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Drainage Pattern Analysis for Sustainable Environmental Planning, Himachal Pradesh, India

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Abstract

The Beas River inducts in the upper Himalayas beginning at Beas Kund contiguous Rohtang Pass in Himachal Pradesh and streams in the east-west course in Himachal Pradesh. Binwa hydropower project, a small potential project is situated in the Kangra district along the tributaries of the Beas River basin. To design the suitable ecological planning and management of rivers, structures acknowledge a dominant occupation. The sustainability of the ecological cycles is sufficient to make changes in morpho-units of the landscapes. To plan base guide from ASTERDEM will be utilized. In the analysis of drainage, Strahler's stream-area methodology of stream demand will be associated. To separate the Sub-basin of Beas River orchestrated distinctive thematic layers of the basin will be used. The morphometric parameter, for example, stream request, number, length, drainage thickness, bifurcation ration, surface, and so forth, are quantitatively investigated. The investigation destinations come into focus on the utilization of the nature of environmental resources, and hydrological planning to build up a system for figuring out the reasonableness for changed usages of the landforms in the setting with condition improvement.

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1. Introduction

The drainage analysis is the pivotal analysis in assessing the landforms. It has a precise relevance to geomorphology. The hydrological response of the basin is characterized by the runoff generation versus precipitation, which thusly is depicted by basin soil characteristics, morphometric properties, and land use network. As an inseparable piece of the topography, the drainage network is an essential portion of the Remote Sensing and Geographic Information System. In a drainage structure; streams constantly interface together to shape frameworks. As of now, much exploration is concerning hydrology and geography. In GIS; such gathering can be important for territory examination or theory (Dash et al, 2019). The GIS application in the Morphometric analysis is a very much time-saving, effective, and accurate technique to plan and manage the watershed basin. The site-specific suitability measures and watershed development and management can be planned accordingly. This has been a proven technique for analyzing morphometric parameters (Saha and Singh 2017). The morphometric components such as land use maps and topographical maps of the basin are mapped and evaluated concerning basin management. The basin possesses the 5th-order of stream of dendritic drainage pattern, which is a sign of the lack of structural control and homogeneity in texture. If the drainage density is very low then the basin possesses very good permeable subsurface formation which in turn prospects for water management (Prakasam, and Saravanan 2020). The detailed analysis of the watershed drainage and morphometric pattern watershed is pivotal in understanding the landforms and land usage using the drainage pattern (Prakasam et al., 2021) studied the hydropower project impact on the downstream side through the GIS application. The drainage analysis highlighted the changes in the basin.

1.1 Types of Drainage

Drainage designs are arranged based on their structure and surface according to incline and structure. Their shape or example creates in response to the neighborhood topography and subsurface geography. There are five kinds of drainage design Dendritic, Parallel, Trellis, Rectangular, and Reticulate. Because of the portrayal of various drainage designs, each example has its attributes, which can be reflected in some quantifiable variables identified with some topological and geometrical viewpoints. In Dendritic, the joining tributaries structure an intense point. The parallel is additionally in parallel structure with stretched watershed with long intense calculated straight tributaries. Trellis shapes the right edge and short straight tributaries. Rectangular curves and structures right point tributary and finally reticulate is in a cross like forming a circle tributary. Therefore, each example can be portrayed by a combination of various variables. In this area, the method for drainage design acknowledgment is introduced. In the first place, terms describing river systems are defined then characterization criteria are introduced and the distinctive strides of the procedure are point by point. Identifying the drainage pattern and its properties helps in characterizing sustainable planning of the watershed for the management of the resources. This paper attempts to understand the drainage pattern of the Binwa watershed for better watershed planning using GIS techniques.

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2. Study Area

Binwa watershed is 340.1 sq, km located in Kangra district, Himachal Pradesh., between Shivalik undulated slopes and Lesser Himalayas (Figure 1). It is located in the Agricultural Economic Region, a warm sub sticky to damp Eco-district with dim-hued woodlands and podzolic soils (Sehgal et al., 1990)].The elevation ranges from 600 to 4286 m above MSL. Binwa watershed is tended to by a wet mild atmosphere with a yearly rainfall ranging from 1757 to 2798 mm. The mean most noteworthy and minimum temperature ranges were from 24.2˚C to 27.7˚C and 13.7˚C to 14.6˚C, independently. The measure of precipitation is gotten during the rainstorm timeframe. The rainfall period is from March to June and October to December. The watershed is portrayed by the closeness of Udic soil dampness administration and thermic temperature administration (Sidhu and Mahapatra 1997).

