and 75°48' to 77°45' East Longitudes. The tract is mountainous, covered by the Dhauladhar and Pirpanjal ranges. The elevation varies from 559 meters to 5563 meters. On the other side the climate of the Ravi River Catchment area may be described as moderate summer and very cold winter. The precipitation is received in both during rainy season and winter season, but in high altitude an area in winter season receives precipitation is in the form of snow and in lower altitude area in the form of Rainfall from Monsoon winds as well as from Western Disturbance. The highest monthly temperature is experienced in June and lowest below 0° C in January. The Ravi River has a total of 5451 sq. Kilometers. Catchment area and its total length are about 158 Kilometers. in Himachal Pradesh. The Ravi River originates in Bara Bhangal area of the Multhan Tehsil of Kangra. This River rises at the elevation of 4300 meters on the southern side of the mid Himalayas. It flows through Bara Bhangal, Bara Bansu and Chamba District. It flows in forms of Rapids in its initial reaches with boulders seen scattered in the bed of the River. The Ravi River in this reach flows in a gorge with a River bed slope of 1:185 feet per mile, and is mostly fed by snow. It is called Ravi after meeting two tributaries Tantgari and Badal

in Bara Bhangal area of Kangra District. The main tributaries of Ravi River are Badal, Tantgari, Budhil, Tundah Nala, Chirchind Nala, Nai, Batog Nala, Saho Nala, Baira and Siul etc. It left Himachal at Khairi and enters in Punjab.

The most important factors governing the development of landforms are resistance to erosion and geologic structure of the underlying rocks, Climate and vegetation covers. Morphometry is gaining importance in evaluating hydrologic parameters of drainage basins. This basin (e.g. for stream characteristics, drainage basin or slopes) is becoming prevalent in geomorphology. Relationships between precisely measured aspects of landscape are revealed, particularly by the use of statistical methods. The study helped in finding out various morphometric parameters such as those dealing with length, area, slope and form factors of the Ravi River basin in Himachal Pradesh located in Chamba and Kangra Districts of Himachal Pradesh.

2. Research Objectives

Morphometric aspects of Ravi River Basin area of Himachal Pradesh have been analyzed for this research paper.

3. Research Methodology

The Research methodology of this research paper is qualitative. The data of this research paper are obtained from topographical sheets of District Kangra and Chamba of Himachal Pradesh.

4. Literature Review

In 2015 Shaikh pointed out how Morphometry is useful to obtain quantitative information of a watershed. He also pointed out the drainage network of the basin exhibits as mainly dendritic type which indicates the homogeneity in texture and lack of structural control. In the same year Kumar pointed out drainage density and frequency are more and drainage texture is fine which shows that basin is impermeable and having low ground water recharging characters with sparse vegetation. They also pointed out the runoff of Paisuni basin is moderate to high. In 2015 Saha pointed out that GIS techniques are more reliable and accurate than conventional methods of morphometric analysis. In 2015 Dhawaskar pointed out that 1st and 2nd order streams are not useful for construction of check dams because these streams are situated on hilly terrains. She also pointed out that the Mhadei River basin exhibits dendritic drainage pattern. She also identify that the development of stream segments in the basin area is more or less affected by rainfall. In 2015 Rekha pointed out how morphometric analysis is important in any hydrological investigation and it is inevitable in development and management of drainage basin. She is also pointed out how relief aspect of the watershed plays an important role in drainage development surface and sub-surface water flow, permeability, landform development and associated features of the terrain. In 2015 Osano pointed out the analysis of watershed and morphometric parameters demonstrates that GIS and Remote sensing based approach is more appropriate and efficient than the conventional methods in understanding morphometric parameters and their influence on soils, landforms and eroded land characteristics in a River catchment. Through the approach, it is possible to explore the relationship between the drainage morphometry and properties of landforms and the analysis of different morphometric parameters. Drainage density and stream frequency from the result are more useful criteria for the morphometric classification of drainage system and pattern in Njoro River catchment. In 2015 Sangle pointed out how use of GIS and remote sensing to prepare management and planning of natural resources of the geography is widely acknowledged. Progress in these technologies offers many advantages of taking a

synoptic view of the natural resources, natural features at a glance to quicker planning and management of the end user related issues. He also pointed out how work focuses on management of Natural resources used in water conservation, such as primarily drainage development, watershed evaluation and its characterization, harnessing the morphometric parameters of the topography. It's helpful in management of drought affected area and agriculture practices; finally enhances water tables and the requirement of water for food production ultimately full filled.

