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GEOMORPHOMETRI ANALYSIS AND PRIORITIZATION OF SUB CATCHMENTS OF SAVITRI BASIN IN KONKAN REGION OF MAHARASHTRA, INDIA USING GIS TECHNIQUE

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ABSTRACT

Hydomorphometric is the basic properties of the river catchment, which help to identified hydrologic response (runoff and sediment) from catchment and their management on watershed basis and estimation is basic for any watershed management programme. Remote Sensing (RS) and Geographic Information System (GIS) are most appropriate, cost effective and quick technique for estimation of hydromorphometric properties over traditional methods. In Present study, linear, aerial and relief hydromorphometric properties were estimated using ASTERGEO DEM data in GIS environment using ARC GIS 10.1 software and prioritized the Savitri basin of Konkan region of Maharashtra. The Savitri basin has total of 994 Sq Km. It has four sub catchments viz Ganhdari,Savitri, Kal and Bhaovira with runoff contributing area of each 137, 354, 332 and 47 Sq Km respectively. The time series analysis of rainfall and stream discharge from 1992 to 2011 was in increasing trends. The time of concentration of runoff of the Savitri basin was 6.7 hr for stream length of 57 Km. The drainage pattern was dendrites with VIIth highest drainage order. The drainage density is high and texture is observed as course in nature. The relief of the basin is high to moderate. The basin was found to be highly runoff producing and moderate recharge capacity. The hypsometric analysis of basin indicates basin is mature in erosion process.

KEYWORDS: Aerial, Bifurcation Ratio, Drainage, Hypsometric, Relief

INTRODUCTION

Land and water resources are limited and their wide utilization is imperative, especially for countries like India, where the population pressure is increasingly continuously at alarming rate. Drainage basins, catchments and watershed are the fundamental units for administrative purposes to conserve natural resources (Mishra, 2010). The drainage basins are the response of slope, bedrock lithology, associate geology, and climate of that region which determines the characteristic of basins. Hence, quantities analysis and their interrelationship are important to support decisions for various themes. Such as water resources development and their management, hydrologic responses and soil conservation practices adoption on watershed basis (Jolly, 1982, Ogunkoya *et al*., 1984; Aryadike and Phil-Eze, 1989), etc. The morphometric descriptors represent relatively simple approaches to describe basin attributes and find out their impact on the development of erosion process in the areas and to compare basin characteristics (Mesa, 2006, Biswas *et al*., 1999) and enable to enhanced understanding of the geomorphic history of a drainage basin (Strahler, 1964). The method of quantitative analysis of drainage basins was developed by Horton (1945), and modified by Strahler (1964, 1969)) in conventional means but

recently GIS and Satellite Remote Sensing is a complete tool to analyze, to update and to correlate the measurements with periodic changes. Therefore, the results are more realistic and less time consuming. Remote Sensing and GIS has effective tools to overcome most of the problems of land and water resources planning and management on the account of usage of conventional methods of data process (Nageswara *et al*., 2010, Umrikar *et al*, 2013). Geographical Information System (GIS) techniques provide a favorable environment and a powerful tool for the analysis and depiction of spatial information (Srivastava and Mitra, 1997; Agarwal, 1998; Nag, 1998; Das and Mukherjee, 2005). This study was conducted to analyze morphometric parameters of Savitri Basinin in Konkan Region of Maharashtra comes under Western Ghat of South Tapi tributaries and prioritization for characterized the hydrological (Runoff and sediment) response behavior of the watershed for suitable soil and water conservation management alternatives in GIS environment.

MATERIALS AND METHODS

Study Area

The Savitri river basin is comes under the Western part of Sahayandri Ghat part of Konkan region. Study area belongs to Mahad and Poladpur Tahashil of Raigadh district in Konkn region of Maharashtra state. It started from Mahabaleswar in Sahayandri ranges and fed to Arabian Sea. Total area of Savitri river catchment under study is considered as 994 Sq Km at the outlet point which gauged at near Mahad city. The location of study area is given in Figure 1 and location of sub catchment is given in Figure 2. The latitude and longitude of the study area is $18^0$20'N to $17^0$51'N and $73^0$22' E to $73^0$41'E respectively and elevation ranges from 6.50 m to 1366.23 m above mean sea level**.** The main stream of the study is Savitri river basin has average length of 57.57 Km. The Savitri river basint comprises of four rivers namely Gandhari, Kal, Savitri and Bhaovira having catchment area of 137, 332, 354 and 47 Sq. Km respectively. Each has hydrological and meteorological gauging stations located at Koturde, Birwadi, Kangule and Bhave at their outlets point.

Climate

The region falls within sub-tropical climate with alternate dry and wet periods with three well defined seasons i.e. summer, monsoon and winter. Average annual rainfall in the area is 3560 mm in the form of intense storms and its distribution is highly erratic as more than 90% is occurred during the monsoon months (June to October). Daily mean temperature ranges from a maximum of 35^{o}C (May) to minimum of 21^{o}C (January). The daily mean relative humidity varies from a minimum of 55.15% (April) to a maximum of 99 % (July). The Mean daily evaporation, Wind speed and Sunshine hours were 4.66 mm, 2.48 m/s and Sunshine duration was 11.12 hours, respectively.

Physiography

Topography of the watershed is undulating with the land slope varying from more than 50 % The general aspect of the area is from West and southwest to north and northeast. The drainage pattern is up to fifth to Seventh order as per Strainers method of drainage network classification.

Soils

Predominant soil textures of the catchment are sandy loam (73.6%), and sandy clay loam (26.4%). The soils of the watershed were classified into Mahad, Sakhar, and Mangaon series, which belong to clay-skeletal to fine, mixed Isohyperthermic, Typic Halusstepts soil series. These soils are coarse, mixed calcareous, non-saline, dark brown to very dark brown in colour and have moderate permeability and well drainage. Most of the watershed area comes under degraded land with less soils depth (25-50 cm).

Methodology

The remotely sensed data coupled with topographical data analysis procedures have made satellite sensor data based morphometric analysis a highly effective tool to understand and manage the natural resources (Srinivasan, 1988). Integration of remotely sensed data and GIS provides an efficient way in analysis of morphometric parameters and landform characteristics for resource evaluation, analysis and management (Srinivasa et al., 2004). An attempt has been made to utilize the interpretative techniques of GIS to find out the relationships between the morphometric parameters at Savitri river basin. Morphometric properties of the Savitri basin were estimated from ASTERGEO 10 DEM (Figure 3 and Figure 4 (a-d)) with 30 m resolution in ARC GIS 10.1 software using hydrology tool. The parameter related to linear, aerial and reliefs were estimated with different formulae given in Table 1. The various aspects were studied for their inter-relationship which helps to depict the nature of the sub-catchments.

RESULTS AND DISCUSSIONS

Linear Aspects

The linear aspects such as drainage order, total stream length, number of steam lengths, mean stream length, length ratio and bifurcation ratios were estimated in GIS environment in hydrologic model using ARC GIS 10 Software and presented in Table. 2.

- **Drainage Order**

It is the unbranched fingertip stream designated as 1^{st} order, the confluence of two 1^{st} order channels gives channel segments of 2^{nd} order, two 2^{nd} order streams join to form a segment of 3^{rd} order and so on. The Drainage order map Savitri Basin (Figure 5) and Gandhari, Savitri, Kal and Bhaovira river are presented in Figure 6 (a-d). The drainage order of Gandhari, Kal rivers, Bhaovira were V^{th} Whereas Savitri River has VI^{th} order (Table 2). The overall Savitri basin has highest drainage order of VII^{th}.

