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Study of geomorphology and drainage basin charcteristic of Kaphni Glacier, Uttarakhand, India

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ABSTRACT
This paper discusses a new and more suitable methodology for drainage network. The Kaphani River originates from Kaphni glacier at the height of 3810m and is located in the central Himalaya of Uttarakhand at Bageshwar District in Kumaon region. It is the fourth order stream of Pindar river and its confluence point to Pindar River is at the height of 2544m which is known as Dawali. In this study morphometric analysis of the Kaphni basin developed in a shear zone of central Himalaya is reported. The main aim of this study is to analysis morphometric parameter of river basin area. The geometric properties of drainage basin are estimated on Topographical Sheet, Satellite imagery and GIS techniques on the scale of 1:50,000. The study gives a wide description of drainage network analysis, like streams order, drainage density, drainage frequency, length ratio, relief ratio etc. and these are clear evidences for the structural control. The drainage analysis involves the study of drainage textures. The drainage features of the Kaphni gad Basin are dependent on the geology, geomorphology, topography and climate. Therefore in the study a systematic analysis of the pattern in the drainage network as well as the morphometry of the basin has been undertaken.

Key Words: Morphometry, geology, geomorphology, watershed, Kaphni glacier

INTRODUCTION

The term Geomorphology is the combination of three Greek words; i.e. Geo (earth), Morpho (form) and logos (discourse), which means the study of forms of the earth’s surface. But land forms have far less attention, even though landform mapping dates back to early geological research (Close,1867) and has been subject to a number of study in the 1960’s and 70’s (Rose and Letzer, 1975).

Historically, the popularity of Glacial and Fluvial Geomorphology can largely contributed to the development of landform studies in those densely populated area of northern hemisphere middle altitude which has been so drastically affected by Glacial and Fluvial processes. However the status and traditions of glacial geomorphology varies greatly between one country to another. Insufficient modern glaciological theory has been applied to the study of glacial geomorphology and glaciologists have not been provided with reliable information on landforms. Perhaps there is a need for a more glaciological type of Geomorphology and more Geomorphological type of glaciology.

On the same side drainage, warrant geographical study for three main reasons. First, their existence in the physical landscape and their significance for producing fluvial landforms; secondly their importance indirectly in relation to many other geomorphological processes in fluvially-dominated landscapes and thirdly, their significance for human use. Drainage analysis is the most important aspect of the landforms. The analysis of drainage basin has a particular relevance to geomorphologically, fluvial eroded landscapes area composed by drainage basin. Drainage basin is a standard topographical unit, has not been tested in the mountain region particularly in the Himalaya, thought R.E.Horton established the pioneering framework for the quantitative discharge in stream eroded landforms as early as 1945. The present study of Glacial Landform and Fluvial analysis deals with the morphometric evaluation of drainage network of the Kaphni Glacier with its basin and its objective is to delineate the boundary of kaphni Glacier and its Basin with analyzing its physical environment through attributes i.e. Slope, Relief and Drainage and prepare maps on its drainage basin characteristic.

The reconstruction of the dynamics of glaciers landforms and fluvial character evidence requires the synthesis of regional data sets, integrated across the multiple scales. Initially researchers used information such as contour and hill-shading to depict the glacial land forms (Rose and Letzer, 1975), then used field mapping to record landform upon topographic based maps (Close, 1867; charlesworth, 1928, Rose and Letzer, 1977). To a large extension, this methodology has been superseded by remote sensing techniques such as aerial photography (Prest et. al., 1968), satellite imagery (Punkari, 1982) and the application of digital elevation models DEMs; (Clark and Meehan, 2001).

GEO-IDENTITY

The Kaphani River originates from Kaphni glacier at the height of 3810m and is located in the central Himalaya of Uttarakhand at Bageshwar District in Kumaon region **Figure 1**. Highest elevation point is 5447 m and lowest of glacier 3930 m. with extension of N 30^{o}15’94” to 30^{o}9’20” latitude and E 80^{o}0’46” to 80^{o}5’70” longitude. It is the fourth order stream of Pindar river and its confluence point to Pindar River is at the height of 2544m which is known as Dawali. On its south is Surju water divide, in west flows Pindar River and in its east flows Ramganga River. The basin lies in NE direction and the area of this watershed is 59.58km^2 and the length of this perennial stream is 10km. In this study morphometric analysis of the Kaphni basin developed in a shear zone of central Himalaya is reported. The main aim of this study is to analysis morphometric parameter of river basin area. The rock formation present here is Vaikrita Group by Valdiyas (1980). The rocks are garnetiferous mica schist’s, micaceous quartzite, augen gneisses, graphite schists and phyllites.