5. Data Analysis/ Findings

5.1 Stream Ordering:

Stream ordering is a method of assigning a numeric order to links in a stream network. This order is a method for identifying and classifying types of streams based upon their number of tributaries. Some characteristics of streams can be inferred by simply knowing their order. The designated stream order is the first step in the drainage basin analysis. In the present study, ranking of streams has been carried out based on the method proposed by Strahler (1964). It is noticed from the table that the maximum frequency is in the case of first order streams. It is also observed that there is a decrease in stream frequency as the stream order increases. Stream ordering refers to the determination of the hierarchical position of a stream with in a drainage basin. A River basin consists of its several branches (segments) having different positions in the basin area and they have their own morphometric characteristics and therefore, it becomes necessary to locate the relative position of a segment in the basin, so that the hierarchical organization of stream segments is visualized. Thus stream order is defined as a measure of the position of a stream in the hierarchy of tributaries (Leopold et.al, 1969). A.N. Strahler modified the Horton's scheme of stream ordering by removing the problem of reclassification and renumbering of streams. According to him each fingertip channel is designated as a segment of first order. At the junction of any two 1st order segments, a channel of 2nd order is produced and extends down to the point, where it joins another 2nd order segment where upon a segment of 3rd order results and so forth (A.N. Strahler, 1975). It may be mentioned that the hierarchical order increases only when two stream segments of equal order meet and form a junction. The order does not increase if a lower order stream segment meets a stream segment of higher order. Strahler's scheme is popularly known as "stream segment method".
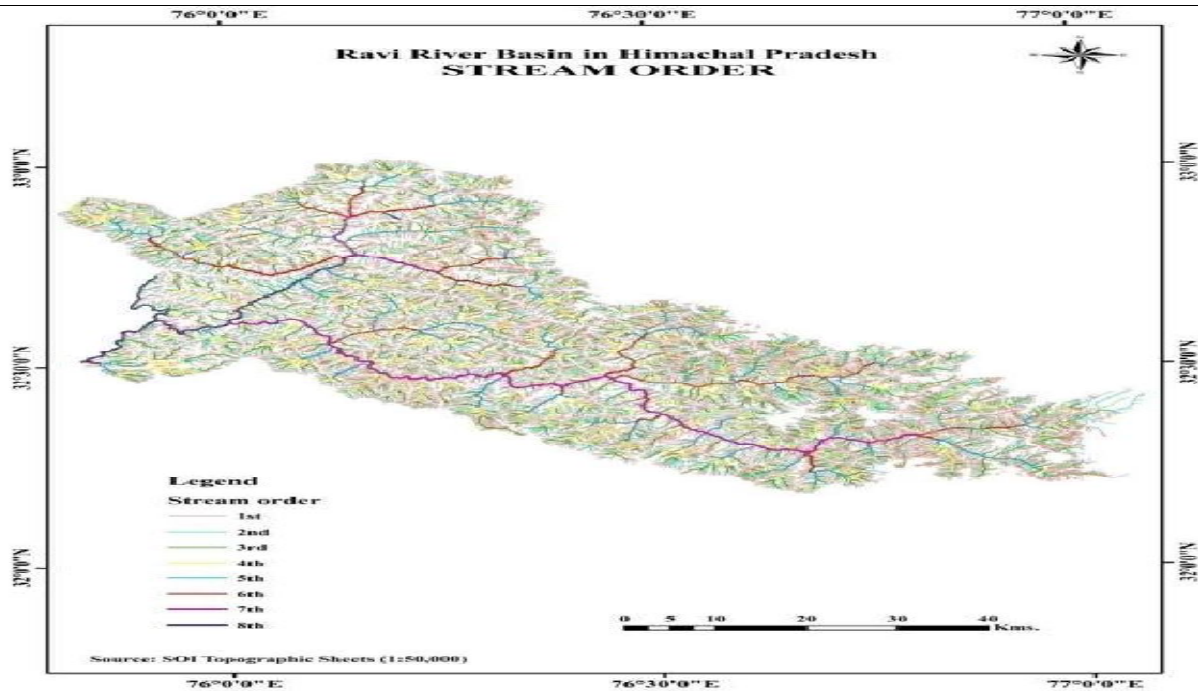
Figure: 1

There are 27701 streams of first order , 5162 of second order streams, 1094 of third order, 253 of fourth order, 62 of fifth order, 17 of sixth order, 3 of seventh order and 1 of eighth order streams in this basin (Table 1).

Table 1
Stream ordering of Ravi River Basin in Himachal Pradesh

Sr. Number	Stream Order	Number of Streams
1	1	27701
2	2	5162
3	3	1094
4	4	253
5	5	62
6	6	17
7	7	3
8	8	1
Total		34293

Source: Calculated from Topographical Map of Kangra and Chamba, Districts.