- **Stream Number**

It is total number of stream in each order stream. The total number stream 1101, 1990, 1887 and 262 were observed for Gandhari, Savitri, Kal and Bhaovira rivers respectively (Table 2). The total number of steams in Savitri basin in all drainage orders was 5960. There are highest numbers of steams observed in first order for all rivers such as Gandhari Savitri, Kal, and Bhavira and Savitri Basin. It is followed by II^{nd} order, III^{rd} order and so on. It is also observed from Table 2 that, increasing stream order decreases the total numbers of stream vice versa.

- **Total Stream Length**

The total length of individual stream segments of each order is the stream length of that order. Total stream length of Gandhari, Savitri, Kal and Bhaovira rivers were 295.22, 650.08, 649.70 and 92.82 Km respectively and total stream length of Savitri Basin was 1759.8 Km (Table 2). It is observed that, stream length is decreasing with increases the stream order.

- **Mean Stream Length**

It is the ratio of total length of stream in each order to total no. of stream in each order. The mean stream length for Gandhari, Saviri, Kal and Bhaovira rivers were 0.27, 0.33, 0.34 and 0.35 Km/Km respectively and stream length ratio for Savitri basin observed was 0.30 (Table 2). It is directly related to the drainage density and basin shape of the basin.

Lesser the mean stream length longer the basin length compared to other basin.

- **Length Ratio**

The Length Ratio (RL) is the ratio of the mean length of the stream of a given order (Lu1) to the mean length of the streams of the next lower order (Lu-1). The length ratio for Gandhari, Saviri, Kal and Bhaovira rivers were1.86, 2.28, 1.91 and 2.64 respectively and of Savitri basin was 2.19 (Table 2). The lowest length ratio is observed for Gndhari river compared to other rivers and highest for Bhavira river. It is because of rivers shape and drainage order of the each rivers streams.

- **Bifurcation Ratio**

The bifurcation ratio is the ratio between the number of streams in one order and in the next. The bifurcation ratio for Gandhari, Saviri, Kal and Bhaovira rivers were 2.12, 2.28, 1.89 and 3.54 respectively and for Savitri basin was 2.27 (Table 2). The highest value of bifurcation ratio for low order streams and decreases consequently with increasing stream drainage increases for all sub catchments. Bifurcation ratio is also called shape factor. The bifurcation ratio is the resultant of the shape and drainage characteristic of the rivers catchments.

- **Length of Overland Flow**

Horton (1945) expressed it as equal to half of the reciprocal of Drainage Density (D_d). The length of overland flow for Gandhari, Savitri, Kal and Bhaovira rivers were 0.23, 0.27, 0.26 and 0.25 respectively and for Savirtri Basin was 0.28 (Table 2). The lowest value observed for Gandhari river and highest for Savitri river. Lowest value represented the time of concentration for accumulation of flow is less whereas highest value repressed more. But there is not much variation for all rivers under study. It is factor dependent of drainage density mean all factor i.e relief, slope and length of stream play important role in flow accumulation.

- **Relation of Drainage Order and Stream Number**

The plot of logarithm of cumulative stream Number along ordinate and stream order along abscissa for the river catchments is a straight line fit as shown in Figure 7. The straight line fit indicates that the ratio between cumulative Streams Number is constant throughout the successive order of a basin and suggests that geometrical similarity is preserved in basins of increasing order (Kumar *et al.*, 2001 and Gupta, 2003). From Table 3 it is observed that, the correlation coefficient have values for Gandhari, savitri, Kal and Bhaovira rivers were 0.92, 0.94, 0.95, and 0.86 respectively. Whereas for Savitri Basin was 0.94. This indicates logarithmic relation between stream number and order exist for the Savitri basin and it validated with confidence limit of 5 percent

- **Relation of Drainage Order and Stream Length**

The plot of logarithm of cumulative stream length along ordinate and stream order along abscissa for the river catchments is a straight line fit as shown in Figure 8. The straight line fit indicates that the ratio between cumulative stream lengths is constant throughout the successive order of a basin and suggests that geometrical similarity is preserved in basins of increasing order (Kumar *et al.*, 2001 and Gupta, 2003). From Table 3 it is observed that, the correlation coefficient have values for Gandhari, savitri, Kal and Bhaovira rivers were 0.96, 0.94, 0.93, and 0.87 respectively. Whereas for Savitri Basin was 0.94. This indicates logarithmic relation between stream length and order exist for the Savitri basin and it validated with confidence limit of 5 per cent

AERIAL ASPECTS

The aerial aspect is the two dimensional properties of a basin. It is possible to delineate the area of the basin which contributes runoff to each stream segment. It includes the Drainage area, Perimeter, width, basin length, drainage density, shape factor, elongation ratio, circulatory ratio, drainage texture, drainage frequency and constant of channel maintenance. The estimated parameters in GIS environment are presented in Table 4.

- **Stream Area, Length Area and Perimeter**

The entire area drained by a stream or system of streams such that all streams flow originating in the area is discharged through a single outlet is termed as the stream area. The total stream area of Gandhari, Savitri, Kal and Bhaovira rivers were 137.0, 354.0, 332.0, and 47.0 Sq Km respectively. The total area of Savitri Basin is 994.0 Sq Km.

The length area of Gandhari, Savitri, Kal, Bhaovira rivers and Saviti Basin were 26.81, 47.37, 45.58, 14.11 and 88.02 Sq Km respectively. The perimeter estimate presented in Table 4 and it is 59.0, 97.0, 112.0 33.0 and 176.0 Km for Gandhari, Savitri, Kal, Bhaovira rivers and Saviti Basin respectively. All above rivers are contributing water to the Savitri basin. Among all rivers Kal rivrs has higher area, perimeter and stream area flowed by Savitri and Gandhari. Bhaovira is the subtributary of Kal river but is selected for study as it has separate water delivery and hydrologic gauging stations.

- **Shape (Form) Factor (R_f)**

The shape of the basin mainly governs the rate at which the water is supplied to the main channel. The main indices used to analyze basin shape and relief is the elongation and relief ratios. Basin shape **(**Form factor) is the numerical index (Horton, 1932) commonly used to represent different basin shapes. Form factor is a g.ood indicator of outline form of a drainage basin. The value of form factor for Savitri Basin is 0.03 and for Gandhari, Savitri and Bhaovira is 0.04 whereas for Kal river is 0.03 (Table 4). This high form factor value indicates that the watershed has high peak flows for shorter duration (Chakrabory *et a*l 2002). Low form factor ratio will be for basins of flatter peak flow for longer duration (Biswas,1999) with less side flow for shorter duration and main flow for longer duration (Reddy, 2002), and vice versa for high ratio.