METHODOLOGY

Numerical data which is required for the identification of glacial feature and systematization of morphometric method were measured on LANDSAT TM Mosaic image, Google Earth Image, ASTER DEM data and Survey of India topographical sheets (i.e. 62B/3, 4, 53N/16) series in scale of 1:50,000 **Figure 2**.

From ASTER DEM Flow Direction, Accumulation, Stream Order, Slope, Aspect, Shaded Relief and Ice Thickness Maps were prepared in raster layer. Boundary of Kaphani, Drainage, Lineament, Sub-Basin and Contour maps were generated in vector layer. On the bases of raster and vector maps, Geomorphological map was prepared. The

Kaphni Gad Basin lying entirely within the higher Himalaya show high attitudinal difference, number of glacial erosional and depositional landforms and drainage characteristic. This work is done in Different phases.

RESULT AND DISCUSSION

Drainage Analysis

The drainage is a fundamental unit of landforms on fluvial terrain having a particular relevance to morphometric analysis. The term morphometry is used in several disciplines for the measurement and analysis of landform characteristic in geomorphology. It is applied to numerical examination of landform, which may be more properly termed geomorphometry. The Kaphni gad has been divided into seven second and third order intrabasin which form their own ecosystem to regulate their self-sustained cycle of ecology.

Stream order and Area

The hierarchal order has been determined according to Strahler's scheme 1952-1964. The present study has referred Strahler's stream ordering system over other methods, because in the system of Strahler small event such as the addition of just one first order stream can have a marked effect on the final order given to the stream leaving the basin and thereby on the order of the basin (Doornkamp and King1971) According to the strahler's scheme Kaphni Gad is a 4^{th} order basin while the tributary streams basin are either second or of third order.

Thus Kaphni Gad, which is the trunk of the study area is of the fourth order, its Important tributary streams are of third, second and first order. The size of the Individual tributary has been calculated by grid method gives the stream orders and size of Seven tributary basin, besides those of the trunk basin out of Seven tributary basin, i.e. first (1.94km^2), second (2 km^2), third (2.1 km^2), fourth (2.30 km^2), fifth (1.89km^2), sixth (4.1km^2), seventh (1.75km^2).

Stream number

Order-wise stream frequently in the tributary basin of the Kaphni gad basin. It reveals a maximum frequency in case of first order streams further, it is noted that the stream frequently decrease as the stream-order increased. Plots of the number of stream (on log scale along the vertical axis) against the order of stream (on arithmetic scale along the horizontal axis) indicate a linear correlation ship, which means that the number of streams generally decreases in geometric progression as the stream order increase. Order wise stream number in the sample Basin of Kaphnigad.

Stream length

According to the table no.5 the order of stream is increasing as the length of stream is decreasing, but if we observe basin no. 6 and 7 the case is change. The length of third order greater than second order. This discrepancy is due to variation in relief and rock condition over which these stream segments occur. The **Figure 3** reveals that the total length of stream segment is maximum in case of first order stream; it decreases as the order increases, and is lowest in case of the highest order stream in almost all the sampled basin of the Kaphni Gad.

Mean Stream Length

The parameter is having dimensional property revealing the characteristic size of components of the drainage network and its contributing watershed surface (Strahler, 1964). Mean stream length can be obtained by dividing the total length of stream of an order by total number of segments in the order**.**

Stream Length Ratio: Stream length ratio is calculated according to the following formula: -

$$\mathbf{LU=\sum L/Nu}$$

Where:-

LU is mean stream length,
∑L is total stream length
Nu is the no. of segments (N) of stream order (u).