5.2 Stream Length:

Stream length is measured from mouth of a River to drainage divide. Stream length is one of the most significant hydrological features of the basin as it reveals surface runoff characteristics. Streams with relatively short lengths are representative of areas with steep slopes and finer textures whereas longer lengths of stream are generally indicative of low gradients. The length of River network has been

measured using GIS techniques. Length of the stream is indicative of the contributing area of the basin of that order. Generally, cumulative length of stream of a particular order is measured and the mean length (Lu) of that order (u) is obtained by dividing cumulative stream length by the number of segments of that order (Nu). The mean stream length (Lu) of a stream-channel segment of order (u) is a dimensionless property, which reveals the characteristic size of components of a drainage network and its contributing basin surfaces. The stream lengths calculated for Ravi River basin are given in (Table 2).

In Ravi River basin in Himachal Pradesh the total lengths of all orders stream are 20306.93 Kms. and the total streams numbers are 34293. The 1st order streams lengths are 14203.66 Kms. because the streams numbers are about 27701. The 2nd, 3rd, 4th, 5th, 6th, 7th and 8th order streams lengths are 3248.36, 1409.17, 712.42, 346.81, 187.53, 140.33 and 58.64 Kms. respectively in Ravi River basin in Himachal Pradesh (Table 2).

Table 2
Stream Lengths of Different order streams of Ravi River Basin in Himachal Pradesh

Sr. No.	Stream Order	No. of Streams	Total length in Kms.
1	1	27701	14203.66227
2	2	5162	3248.358359
3	3	1094	1409.174234
4	4	253	712.417057
5	5	62	346.811778
6	6	17	187.52995
7	7	3	140.327496
8	8	1	58.644726
		Total=34293	20306.92583

Source: Stream lengths are calculated from Topographical Sheets of Chamba and Kangra, District.
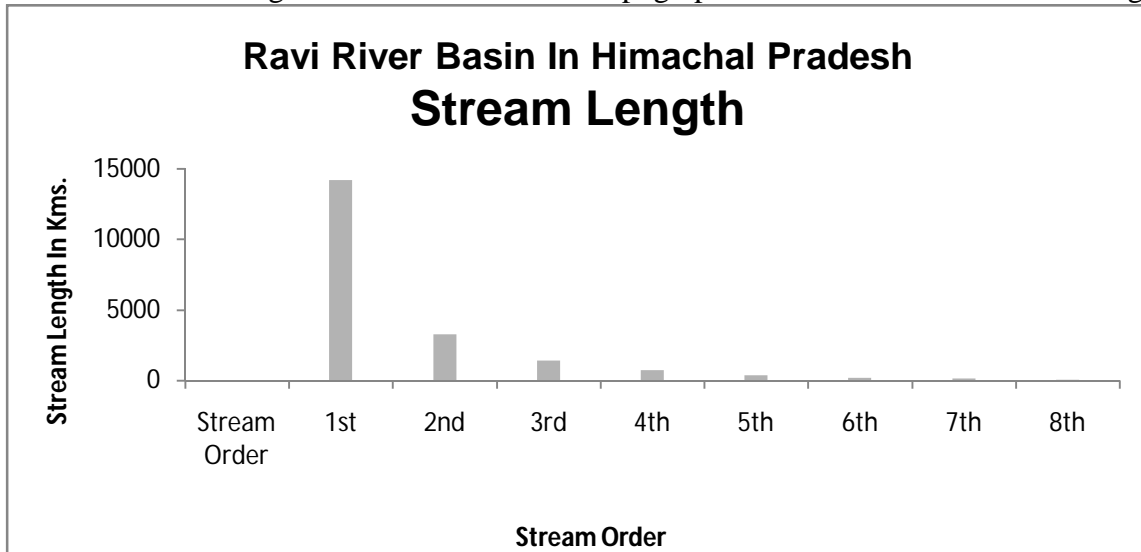

Figure: 2

4.3 Mean Stream Length:

Mean Stream Length of a stream channel system is a dimension less property revealing the characteristics of size of a component of drainage network and its contributing basin set.

$Lu = \_Lu/Nu$

Where, $\_Lu$ = Total length of a order

Nu = No of stream of that order.