- **Drainage Density (D_d)**

Drainage density is considered to be an important index; it is expresses as the ratio of the total sum of all channel segments within a basin to the basin area i.e., the length of streams per unit of drainage density. It is a dimension inverse of length (Horton, 1932). Its values for Gandhari, Savitri, Kal and Bhaovira rivers were 2.15, 1.85, 1.96 and 1.97 respectively (Table 4). The Gandhari river has highest D_d compared to Savitri and Kal river. Lowest value observed for Savitri river. On overall Savitri basin has 1.77 D_d. The drainage density is sensitive parameter which in many ways provides the link between the forms attributes of the basin and the processes operating along stream course (Gregory and Welling, 1973). It reflects the land use and affects infiltration and the basin response time between precipitation and discharge. It is also of geomorphologic interest particularly for the development of slopes. Drainage basin with high D_d indicates that a large proportion of the precipitation runs off. On the other hand, a low drainage density indicates the most rainfall infiltrates the ground and few channels are required to carry the runoff (Roger, 1971). Hence basin has high runoff producing potential, as it has high relief and higher values of D_d.

- **Drainage Frequency (F_s)**

It is the number of stream segments per unit area is termed Stream Frequency or Channel Frequency or Drainage Frequency (Fs) Horton (1945). The Stream frequency for Gandhari, Savitri, Kal and Bhaovira rivers were 8.04, 5.64, 5.68 and 5.57 respectively (Table 4). The stream frequency for Savitri basin was 6.0. The ratio more than three shows the very rough texture and high run off on medium to high relief of low permeability (Reddy, 2002). Hence, Basin has high runoff producing characteristics. As F_s is more than 2 for all river and overall for Basin.

- **Drainage Texture (R_t)**

Horton (1945) defined drainage texture is the total number of stream segments of all order in a basin per perimeter of the basin. It is observed that, R_t for Gandhari, Savitri, Kal and Bhaovira rivers were 18.66, 20.52, 16.85 and 7.95 respectively (Table 4). The stream texture for Savitri basin was 33.86. Drainage density and texture ratio can be considered as two indices of erosion intensity (Morgan, 1986). High values of drainage density and texture ratio indicate high runoff and erosion potential of the basin area. These collectively increase runoff to a higher level (Biswas, 1999). As the Savitri Basin have high drainage texture and its tributary also comparatively high values on an average.

- **Elongation Ratio (R_e)**

Schumm's 1956 used an elongation ratio (Re) defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. It is observed that, R_e for Gandhari, Savitri, Kal and Bhaovira rivers were 0.31, 0.43, 0.30 and 0.36 respectively (Table 4). The elongation ratio for Savitri basin was 0.34. Higher value indicates high infiltration capacity and low run off conditions and vice versa (Reddy, 2002). The on overall elongation ratio of the basin is comparatively high, tends to high runoff potential and susceptible to high erosion.

- **Circulatory Ratio (R_c)**

The circularity ratio is a similar measure as elongation ratio, originally defined by Miller (1953), as the ratio of the area of the basin to the area of the circle having same circumference as the basin perimeter. Its values for Gandhari, Savitri, Kal and Bhaovira rivers were 0.49, 0.47, 0.31 and 0.54 respectively (Table 4), whereas, the Savitri Basin have circulatory ratio of 0.40. This value of circulatory ration for all river including Savitri basin is less than 0.5 indicating the basin is circular in shape. Similar to form factor, value nearer to one means more circular shape (Strahler, 1964). Runoff in circular shape basins gets more time to stay. Therefore, circular to elongate basin is inversely related in their character of movement (rapid or slow) of run off to outlet and infiltration.

- **Constant of Channel Maintenance (C)**

This parameter indicates the requirement of units of watershed surface to bear one unit of channel length. Schumn (1956) has used the inverse of the drainage density having the dimension of length as a property termed constant of channel maintenance. The C for Gandhari, Savitri, Kal and Bhaovira were 0.46, 0.50, 0.51 and 0.51 respectively (Table 4), whereas of Savitri Basin was 0.56. Permeability, rock type, relief, vegetation and duration of rainfall are the affecting factor. The constant of channel maintenance which is indicative area of the basin surface needed to sustain unit length of stream channel. On an average c value approaching to 0.5 indicated soil depth less and more erosion from the surface with high steep slope.

RELIEF ASPECTS

The highest elevation at remote point for Gandhari, Savitri, Kal and Bhaovira rivers were 849.10, 1366.23, 1141.25 and 1336.23 m whereas lowest elevation were 6.38, 8.07, 23.85 and 23.85 m respectively. The heist and lowest elevation for Savitri basin were 1366.23 m and 5.25 m respectively. The total basin relief and relief ration preented in Table 5. It is observed that, The heights total basin relief was observed for savitri rivers whereas lowest in Gandhar rivers. Overall for Savitri basin total basin relief was 1360.98m.

- **Relief Ratio**

It is the ratio between the total relief of a basin i.e. elevation difference of lowest and highest points of a basin, and the longest dimension of the basin parallel to the principal drainage line (Schumn 1956). These ranges between 0.03 to 0.09. The highest value for Bhaovira river whereas lowest for Kal river. The Savitri Basin has relief ratio as 0.03 (Table 5). The relative relief of Savitri basin was observed as 0.01. It is much low as compared as slope parameter.

- **Slop of Basin**

The slope of the basin was estimated from DEM data set in GIS environment and presented in Figure 9 for Savitri basin and Figure 10 (a-d) of Gandhari, Savitri, Kal and Bhaovira. It is observed from Figure that, average slope of the rivers is much high and ranges more than 50 per cent.

- **Channel Gradiant**

Channel slope were estimate by elevation deference to the horizontal length of channel. It is observed that, Savitri basin has 24 per cent slope whereas Bhaovira shows more channel slope (85.75 per cent). It may due to low channel length and highest channel elevation difference.

- **Ruggedness Number**

Strahler (1969) describes ruggedness number (HD) as the product of maximum basin relief and drainage density and it usually combines slope steepness with its length. The ruggedness number for the basin was 2.41. It is varied in between 1.82 to 2.19 for Gandhari, Savitri, Kal and Bhaovira rivers (Table 5). This is moderate value for the basin. Which is indicates the responses to the sediment rate and runoff rate production characteristics of basin

CONCLUSIONS

Morphometric analysis of river basin is found to be of immense utility in river basin evaluation, natural resource management and watershed prioritization. GIS technique is found useful for the analysis because it provides more reliable and accurate measurement of morphometric parameters of watersheds. Prioritization of watershed is an important tool for planning and management of water resources. The morphometric analyses were carried out through measurement of linear, areal and relief aspects of the watershed. The morphometric analysis of the drainage network of the watershed shows dendrite and radial patterns with moderate drainage texture. The variation in stream length ratio might be due to change in slope and topography. The bifurcation ratio in the watershed indicates normal watershed category and the presence of high drainage density suggesting that it has moderate permeable sub-soil, and coarse drainage texture. The value of stream frequency indicate that the watershed show positive correlation with increasing stream population with respect to increasing drainage density. The Savitri Basin has been divided into four sub river catchment viz Gandhari, Kal, Savitri

and Bhaovira. It is observed that Bhaovira has high flood proan and less recharge capacity compared to other rivers. The Savitri basin is found to be an old and mature basin in erosion process.