Table 1 gives description, in case of sixth sampled basin the mean length of second order stream is relatively greater than that of third order stream. Due to more sinuous course of the second order stream segment which flow over foliated slates, phyllites and ortho-quartzites of the basin. It is noted that the stream length ratio of each of the successive order of the kaphni gad and its sampled basin bury due to difference in slope and topographic condition. The stream length ratio between first and second order stream segments of the seventh tributary basin of kaphni gad is somewhat similar, generally fluctuating around .1 but ranging from a maximum of 1.4 in case of the seventh sampled basin to a minimum of 0.15 for the second sampled basin. These are characterized by moderate and steep slopes respectively. Likewise the length ratios between second and third order stream ranging from 0.29 in sixth sampled basin to 1.4 in the seventh sampled basin

Bifurcation Ratio: This bifurcation ratio is calculated by using the following formula.

$$\mathbf{Rb = NU/NU+1}$$

Where
Rb = Bifurcation ratio
NU = Number of segments of given basin
NU+1= Number of segments of the next higher order

The bifurcation ratios between stream of various order in seven tributaries basin of the Kaphni Gad in general, the bifurcation ranges from2.33 to 8, but higher values are noted in a third to fifth Basin (eight), second and third basin (five & four), fourth basin (four), sixth and seventh basin (2.66 to 3 &2.33 to 3).

Sinuosity index: Muller has taken the channel length (CL), the valley length (VL) and the air distance from source to mouth as sinuosity attributes calculation of various types of sinuosity indices are made on the basin of the following formula.

1. Channel index (CI) = CL/ Air length (Hydraulic and topology graphic sinuosity)
2. Valley index (VI) = Valley length (Hydraulic and topology graphic sinuosity)
3. Hydraulic Sinuosity index (HSI) = % equivalent of CI/VI

4. Channel sinuosity index (CSI) = CL/VL
5. Standard sinuosity index (SSI) = CL/VL

The Channel hydraulic and Topography sinuosity Index of Sample basin in the Kaphni Gad.

Drainage Frequency: The distribution of drainage frequency in the basin revels that 26.91% of it area has Low drainage frequency, very high drainage frequency characterize 8.43% and moderate and moderately high are covering area of 50.67 % and 65.96% of the basin area respectively. Table 2.

Drainage Density: Drainage density is defined as the total length of stream segment per unit area it is function of intensity of run- off erosion proportionality factor, relief, density and absolute viscosity of the flu d and its acceleration due to gravity. Analysis of the drainage density was first introduction by Horton (1932) drainage density is calculated according to the following formula

$$\mathbf{DD = \sum L/A}$$

Where:

DD = drainage density
$\sum$L = Total stream length per km^2
A = unit area

The drainage density in the Kaphni Gad obtained by measuring the total length of the stream segment in sq. grid, with an unit area of 2 km^2, ranges from below 2 and above4 km^2. These values have been grouped into 5 classes. It is concluded that the drainage density increase with the decrease in aerial coverage and the soil moisture in the region remains more similarity as the drainage density decreases.

- The Drainage Frequency is calculated as the total number of stream segment per km^2.

  (No. of stream in 1 km=2cm)

- The Drainage Density is calculated as the total length of stream segments per km2.

  (Total length of stream in 1 km=2cm)

Drainage Texture: Drainage texture is calculated by following formula

$$\mathbf{Dt = \sum DD/A}$$

Where Dt is drainage texture

$\sum$DD is total drainage density per km2

A is total area of basin

The maximum drainage density occurs in the southern part of the Kaphni gad basin which is 7th sampled basin where higher drainage texture is recorded. Similarly the lower drainage texture occurs where the lower density is observed this is sampled basin number four (2.17km2). The intra drainage basin in the Kaphni Gad Basin have drainage texture ratio between 2.17 to 6.28 km2. The maximum range of texture ratio has been observed in the sampled basin number seven. Interfluves region due to greater number of stream, high gradient gullies, faults and also presence of lime stone. The lower range of texture ratio is found in the fourth sampled basin due to gentle slope and absence of fault.

Relief Ratio: The relief ratio is the ratio between the total relief of the basin and the longest dimension of the basin parallel to the principal drainage line (schumm 1956) According to Schumm 1963, it is a dimension less height-length ratio equal to the tangent of the angle formed by the two planes intersecting at the mouth of the basin, one representing the horizontal, the other passing through the highest point of the basin. It denotes the overall steepness of a drainage basin and is an indicator of the intensity of degradation processes operating on slope of that basin correlation between relief ratio and the hydrologic characteristics of a basin can be also analysis (Schumm, 1954) this ratio is calculated by using the following formula:

RH=H/Lb

Where 'RH' is the relief ratio
H is the total relief and
Lb is basin length.