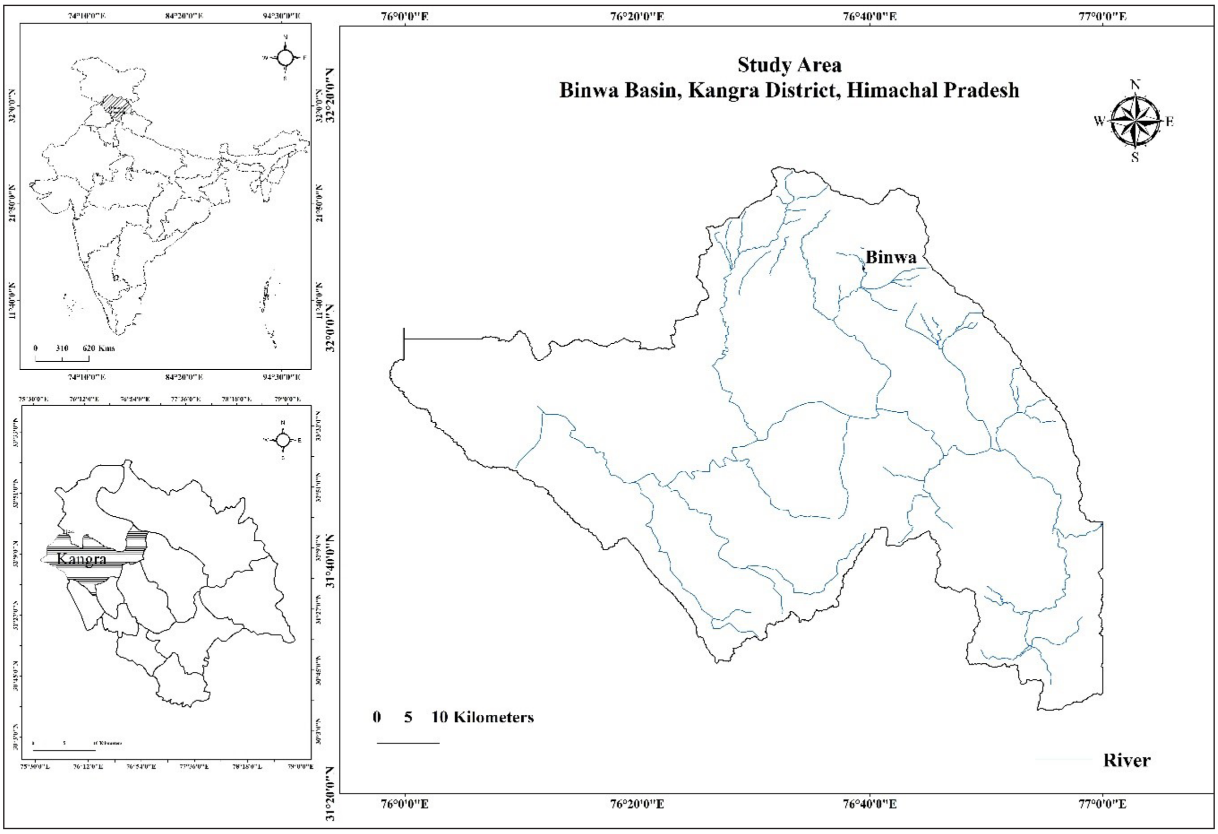

Figure 1. Index map of the Study Area.

From the grained rocks of Shivaliks and lower Himalayas such as phyllite, quartzite, granite, shale, sandstone, gneiss, etc., the Binwa watershed soils are formed along with fluvial deposits. Fluvial patios are created because of the water developments at the edge of the streams in the low slope zone.

3. Materials and Methods

The drainage pattern of the Suketi river basin has been studied for planning environmental aspects properly (Verma et al., 2012). 1:50000 scale SOI Topo sheets were used to set up the base guide to dissecting Stahler's stream and different layers were ready to outline the Suketi waterway bowl feeders (Momoh and Rilwani 2014). Displayed geo informatics-based for Muya watershed for its drainage characteristics in the Upper Niger bowl, Nigeria. Stream design was made utilizing the Landsat and geographical data, while at first DEM was made utilizing the geography map. The interaction evaluated the Fundamental drainage boundaries, for example, accumulation, direction, length, density, bifurcation ratio, and so forth, which were assessed to give a concise thought regarding the seepage model in the review region (Zhang and Guilbert 2012). Presented a procedure reliant upon mathematical quantitative markers to see the seepage plans in a waterway regularly. The creator gave an outline of various kinds of waste examples and their attributes. The linear aspects consist of stream number, stream order, bifurcation ratio, stream length, and stream length ratio (Rathore et al. 2022). Javarayigowda (2018) an attempt has been made utilizing GIS to look at the morphometric boundaries of the Karadya limited scope watershed. The examination uncovers that the landscape shows a dendritic sort seepage plan with the most critical stream demand being the third order. The Aster DEM has been downloaded from the open-source network known as the earth explorer site and imported into the GIS environment. The process starts with filling up the voids and is followed by the flow direction. The next step is flow accumulation. Using the calculator, the accumulation value greater than 1000 is delineated using GIS and finally, the drainage has arrived. The basin is then clipped for the study area purpose (Prakasam et al, 2021).