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APPENDICES

Figure 1: Location Map of Study Area

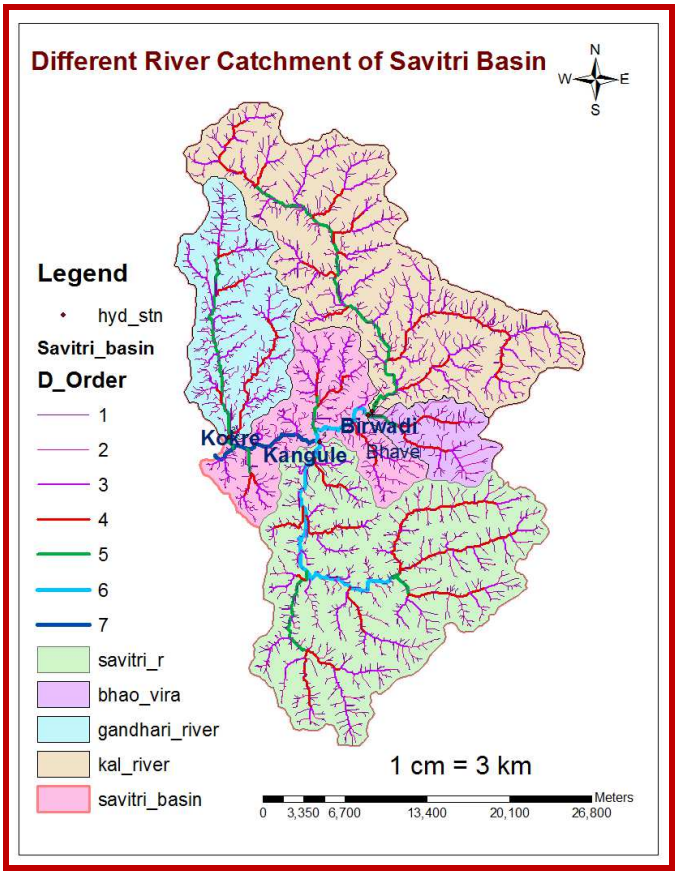


Figure 2: Location Map of Different River Catchments in Savitri Basin

Table 1: Formula Adopted for Computation of Morphometric Properties

Sr No.	Properties	Formulae*
A)	**Linear Morphometry**	
i)	Stream number in each order (N_o)	Hirachecal order
ii)	Total strteam number inn basin (N)	$N = \frac{R_b^s - 1}{R_b - 1}$
iii)	Average stream length (Lo)	$\bar{L}_0 = \bar{L}_1 R_L^{o-1}$
iv)	Total stream length (Lo)	$L_o = \bar{L}_1 R_b^{s-1}\left(\frac{u^s - 1}{u - 1}\right)$ where $u = R_L/R_B$
v)	Bifurcation ratio (Ro)	$R_b = N_o/N_{o+1}$
vi)	Length ratio (R_L)	$R_L = \bar{L}_o/\bar{L}_{o+1}$
vii)	Length of overland flow (**λ**o)	$\ell_o = \frac{1}{2D}$
B)	**Areal Morphometry**	
i)	Stream area in each order	$\bar{A}_o = \bar{A}_1 R_a^{o-1}$
ii)	Length area	$L = 1.4A^{0.6}$
iii)	Basin shape	$R_F = \frac{A_o}{L_b^2}$
iv)	Drainage density	$D = \frac{\Sigma L}{A}$
v)	Stream frequency	$F_s = \frac{N}{A}$
vi)	Constant of channel maintenance	$C = \frac{1}{D}$
C)	**Relief Morphometry**	
i)	Relief ratio	$R_h = H/L_o$
ii)	Relative relief	$R_{hp} = H/p$
iii)	Relative basin height	$y = h/H$
iv)	Relative basin area	$x = a/A$
v)	Ruggedness number	$R = DH$

*Adopted from Strahler (1964)

Table 2: Linear Geomorphologic Aspect of Savitri Basin

SI. No	River/ Basin	Order, (U)	No. of Streams, (N_u)	Total Steam Length, Km	Mean Stream Length, Km	Length Ratio, (R_L)	Bifurcation Ratio,(R_b)
A	Gandhari River	I	659	153.12	0.23	2.1	2.9
		II	227	73.00	0.32	2.18	2.08
		III	109	33.41	0.31	1.5	1.56
		IV	70	22.30	0.32	1.67	1.94
		V	36	13.39	0.37	-	-
		Total	**1101**	**295.22**	**0.27**	**1.86**	**2.12**
B	Savitri River	I	1015	342.14	0.34	2.38	2.15
		II	472	143.72	0.3	2.04	2.12
		III	223	70.6	0.32	1.15	1.16
		IV	193	61.15	0.32	5.28	5.22
		V	37	11.58	0.31	0.53	0.74
		VI	50	21.79	0.44	-	-
		Total	**1990**	**650.98**	**0.33**	**2.28**	**2.28**
C	Kal river	I	1016	345.69	0.34	2.55	2.35
		II	432	135.78	0.31	1.51	2.24
		III	193	90.21	0.47	1.81	1.24

		Table 2: Contd.,				
		IV	156	49.92	0.32	1.77	1.73
		V	90	28.16	0.31	-	-
		Total	**1887**	**649.76**	**0.34**	**1.91**	**1.89**
D	Bhao Vira river	I	133	54.91	0.41	2.92	2.25
		II	59	18.79	0.32	3.48	3.28
		III	18	5.4	0.3	0.5	0.43
		IV	42	10.77	0.26	3.65	4.2
		V	10	2.95	0.3	-	-
		Total	**262**	**92.82**	**0.35**	**2.64**	**3.54**
E	Saitri Basin	I	3059	924.2	0.3	2.44	2.25
		II	1360	379.49	0.28	1.74	1.82
		III	748	218.48	0.29	1.48	1.48
		IV	505	147.59	0.29	2.63	2.56
		V	197	56.21	0.38	2.3	3.03
		VI	65	24.41	0.36	2.56	2.5
		VII	26	9.44	0.3	-	-
		Total	**5960**	**1759.8**	**0.30**	**2.19**	**2.27**