The relief ratio for a total seven tributary basin of Kaphni gad it shows that the relief ratio varies from 0.21 third sampled basin to 0.05 for first sampled basin. A direct relationship between relief ratio and channel gradient has been noted, i.e. lower the relief ratio lower will be the mean channel gradient of the main valley and vice-versa. The areas of strong relief and steep slopes are characterized by high run and .456 for relief ratios. It is noted that the relief ratios of three tributary basins vary from 0.21 to 0.38. These basins are composed of resistant roc ands. High relief ratio is also found in areas of weak rock. Such as 0.50 for first basin and .45 for second basin and .456 for fifth basin are developed over the shale's with local occurrence of foliated schist and sandstone and chlorite-Schist with local occurrences of favorable sandstone respectively.

Area Height Curve:

Area height curve indicate actual areas between two successive contours and hence horizontal axis represents area in terms of percentage in total area and vertical axis shows height Table 10 shows the percentage of area falling between two successive contours for the entire kaphni gad basin on this basis a diagram has been shown in Figure.

Ice-Thickness:

Determination of Thickness using the Surface Slope. The determination of ice thickness by mathematical modeling (Nye, 1952)

H=Tb/F*p*g*sin θ

Where:-
Tb=Sheer stress on the glacier bed which usually being taking as 1bar (1Bar=106 dynes/cm2)
F=valley factor, usually taken 1 for elliptical shape of the valley.
p=density of ice which is equal to .91gm/cm3
g =981cm/sec2
Sin θ =Slope degree map.

GLACIAL LANDFORMS

The Kaphni Glacier belongs to the "U" shaped valley type. The main Glacier is lightly crescent in shape and arching south at the lower accumulation zone. The glacier is fed by many covering mountain glacier tributaries. The main Glacier flows in the direction NS for 1km in accumulation zone and then changes the direction to SW at main Pindar valley. The glacier surface slopes vary between 2^o to 15^o whereas the side wall slopes reach maximum of 78^o. The altitudinal range from about 6100 to 2800m above mean sea level. The ablation zone length is about 3.10 km, and area covered is 3.21 km^2, accumulation zone area is 1.06 km^2. So the surface area is 4.27 km^2.

According to the Interpretation of Imagery the study area indicates certain feature:-

U shaped valley- Steep valley walls with concave slope and broad and flat valley floor.

Hanging Valley- U shape valleys are associated with tributary valley are known as hanging valley.

Cirques- Steep sided, half- bowl shaped recesses caves into mountain at the head of glacial valleys.

Crevasses- These are fractured formed in the upper rigid zone during glacier flow.

Arêtes- Sharp ridges separating glacial valley.

Horns- Sharp peaks remaining after cirques have cut back into a mountain on several sides.

Conclusions

The Kaphani Basin has been studied in two aspect first glacial feature and second Drainage characteristic. According to the study interpretation of glacial feature was done and then the ice thickness was also calculated. The ice thickness of the area is varying from 40 cm to<110 cm per unit area. The drainage characteristic of the basin has been carried out with the help of different Morphometric attributes Stream order, Drainage frequency, Drainage density, stream number, stream length and stream length ratio. Where there are seven small water shed of second and third order. The analysis of frequency in the tributary basin of the Kaphani Gad reveals that maximum frequency is in the first order stream and total length of stream segment is also maximum in case of first order both features decrease as the order increases. The bifurcation ratio has been calculated according to Horton's formula. The ratio ranges from 2.33 to 8, but higher values area also observed in some basins the stream length ratio of each successive order varies due to difference in lithological and topographic conditions. The analysis of area height curves of Kaphni Gad basin indicates that area, under 6000-7000m has least coverage (5.22%) and maximum area of the basin fall in4000m to 4500m which has an area of 28.57%. High relief ratio is also found in areas of weak rock. These basins are developed over the shale's with local occurrence of foliated schist and sandstone and chlorite-Schist with local occurrences of favorable sandstone respectively.