3.1 Stream order

It is the proportion of the overall size of streams and the littlest tributaries, generally enduring are alluded to as first-request (first) streams, trailed by a second request beginning where two 1st orders meet to shape the second request, in that movement until the water exhausts into another significant river (Figure 2) (Oyedotun 2020). The stream order is directly proportional to the size of the drainage, sub-basins, and river discharge. The study area comprises stream order up to 6th order. The first-order stream is 48 % followed by 25% of the second-order stream, third order stream is 13% and the fourth, fifth, and sixth-order streams are 7%, 3%, and 5% respectively. Here the lower-order stream is high in number and hence the yielding capacity of the water basin is high during the rain and also contributes to the groundwater.

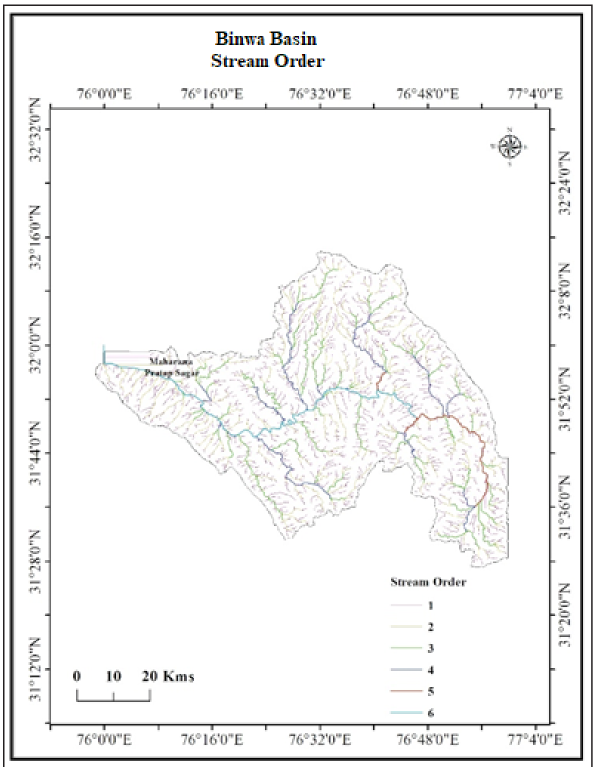

Figure 2. Map showing the Stream order in the Study area (source: ASTERDEM).

3.2 Stream Number (Nu)

The total number of stream fragments based on the stream order is the stream number (Bharath et al. 2021). It refers to the cumulative amount of stream/drainage segments of each order. It prompts the inference that a few streams generally upsurge in geometric movement as the order of the stream increases. A higher stream number indicates lesser porousness and infiltration (Figures 3and 4). The plot between the stream order and number gives the idea of the total number of streams present in the drainage pattern. Here a total of 5079 of the stream is present, out of which first-order contributes much to the overall rate with 2440 streams in total. It indirectly indicates that the infiltration capacity of the study area is also high. The plot between the order and number shows that the drainage pattern is healthy, as good drainage conditions contribute to better water-holding capacity and flowing properties present (Table 1).

Table 1. Stream order, counts and percentage

Stream order	Stream counts	Percentage of stream%
1	2440	48
2	1249	24
3	655	13
4	350	7
5	145	3
6	240	5
	5079	100