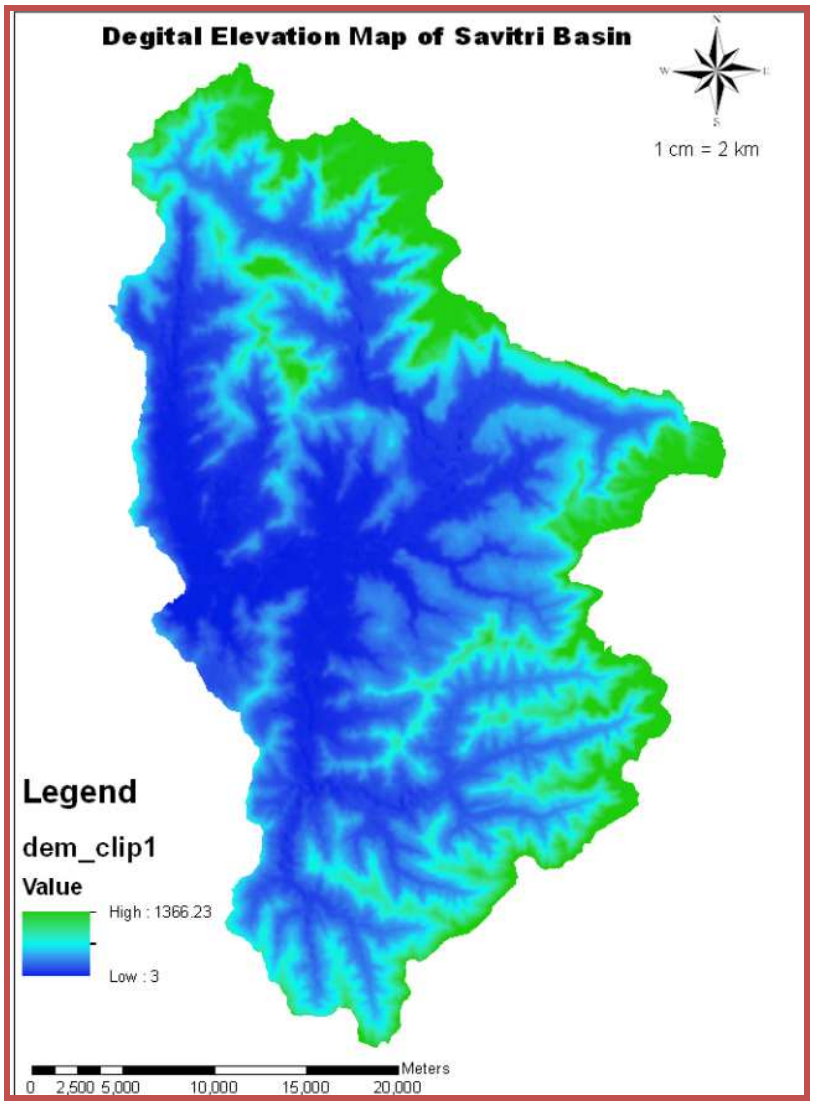


Figure 3: Digital Elevation Model of Savitri River Basin

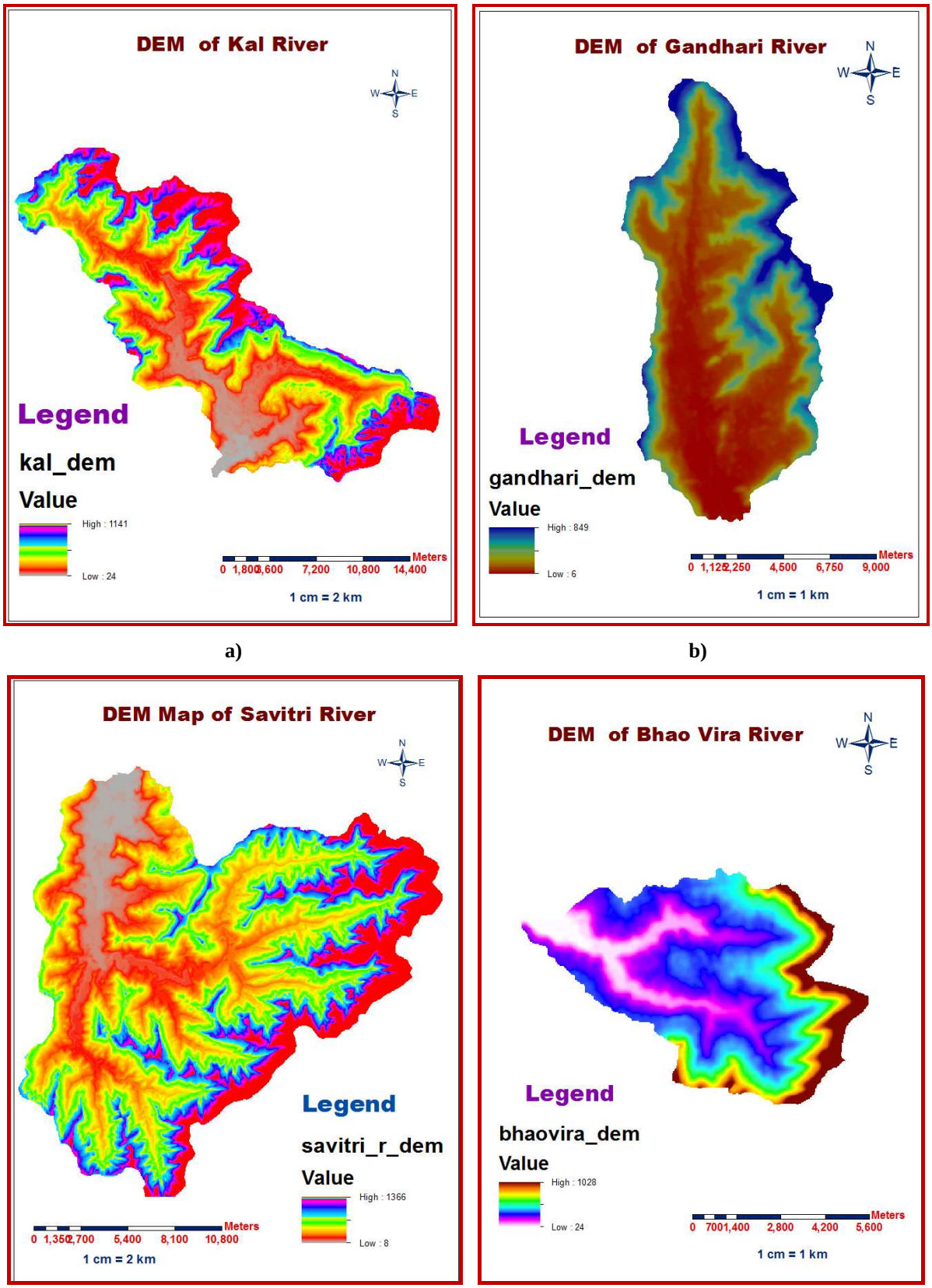


Figure 4 (a-d): DEM of Gandhari Kal, Savitri and Bhaovira Rivers of Savitri Basin