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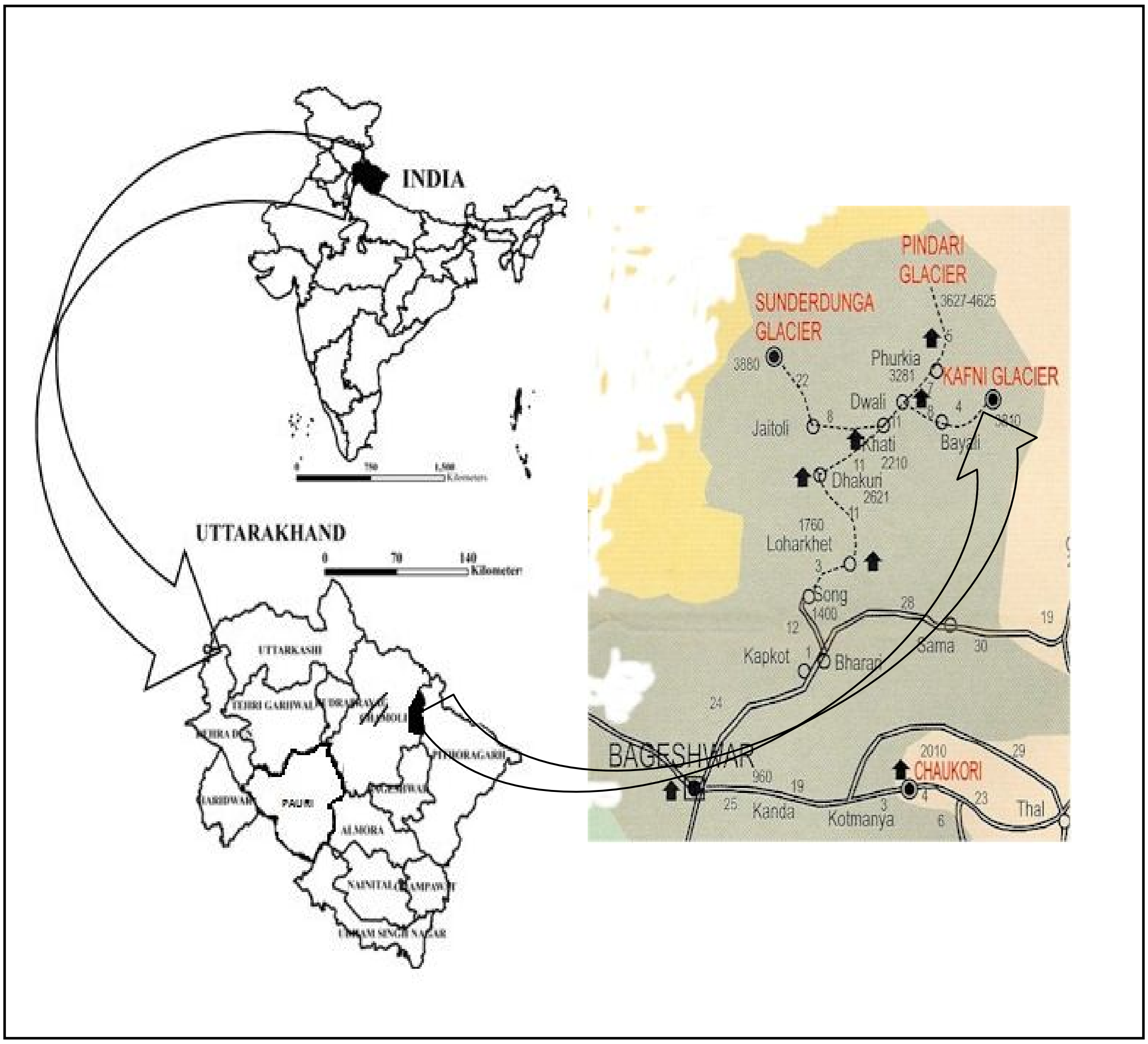