Mean stream length (Lsm) is a characteristic property related to the drainage network components and its associated basin surfaces (Strahler, 1964). This has been calculated by dividing the total stream length of order (u) by the number of streams of segments in the order. It is found out from Topographic Maps of Chamba and Kangra Districts that the mean stream lengths of first order streams are 0.51 Kms. in this basin. The 2nd, 3rd, 4th, 5th, 6th, 7th and 8th orders mean streams length are 0.63, 1.29, 2.82, 5.59, 11.03, 46.78, and 58.64 Kms. respectively in Ravi basin in Himachal Pradesh. It is also observed that with the increasing of streams order, the mean lengths are also increased (Table 3).

Table 3
Mean Stream Length of Ravi River Basin in Himachal Pradesh

Sr. No	Stream Order	Number of stream	Total Length in Kms.	Mean stream length
1	1st	27701	14203.66227	0.51274908
2	2nd	5162	3248.358359	0.629282906
3	3rd	1094	1409.174234	1.28809345
4	4th	253	712.417057	2.815877696
5	5th	62	346.811778	5.593738355
6	6th	17	187.52995	11.03117353
7	7th	3	140.327496	46.775832
8	8th	1	58.644726	58.644726

Source: Mean Stream Lengths are calculated from topographical Map of Kangra and Chamba, Districts.
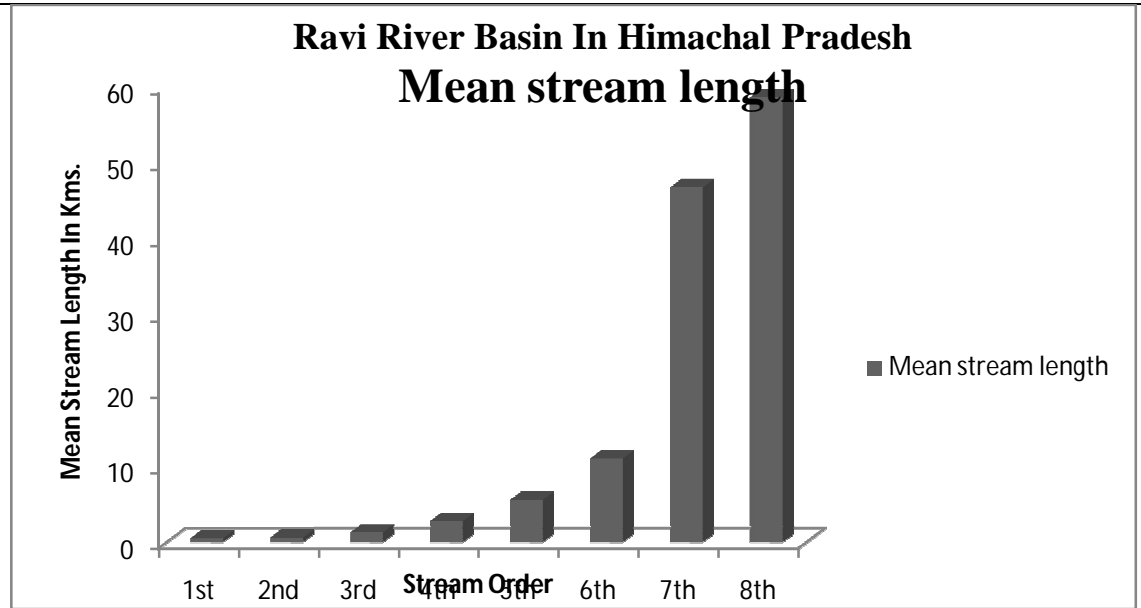
Figure: 3

5.4 Stream Length Ratio:

Stream length ratio (RL) is the ratio of the mean length of the one order to the next lower order of the stream segments. Stream length Ratio (Rl) is calculated by the following formulae;

$(Rl) = Lu/Lu-1$

$(Rl) = Nu-1 / Nu$

Where (Rl) = stream length ratio, Nu = length of an order, and Nu-1 = length in the next higher order.

The Stream length ratio (RL) is the ratio of the mean length of the one order to the next lower order of the stream segments. In this basin the stream length ratio between 1st and 2nd order is 1.23 Kms., between 2nd and 3rd order is 2.05, between 3rd and 4th order is 2.19, between 4th and 5th order is 1.99, between 5th and 6th order is 1.97, between 6th and 7th order is 4.24 and between 7th and 8th order is 1.25 Kms. stream length ratio in Ravi River basin in Himachal Pradesh (Table 4).