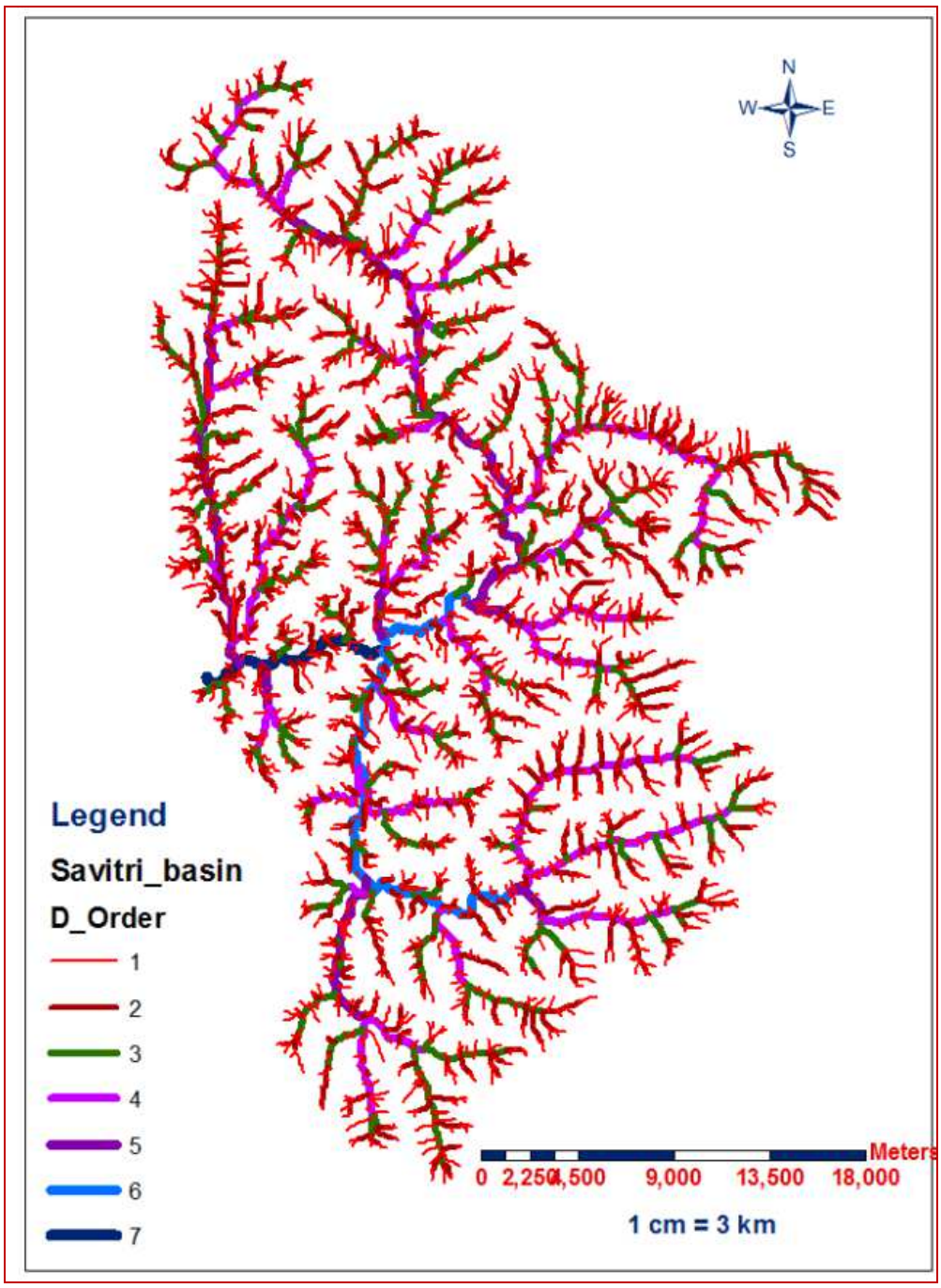
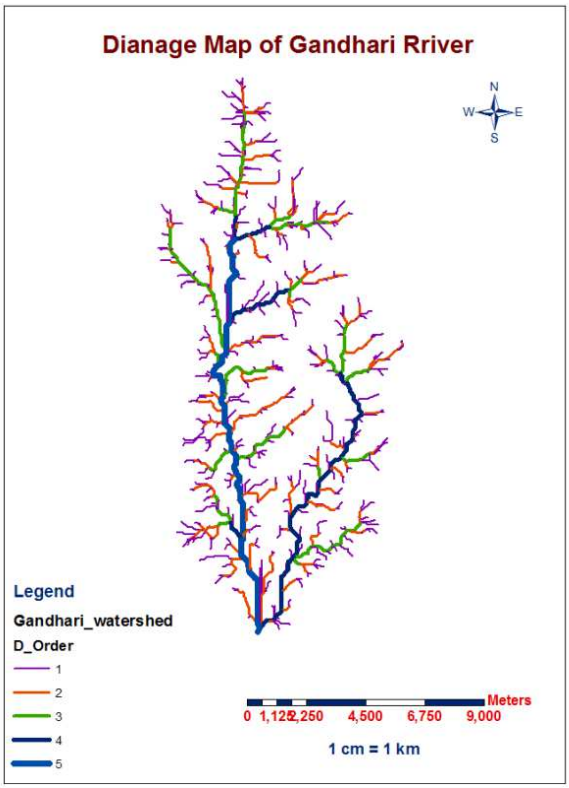


Figure 5: Darianage Map of Savitri River Basin



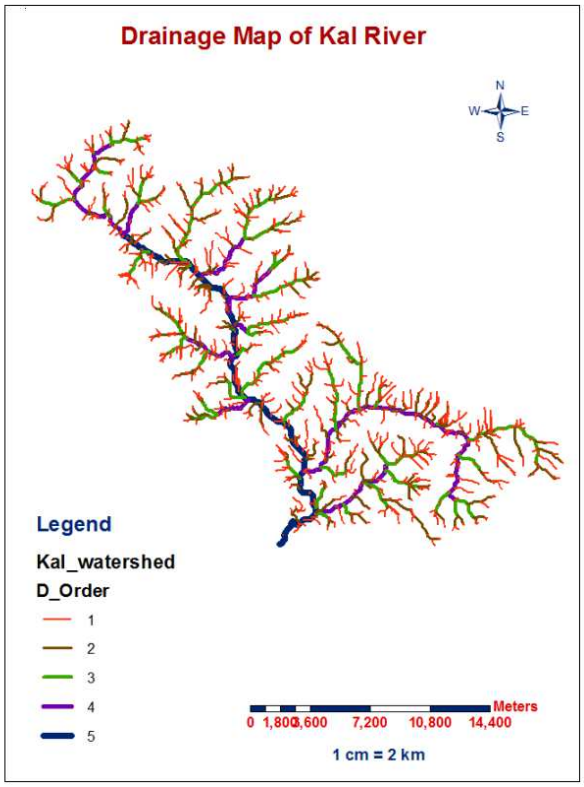
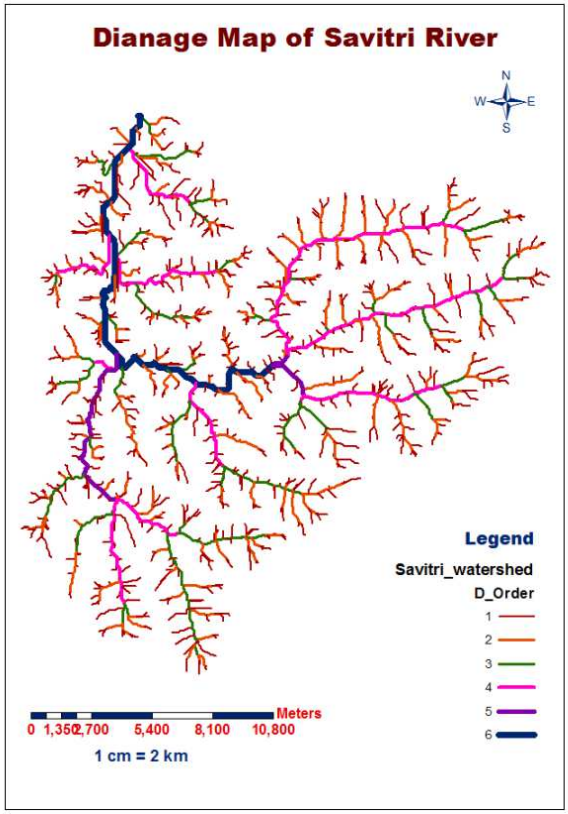


Figure 6(a): Drainage Order Map of Gandhari River **Figure 6(b): Drainage Order Map of Kal River**