Figure 1: Location Map

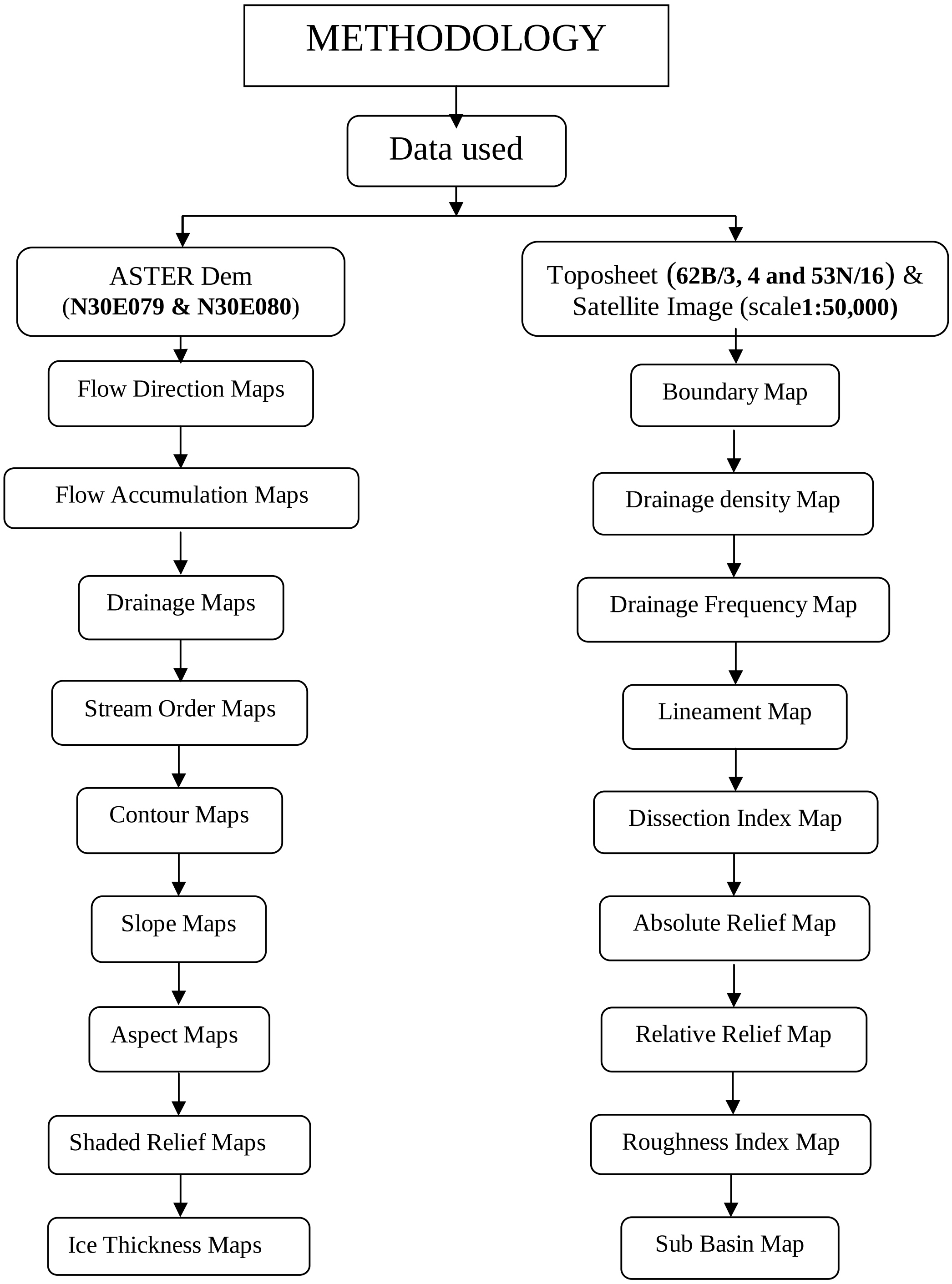

Figure 2: Methodology in Flow Chart

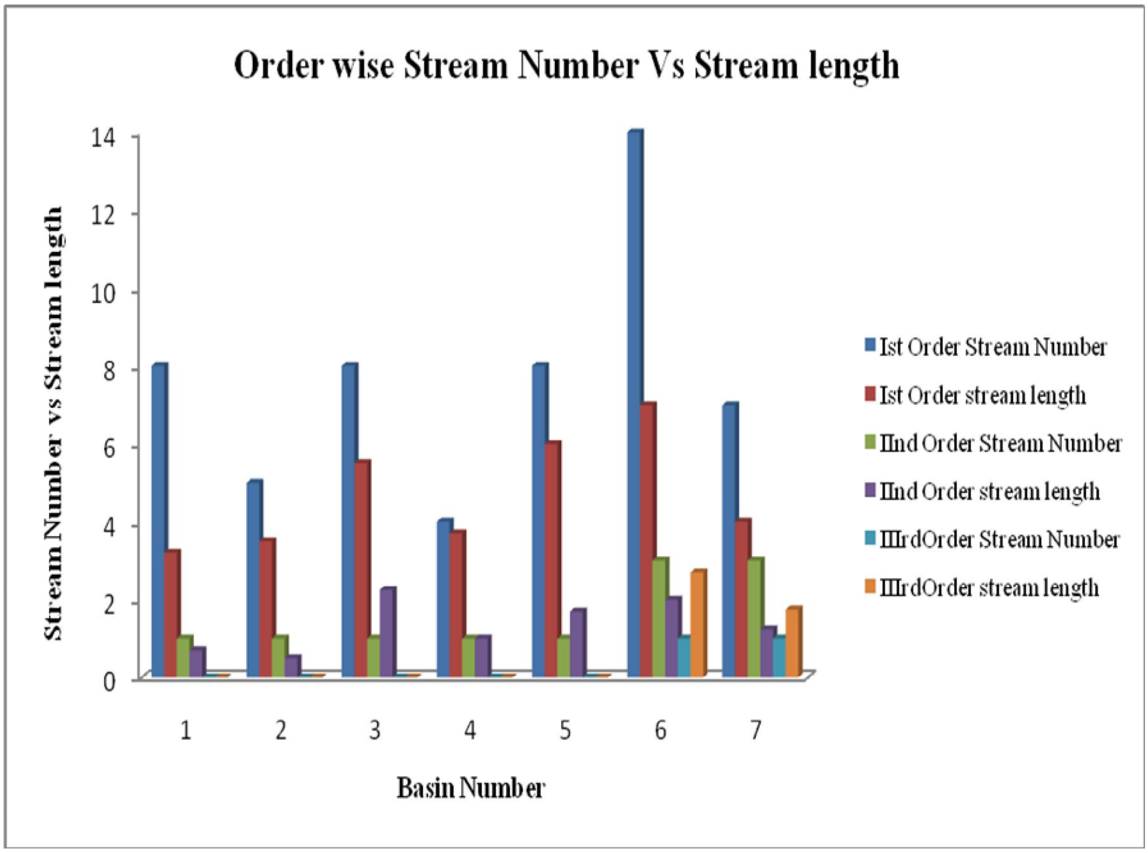

Figure: 3 Stream Number Vs Stream Length

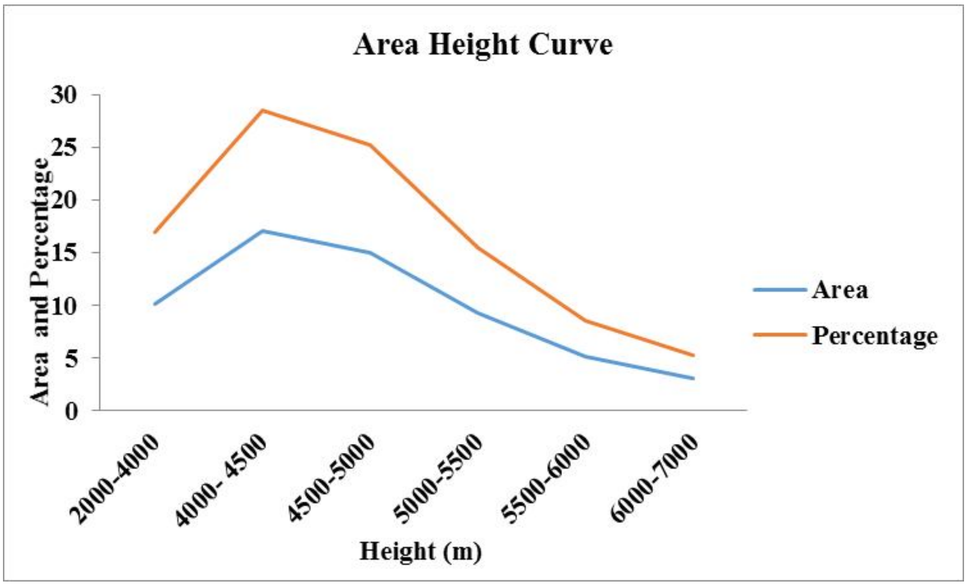

Figure-4 Area Height Curve

Table: 1 Morphometric Parameters

Basin	Order	Area (km2)	Order Wise												Stream Length Ratio		Bifurcation ratio		Mean weighted Bifurcation Ratio	Sinuosity Index of Kaphani Gad					
			Stream Number				Stream length				Mean Stream Length									Channel Index	Valley Index	Hydraulic Sinuosity Index	Topographic Sinuosity Index	Channel Sinuosity Index	Standard Sinuosity Index
			Ist	IInd	IIIrd	Total	Ist	IInd	IIIrd	Total	Ist	IInd	IIIrd	Total	Ist/IInd	IInd/IIIrd	Ist/IInd	IInd/IIIrd							
SW 1	**IInd**	1.94	8	1	0	9	3	0.7	0	3.9	1	5.6	0	6.79	0.22	0	8.00	0	8.00	1.36	1.18	50	50	1.15	1.15
SW 2	**IInd**	2.06	5	1	0	6	4	0.5	0	4	1	8	0	9.14	0.14	0	5.00	0.00	5.00	1.33	1.2	39.39	60.61	1.53	1.11