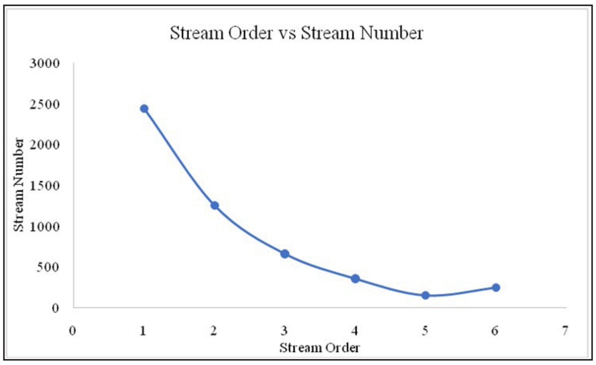

Figure 3. Plot between Stream order vs Stream number

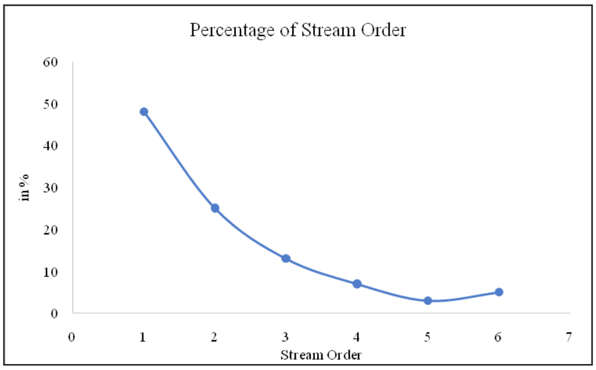

Figure 4. Stream order vs Stream number

3.3 Drainage pattern

Based on the physical characteristics of the drainage such as joint angle, length of the stream, and shortness, the pattern has been characterized (Qadir et al., 2021). The drainage pattern has been derived from the hydrological analysis of the DEM. The western side (downstream) end has a reservoir namely Maharana Pratap Sagar. Hence the drainage lines show straight in that region. The influence of the geological structures won't affect much on the drainage pattern if the bifurcation ratio is between 3.84 and 5.30. The bifurcation ration and flooding are inversely proportional. Studying the pattern helps in determining the plan of the study area, as each pattern has different properties for conducting the drainage. Based on the angle, length of the stream, etc., it is identified that the dendritic pattern of drainage is found in the study area. It is tree-like patterns are found in places where there is no robust geological control and homogenous texture (Figure 5).

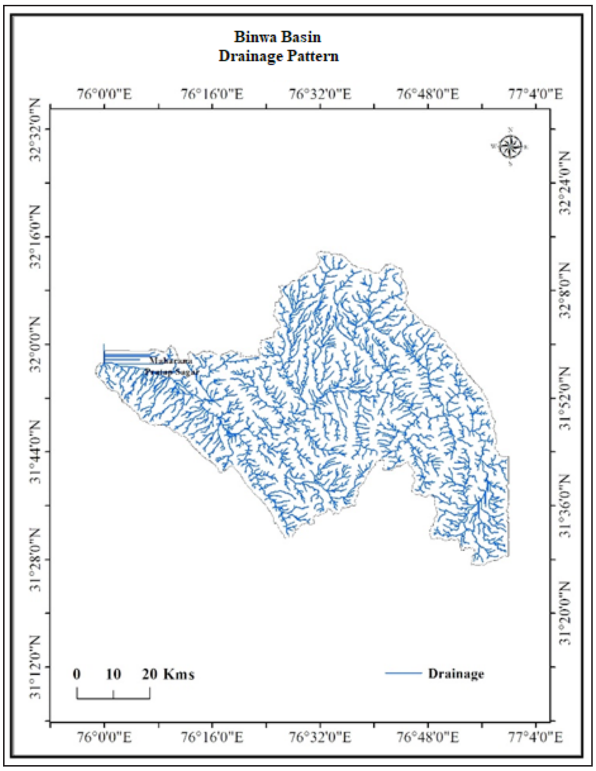

Figure 5. Map showing the Drainage pattern in the Study area.

3.4 Drainage density

The ratio between the total lengths of the stream in the numerator to the area of the basin in the denominator is the drainage density (Figure 6) Melese and Belay (2021). Drainage density is inversely proportional to the groundwater probability. Since runoff and permeability are related to the drainage density, it indirectly indicates the groundwater potential in the proposed area:

Drainage density =
(Total length of the drainage / Area of the basin) ……..… (1)