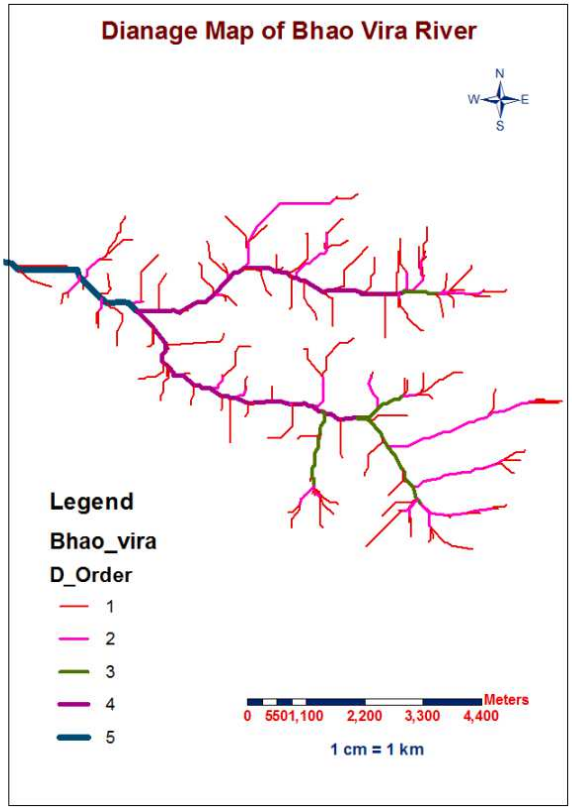


Figure 6(c): Drainage Order Map of Savitri River **Figure 6(d): Drainage Order Map of Bhaovira**

Figure 6(a-d): Drainage Order Map of Subcatchment of Savitri Basin

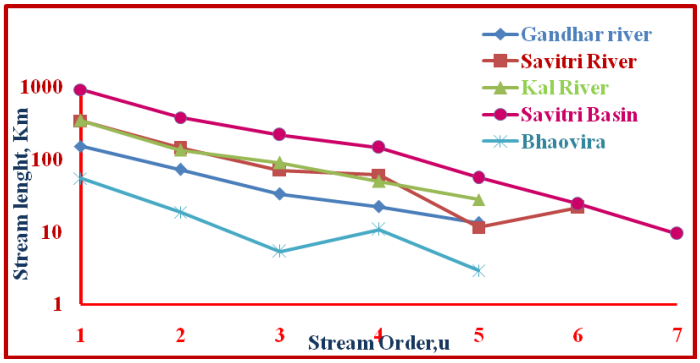


Figure 7: Regression of Logarithm of Stream Length Versus Stream Order

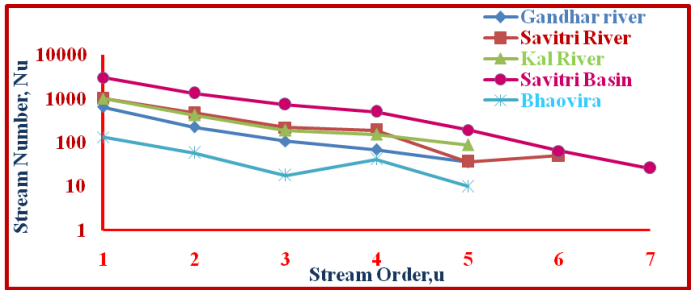


Figure 8: Regression of Logarithm of Number of Streams Versus Stream Order

Table 3: Logarithmic Regression Equations for Stream Number and Stream Length

River	Stream Number, Nu	Regression Coefficient, (R^2)	Stream Length, Lu	Regression Coefficient, (R^2)
Gandhari	y = -385.ln(x) + 588.9	0.92	y = -88.4ln(x) + 143.7	0.96
Kal	y = -578.ln(x) + 931.1	0.94	y = -194.ln(x) + 316.2	0.94
Savitri	y = -543.ln(x) + 927.6	0.95	y = -179.ln(x) + 305.3	0.93
Bhao Vira	y = -71.7ln(x) + 121.0	0.86	y = -31.1ln(x) + 48.34	0.87
Savitri Basin	y = -1532ln(x) + 2716.	0.94	y = -456ln(x) + 806.7	0.93

Table 4: Aerial Geomorphologic Aspect of Savitri Basin

SI No	Parameters	Gandhar	Savitri	Kal	Bhao vira	Savitri Basin
1	Stream area (A), Sq Km	137.00	354.00	332.00	47.00	994
2	Length area (La), Sq Km	26.80	47.37	45.58	14.11	88.02
3	Perimeter (P), Km	59.00	97.00	112.00	33.00	176.00
4	Basin length (L), Km	21.3	24.55	34.34	10.79	52.85
5	Width of Basin (W), Km	8.61	24.29	13.02	7.02	26.12
6	Length of Main stream (Lb), Km	22.63	35.95	31.68	11.99	57.29
7	Shape Factor (Rf)	0.04	0.04	0.03	0.04	0.03
8	Drainage density (Dd)	2.15	1.84	1.96	1.97	1.77
9	Drainage frequency (Fs)	8.04	5.62	5.68	5.57	6.00
10	Drainage texture (Rt)	18.66	20.52	16.85	7.94	33.86
11	Elongation ratio (Re)	0.31	0.43	0.30	0.36	0.34
12	Circularity ratio (Rc)	0.49	0.47	0.33	0.54	0.40
13	Length of overland flow (λo)	0.23	0.27	0.26	0.25	0.28
14	Constant of Channel Maintenance (C)	0.46	0.54	0.51	0.51	0.56

Table 5: Relief Geomorphologic Aspect of Savitri Basin

SI No	Parameters	Gandhari	Savitri	Kal	Bhao vira	Savitri Basin
1	Height of height point on the Basin, Max H, m	849.10	1366.23	1141.25	1028.11	1366.23
2	Lowest point of the river basin, Min H, m	6.38	8.07	23.85	23.85	5.25
3	Total Basin Relif (Bh)	842.72	1358.16	1117.40	1004.26	1360.98
4	Relief ratio (Rh)	0.04	0.06	0.03	0.09	0.03
5	Relative relief	0.01	0.01	0.01	0.03	0.01
6	Ruggedness number (Hd)	1.82	2.50	2.19	1.98	2.41
7	Time of concentration Tc (min)	65.34	92.86	86.01	86.00	159.07
8	Channel slope, Percent	37.52	38.00	36.02	85.75	23.85