Table 4
Stream Length Ratio of Ravi River Basin in Himachal Pradesh

Sr.No	Stream Order	Numberof stream	Total Lengthin Kms.	Mean streamLength	Stream lengthratio
1	1st	27701	14203.66227	0.51274908	1.227272617
2	2nd	5162	3248.358359	0.629282906	2.046922677
3	3rd	1094	1409.174234	1.28809345	2.186081838
4	4th	253	712.417057	2.815877696	1.986499046
5	5th	62	346.811778	5.593738355	1.972057474

6	6th	17	187.52995	11.03117353	4.240331446
7	7th	3	140.327496	46.775832	1.25373988
8	8th	1	58.644726	58.644726	

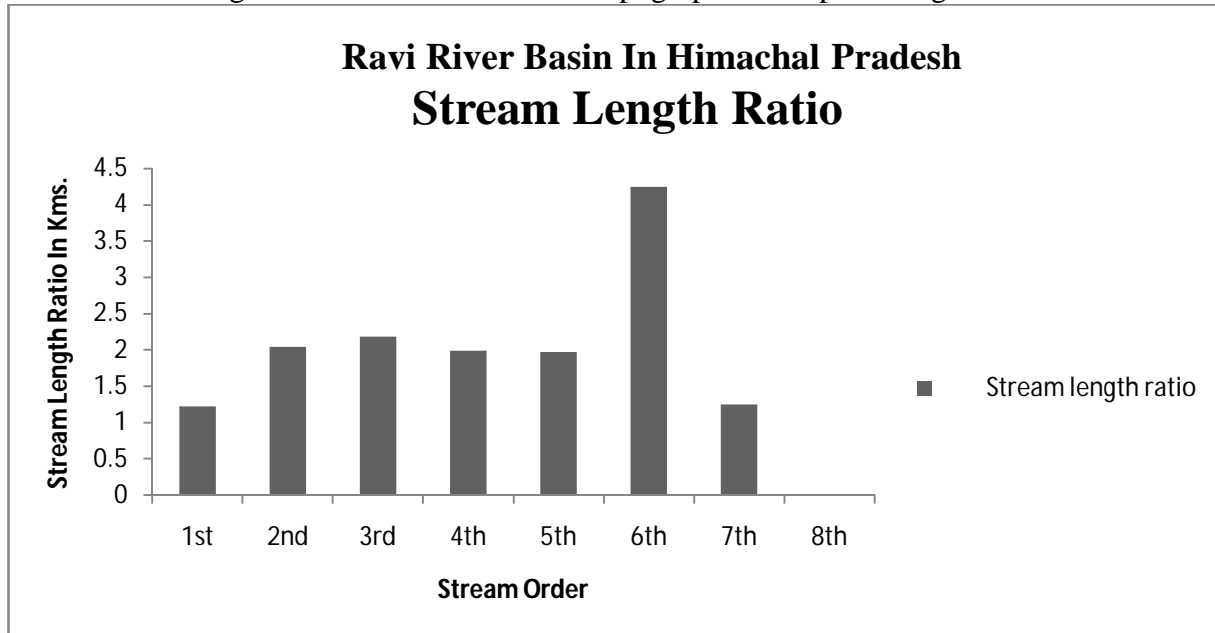**Source:** Stream length ratio is calculated from Topographical Map of Kangra and Chamba Districts.

Figure: 4

4.5 Bifurcation Ratio:

Bifurcation ratio is the ratio between the number of streams of any order and the number of streams of the next higher order. For example in a particular area there are three streams of the first order and have only one stream of second order, then the bifurcation ratio is 3% since there are three times as many streams of one order as of the next higher order. The bifurcation of stream segment is largely dependent on the composition and shape of a basin. It is mainly the structure, shape, size and climatic conditions of the Watershed which determine the bifurcation ratio of stream segments especially of the first order from the main channel. According to Schumn (1956), the term bifurcation ratio may be defined as the ratio of the number of the stream segments of given order to the number of segments of the next higher orders. Bifurcation ratio shows a small range of variation for different regions or for different environments except where the powerful geological control dominates (Strahlar, 1957). Bifurcation ratio is defined as the ratio of the number of stream of a given order to the number of stream to the next higher order which is expressed in terms of following equation-

$Rb = Nu/ Nu+1$

Where, Rb = Bifurcation Ratio.

Nu= Number of segments of a given order segment.

Nu+1=Number of segments of the next higher order.