SW 3	**IInd**	2.1	8	1	0	9	6	2.3	0	7.75	1	3.4	0	4.85	0.41	0	8.00	0.00	8.00	1.25	1.1	60	40	1.13	1.14
SW 4	**IInd**	2.3	4	1	0	5	4	1	0	4.7	1	4.7	0	5.97	0.27	0	4.00	0.00	4.00	1.5	1.35	30	70	1.11	1.11
SW 5	**IInd**	1.88	8	1	0	9	6	1.7	0	7.7	1	4.5	0	5.81	0.28	0	8.00	0.00	8.00	1.25	1.15	40	60	1.08	1.08
SW 6	**IIIrd**	4.1	14	3	1	18	7	2	2.7	11.7	2	5.9	4.3	11.9	0.29	1.35	4.67	3.00	5.07	1.95	1.13	86.32	13.68	1.72	1.72
SW 7	**IIIrd**	1.75	7	3	1	11	4	1.3	1.75	7	2	5.6	4	11.4	0.31	1.4	2.33	3.00	3.21	1.4	1.2	50	50	1.16	1.72
Total		16.13	54	11	2	67	33	9.4	4.45	46.75	10	38	8.3	55.8	1.92	2.75	40.00	6.00	41.29	10.04	8.31	355.71	344.29	8.88	9.03

Table:2 Drainage density Vs Drainage Frequency.

<table>
<tr><th colspan="4">Drainage Density Of Kaphni Gad</th><th colspan="5">Drainage Frequency Of Kaphni Basin</th></tr>
<tr><th>Categories</th><th>Area</th><th>Percentage</th><th>Cumulative %</th><th>Categories</th><th>Area</th><th>Percentage</th><th>Cumulative %</th><th>Remark</th></tr>