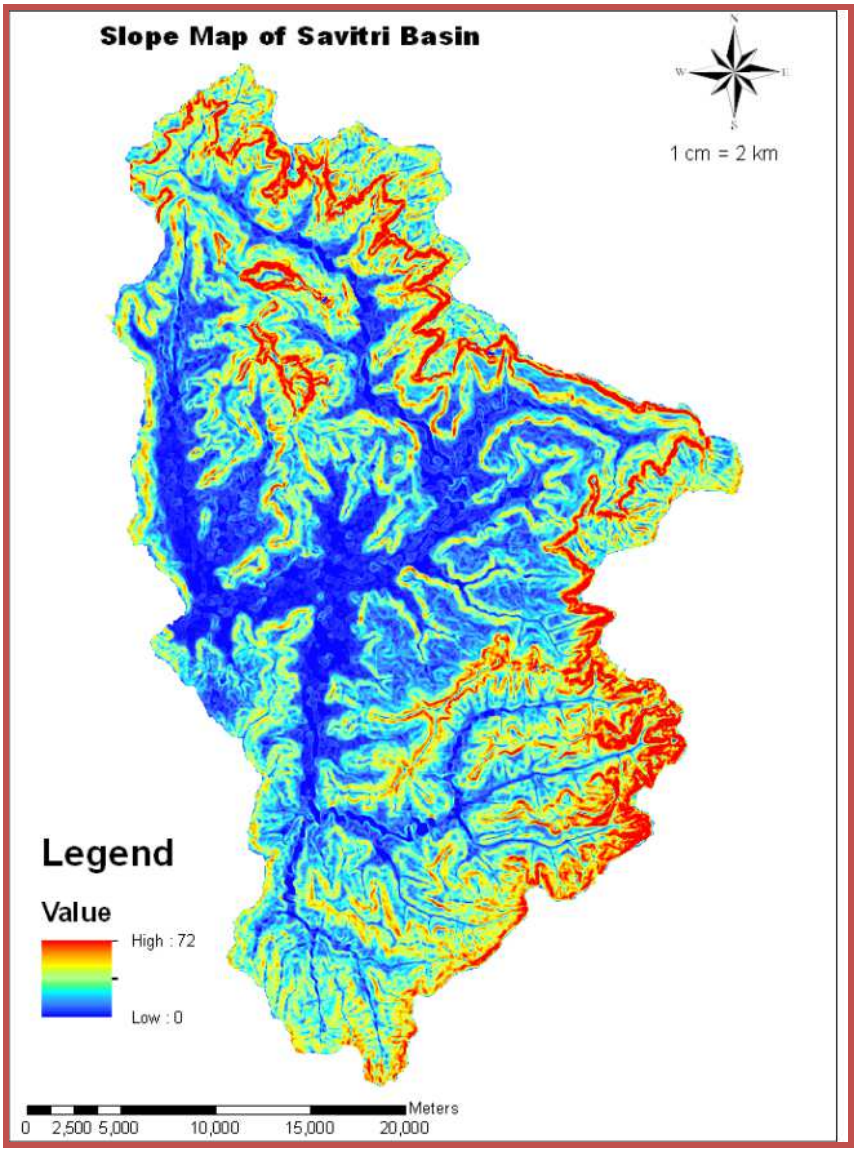


Figure 9: Slope Map of Savitri Basin

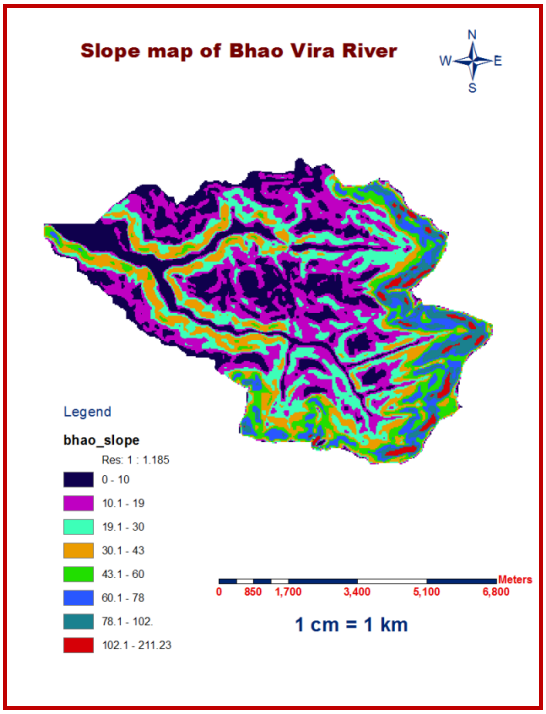


Figure 10(a): Slope Map of Gandhari River

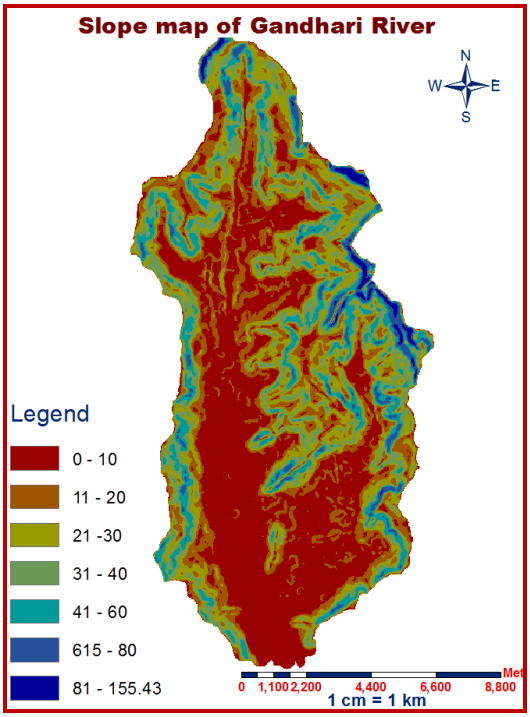


Figure 10(b): Slope Map of Savitri River

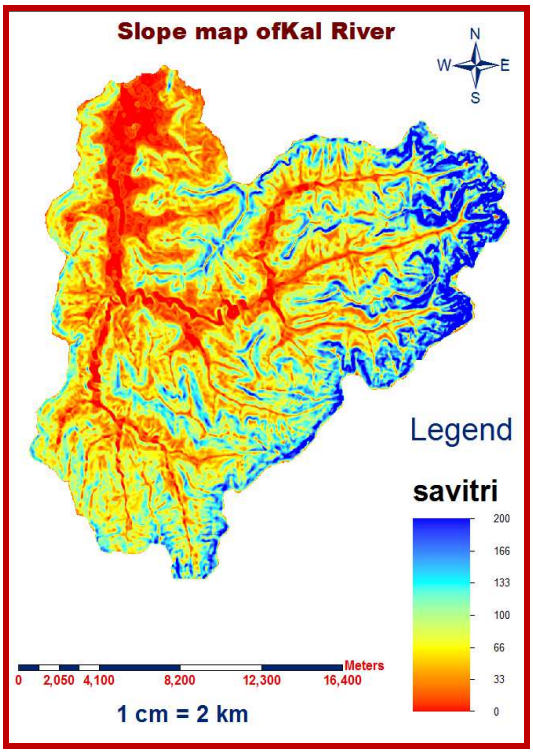


Figure 10(b): Slope Map of Kal River

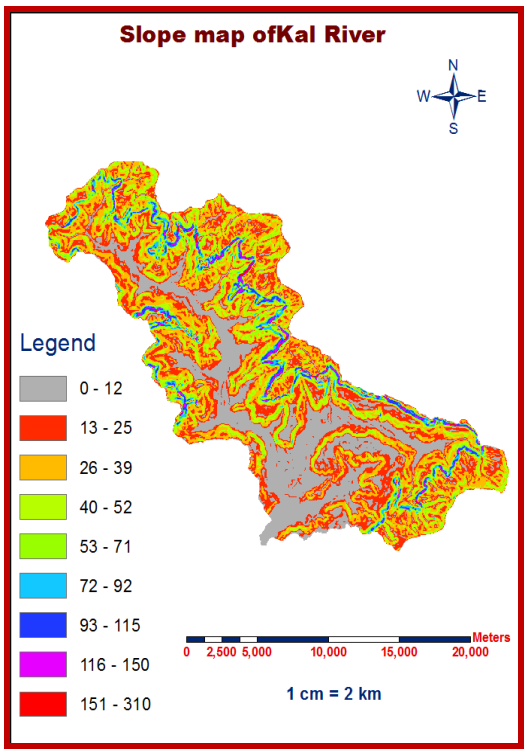


Figure 10(c): Slope Map of Kal River

Figure 10(a-d): Slope Map of Gandhari, Kal, Savitri and Bhaovira Rivers of Savitri Basin