It varies from 2 to 5. Rb is used to find out the degree of integration in drainage basin. Rb depends on the slope, physiography, and climate. Aerial aspects include different morphometric parameters, like

drainage density, texture ratio, stream frequency, form factor, circularity ratio, elongation ratio and length of the overland flow. Bifurcation is the addition of lower order streams, which produce a next higher order stream. There is a constant geometric relationship between streams of lower order and higher order. (Strahlar, 1975) has described the bifurcation ratio in the following equation

RB = N4/B4+1

Where RB = Bifurcation ratio

N4 = Number of streams of a given order

N4+1=Number of streams of the next higher order

In 1964 Strahlar himself observed and declared that bifurcation ratio is a dimensionless property. Harton (1945) stated that bifurcation ratio is one of the most significant features of drainage basin. He concluded that there can be alteration in catchments geometry and bifurcation ratio can vary from lower order to higher order. But it will remain throughout the series.

The Mean Bifurcation ratio of Ravi River basin in Himachal Pradesh is 4.40. The bifurcation ratio between 1st and 2nd order stream is 5.37, between 2nd and 3rd order stream is 4.72, between 3rd and 4th order stream is 4.32, between 4th and 5th order stream is 4.08, between 5th and 6th order stream is 3.65, between 6th and 7th order stream is 5.67 and between 7th and 8th stream order is 3 (Table 5).

Table 5
Bifurcation Ratio of Ravi River Basin in Himachal Pradesh

Sr. No.	Stream Order	Number of streams	Bifurcation ratio	Mean Bifurcation Ratio
1	1st	27701	5.36633088	4.40
2	2nd	5162	4.718464351	
3	3rd	1094	4.324110672	
4	4th	253	4.080645161	
5	5th	62	3.647058824	
6	6th	17	5.666666667	
7	7th	3	3	
8	8th	1		

Source: Bifurcation ratio is calculated from Topographical map of Kangra and Chamba Districts.

5.6 Drainage Density:

Drainage density is defined as the total length of streams of all orders per drainage area. Density factor is related to climate, type of rocks, relief, infiltration capacity, vegetation cover, surface roughness has no significant correlation with drainage density. The drainage density indicates the closeness of spacing of channels (Horton, 1932). It may be considered as one of the methods of measurement of basin area. According to Horton, Drainage Density is defined ratio of total length of all stream segments in a given drainage basin to the total area of that basin. It is expressed by a formula:

DD = _L/A

Where, _L = Total length

A = Total area

The amount and type of precipitations influences directly to the quantity and characters of surface run-off. An area with high precipitation such as thunder showers loses greater percentage of rainfall in run-off resulting in more surface drainage lines. Amount of vegetation and rainfall absorption capacity of soils, which influences the rate of surface runoff, affects the drainage texture of an area. The similar condition of lithology and geologic structures, semi-arid regions have finer drainage density texture than humid regions. Low drainage density generally results in the areas of highly resistant or permeable sub-soil material, sparse vegetation and mountainous relief. Low drainage density leads to course Drainage texture while drainage density leads to fine drainage texture. Chorley (1957) and Morgan (1962) compared three lithologically similar areas in Britain and stated that a close relationship exists between drainage density and rainfall. In 1966 Carlton also emphasized the role of climate in influencing the drainage density. Horton's method (as given above) yields only a single value (of drainage density) for the entire basin and hence it cannot be applied for the study of spatial variations of drainage density within a given basin. The simplest way to calculate drainage density on a regional scale is to divide the basin in to grid squares for one square mile or one square kilometer each and to measure the total stream lengths in each grid square and to group the derived data in to drainage density categories viz. (i) very low (Dd VL), (ii) Low (DdL), (iii) moderate (Ddm), (iv) high (Ddh) and (v) very high (Dd vh). The drainage density of

Ravi River Basin may be sub-divided into ten categories which are as following: (i) Below 1 (ii) 1.01 to 2 sq. Kms, (iii) 2.01 to 3.0, (iv) 3.01 to 4.0, and (v) 4.01 to5.0 (vi) 5.01 to 6.0 (vii) 6.01 to 7.0 (viii) 7.01 to 8.0 (ix) 8.01 to 9.0 and (x) above 9 Kms. per sq. Kms.

In Ravi River basin in Himachal Pradesh, the drainage density is categorized in to 10 categories. In Ravi River basin the drainage density is very high in lower stream orders areas because of dissected topography and due to this the erosion processes are also very high. It is observed that the canopy areas of Dhauladhar and Pirpanjal, the drainage density is very high of more than 9 Kms. per square kilometer.