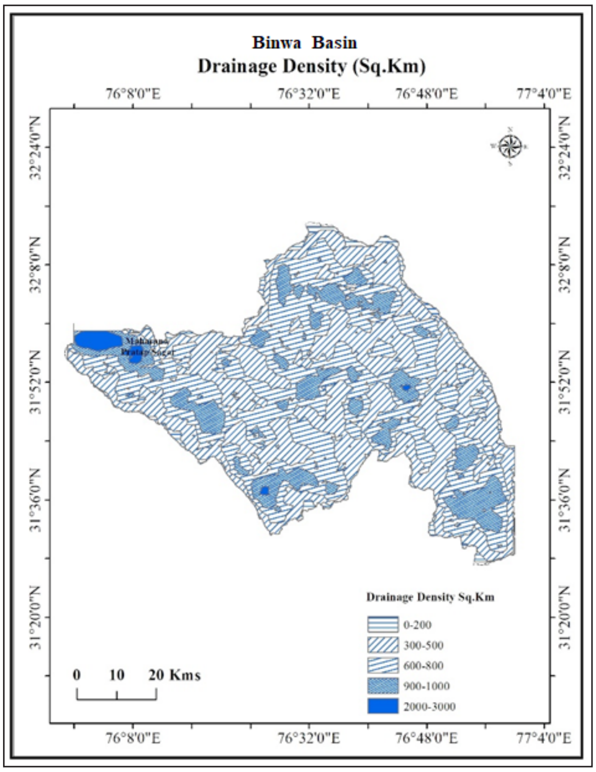

Figure 6. Map showing the Drainage density in the study area.

The drainage density analysis shows that it ranges up to 3000 Sq.Km of the total area. The basin comprises a maximum low-density ratio indicating that the free flow of water in the topology occurs and gets drained soon with less soil moisture and poor vegetation. The high density indicates high vegetation content in the region in which high soil moisture content can be identified in the region. The western portion has a reservoir downstream hence the drainage density is high.

3.5 Texture ratio

The ratio between the numbers of streams/drainage to the perimeter of the study basin. It is indirectly related to the drainage density, as it increases the texture also increases. The basin area is of a homogeneous texture of moderate. The classification of the texture ratio ranges between very coarse to very fine texture.

3.6 Stream Length

The stream length is defined as the stream order's length. The total stream length is 388.99 km. Stream length indicates the contributing area of the basin of each stream order. The length of the first to sixth-order stream is as follows 186.88 km, 95.65 km, 50.16 km, 26.81 km, 11.15 km, and 18.34 km. The plot between the stream order and stream length shows that the first-order stream has a higher length and it gradually decreases. The lithological inconsistency could be the reason why higher stream length in 1st order and gradually decreases with low order streams. The control over the morphological and geological characteristics of the basin could also be a reason (Mallick, et al., 2022).

Table 2. Stream length for each Stream order.

Stream order	Stream length (Km)
1	186.88
2	95.65
3	50.16
4	26.81
5	11.15
6	18.34
	388.99

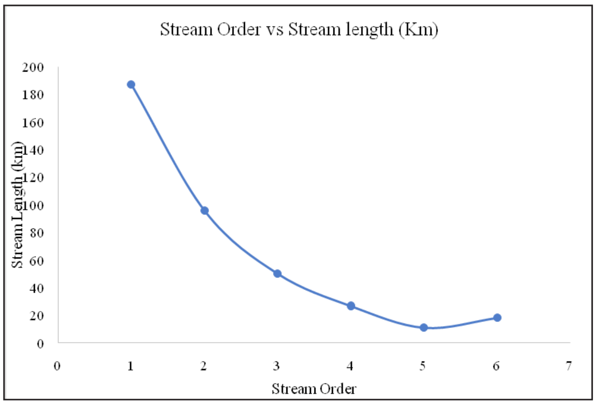

Figure 7. Stream order vs Stream number

3.6 Bifurcation ratio (Rb)

The Bifurcation ratio is termed as the proportion between the quantities of streams in progressive stream order. Here 'Nu' is the stream quantity and (Nu+1) is the number of drainages in the following higher order (Schumm, 1956):

Rb=Nu/Nu+1 ……..… (2)

It is a ratio whose values lie between 3 to 5. The bifurcation ratio is 4.21, indicating a lower permeability region in the study area.

4. Conclusion

The drainage analysis has been carried out for the Binwa basin for preparation and planning of the basin for hydropower project studies. Stream order is a significant boundary in the drainage network framework which upholds a wide scope of utilizations, for example, flood risk appraisal, water asset the board, flood immersion planning, watershed the executives, and some more. The drainage pattern of the considered area is described by a dendritic sort drainage basin. The first-order stream is found to be high in number than the others. The total number of streams is also large for the first-order stream and reduces gradually for the sixth-order stream. During heavy precipitation, the surface drainage system varies from the stream framework essentially. These distinctions are reflected in the thickness and the interior design of the frameworks. The drainage density analysis shows that the study area is of poor soil moisture content and constitutes a maximum of less drainage density in the region. The homogenous texture of moderate range is identified in the study region and the bifurcation ratio is 4.21 indicating lower permeability in the region. Stream length analysis shows that the first-order stream is higher. For better and sustainable watershed management practices in this study area, this research will be helpful. The location of dams, wells, or any water structures can be determined through this study. In this way, Drainage design study proposals will support the decision makers and chiefs to find a genuine answer for the issue picked.

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