<tr><td><1</td><td>10.12</td><td>16.99</td><td>16.99</td><td><3</td><td>16.03</td><td>26.91</td><td>26.91</td><td>Low</td></tr>
<tr><td>1-2</td><td>8.16</td><td>13.7</td><td>30.68</td><td rowspan="2">4-6</td><td rowspan="2">14.16</td><td rowspan="2">23.76</td><td rowspan="2">50.67</td><td rowspan="2">Moderate</td></tr>
<tr><td>2-3</td><td>11.04</td><td>18.53</td><td>49.21</td></tr>
<tr><td>3-4</td><td>9</td><td>15.11</td><td>64.32</td><td>7-9</td><td>9.11</td><td>15.29</td><td>65.96</td><td>Moderately high</td></tr>
<tr><td>>4</td><td>6</td><td>10.07</td><td>74.39</td><td>>9</td><td>5.02</td><td>8.43</td><td>74.39</td><td>High</td></tr>
<tr><td>Glaciated area</td><td>15.26</td><td>25.61</td><td>100</td><td>Glaciated area</td><td>15.26</td><td>25.61</td><td>100</td><td></td></tr>
<tr><td></td><td>59.58</td><td>100</td><td></td><td>Total</td><td>59.58</td><td>100</td><td></td><td></td></tr>
</table>