It is also observed that in Ravi and its major tributaries bed areas, the drainage density is low. It is found out from drainage density map that in Glacier covered areas; the drainage density is also low. It is also found out that with the increasing of stream order the drainage density is decreasing (Figure 5).
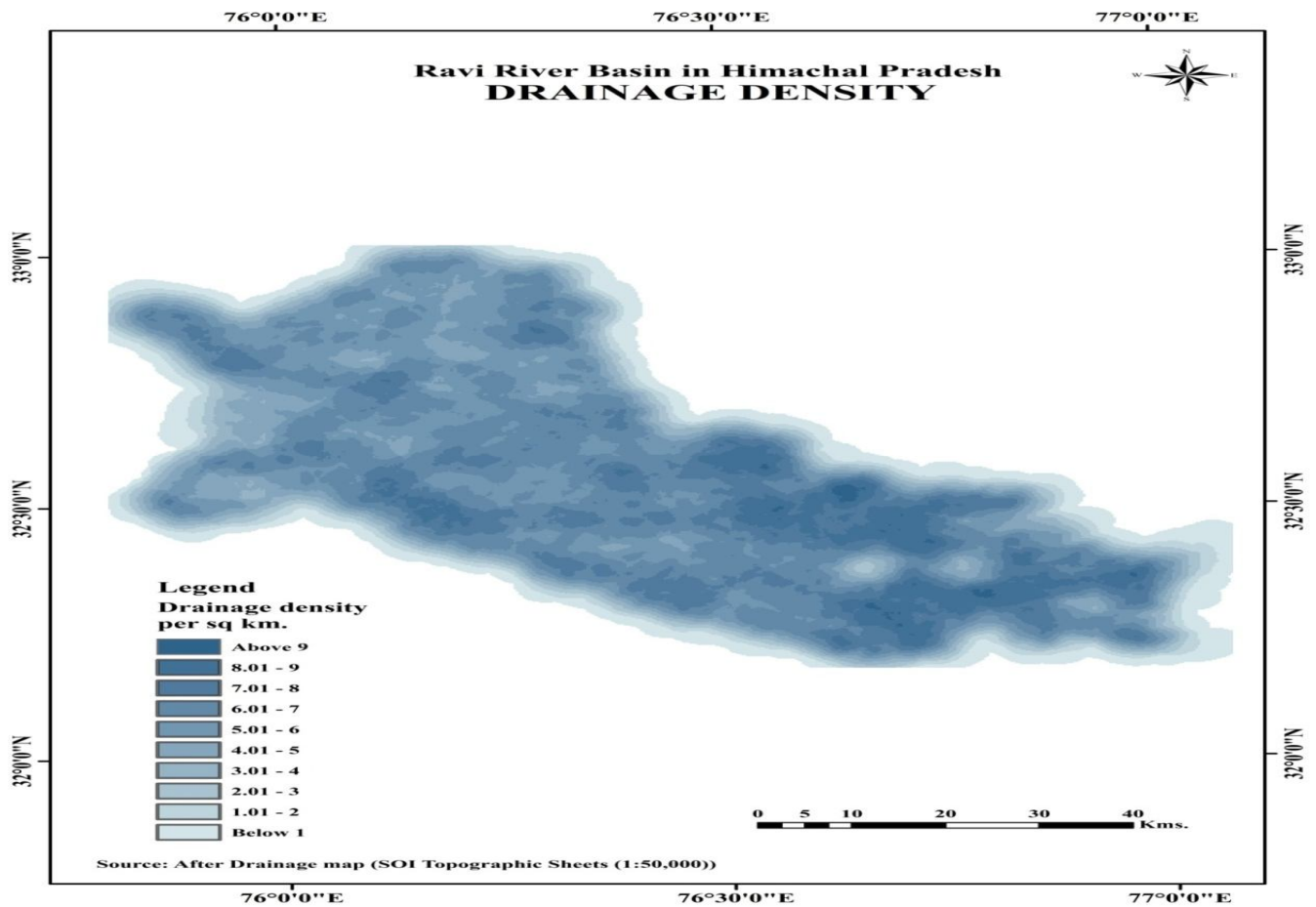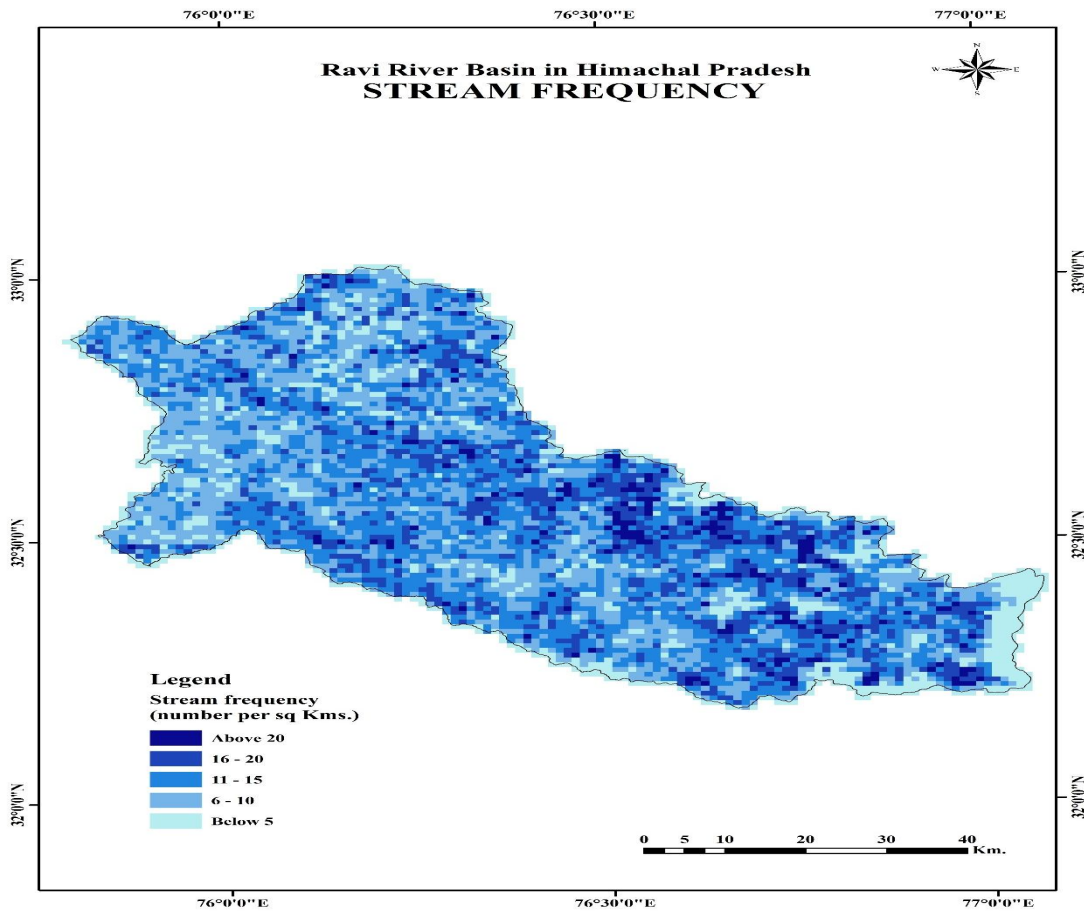
Figure 5

5.7 Stream Frequency/Channel Frequency:

The total number of stream segments of all orders per unit area is known as stream frequency (Horton, 1932). Hopefully, it is possible to have basins of same drainage density differing stream frequency and basins of the same stream frequency differing in drainage density. Stream Frequency is defined as the ratio between the number of stream segment per unit area which expressed by a formula

DF= _N/A where, _N= Total no of stream segment; A= Unit area in km2 or m2.

It is a technique which is also used in planning and development to identify land quality for optimum utilization. In Ravi River basin the stream frequency is 6.291139241. The stream frequency of Ravi River Basin may be sub-divided into 5 categories which are as following: (i) Below 5 streams per Kms. (ii) 6 to 10 streams per sq. Kms., (iii) 11 to 15 streams per sq. Kms., (iv) 16 to 20 streams per sq. Kms. and (v) above 20 streams per sq. Kms. It is found out that stream frequency below 5 streams per sq. Kms. is concentrated in glacier covered regions of Multhan area of Kangra district, Bharmour, Holi and Chaurah area of Chamba District of this basin in Himachal Pradesh (Figure 6).

Source: After Drainage Map (SOI topographic sheets of 1:50,000
Figure 6

5. Conclusion:

Areal, Linear and Relief properties morphometric parameter, using GIS software is found to be immense utility in drainage basin, elevation, watershed prioritization for soil and water conservation, flood Prediction and natural resources management. Application of Morphometric approach revealed that there are total 34293 streams grooved with each other from order 1st to 8th sprawled over 5451 km2 area of the basin in Himachal Pradesh. Detailed study of Ravi River basin gives a useful direction for surface runoff and helps for natural resource development. Bifurcation ratio indicates that the drainage has covered by impermeable sub surface and high mountainous relief. Circulatory ratio, elongation ratio shows watershed have high slope and high peak flow. The study area shows that terrain is made up of mainly basaltic rock and exhibits dendritic and Herringbone drainage pattern is classified as highly sloping and high runoff zone which give rise to high drainage discharge. Thus study shows that the morphometric analysis using GIS helps to understand complete terrain parameters which lead to finalize watershed development planning and management with respect to water conservation.

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