Morphometric Analysis Applying Weighted Sum Approach For Prioritization of Sub Watersheds : A Case Study of Birma River Basin

Varnica Mishra[1], Dr. S.N. Mohapatra[2]
[1, 2] School of Studies in Earth Science, Jiwaji University,Gwalior, India

Abstract- *Birma, a downstream tributary of Betwa river has been elected for quantitative morphometric analysis of ten major sub-watersheds (S1-S10). The Birma watershed (BW) and its sub-watersheds were subjected to a detailed morphometric analysis using remotely sensed data. Morphometric parameters are then utilized for sub watersheds prioritization which are used for identifying critical and subcritical zones prone to soil erosion. Weighted sum approach is a way of prioritizing watersheds, which is fruitful way for making strategies and for better soil and water conservation from base level is utilized for sub watersheds prioritization in this study. Watershed boundaries are extracted using ASTER DEM having spatial resolution of 30m by pour-point method. The results show that drainage density (Dd) and stream frequency (Fu) of BW, sub-watersheds show poor runoff- and high infiltration. Low stream frequency (Fu) values indicate that BW and its sub-watersheds have a low steep slope and high permeability. The Elongation ratio indicates that it has an elongated shape. The values of Ruggedness and Melton Ruggedness number are 0.12 and 4.99 respectively which indicates BW has smooth terrain with steep slope. The S-shaped hypsometric curve shows that BW is prone to moderate erosion and hypsometric integral (HI) value of 0.3 indicates a mature terrain. The present result could aid in the identification of groundwater potential zones as well as water shed management of Birma watershed.*

Keywords- ASTER DEM, Birma,Drainage Density, Hypsometric curve , Stream Frequency.

I. INTRODUCTION

Watershed is described as an area over which run-off deriving from rainfall assemblages and flows from a single point. The watershed development programme has an enormous possibility to provide socioeconomic equity, achieving self-sustenance and stabilized growth (Pawar 2003, Pawar and Panhalkar 2001). Watershed study promotes in lifting up the groundwater recharge in safeguarding and strengthening the water resources arising from catchments, examining soil erosion and minimizing the consequent of sediment yield in the catchments.

Morphometric analysis assists in prioritizing sub-watersheds compensating the utility of soil map of the concerned area (Biswas, Sudhakar & Desai, 1999). It is defined by (Clarke, 1996) as an evaluation of earth's surface and various aspects pertaining to its landform. It gives a computable explanation of drainage system, that is the prime component in delineating watersheds (Strahler,1964). Remote sensing data is utilized in priority assessment, identification of problems, evaluation of management and potential needs, recognizing areas more vulnerable to erosion, developing water management schemes, site selections for check dams and reservoir to name a few. (Dutta et al. 2002). Digital Elevation model and Topographical data is proved to be fruitful in perceiving and managing natural resources. It offers real-time and Precise details associated with various geological and topographical features, as well as assisting in the detection of drainage channels that have been altered by natural or human activities.

The watershed is classified into sub-watersheds, mini-watersheds, milli, micro and macro watersheds depending upon the area of watershed. Morphometric parameters are a fruitful way to analyse sub watersheds in a better and more scientific way and gather interrelation among stream order, stream length etc. For the security of natural resources, watershed protection is one of the ways to achieve this goal with proper scientifi1c and effective way (Gumma et.al, 2016). The drainage attributes can be drawn from shuttle radar topography mission (SRTM) using digital elevation model (DEM) is widely accepted as it is faster, convenient, and scientific way to gather catchment features (Maathuis, 2006; Moore et.al, 1991).

Watershed prioritization is delineation of environmentally deteriorated sub or mini watersheds and utilizing it for soil conservation on the basis of priority wise ranks. Depending upon soil erosion, topographic or geomorphological factors, sediment yield & many scientific studies in past have identified degraded areas of sub or mini watersheds (Shrimali et al., 2001).

Hypsometric study is a way to extract interrelation among horizontal cross-sectional area with respect to its height that permits juxtaposition of watershed and its scale problem (Dowling et al. 1998). Hypsometric curve (HC) and Hypsometric integrals (HI) are essential feature of watershed study (Ritter et al.2002).

The natural resources are the prime factor in shaping the socio-economic growth of a nation and unwarranted utilization of these is directly proportional to the disruption of ecological balance of any country. Efficiency of agricultural land rely on the soil water and resources. There are many ways viz. compound factor value, principal component analysis (PCA), weighted sum approach pertaining to subwater ranking that can be use today which are cheaper, scientific, rapid. Here, weighted sum approach is used which was postulated by (Aher et al. 2014) for prioritization/ranking of sub watershed on Birma river basin which flows across high terrain area of two main district of Uttar Pradesh. There is a fall in the annual monsoon period in the major portions of the area. This will impact in drying of dug wells/shallow wells and declining of groundwater well (CGWB report, Hamirpur district, 2012-2013). Therefore, monitoring soil water and resources by GIS based studies can proved to be worthwhile in its conservation. The morphometric and Hypsometric data of Birma Watershed and its Sub-watersheds is beneficial in protection of water and soil resources.

II. AREA OF INTEREST

Birma river is a downstream tributary of Betwa, originating from Madarka village, Chhatarpur district, Madhya Pradesh (25◦ 05’ 23.36” N to 79◦ 33’ 38.70” E). It crosses three districts Chhatarpur (M.P) , Mahoba and Hamirpur (U.P). The basin lies in between latitude 25◦ 05’ 23.36’’ N to 25◦ 52’ 53.71” N and longitude 79◦ 33’ 38.70” E to 79◦ 54’ 06.98” E. The area of interest is characterized by subtropical climatic conditions, extended summer, significant winter and moderate to high rainfall. Birma watershed is classified in 10 Sub-watersheds named (S1- S10). The Watershed covers 2589.77 Km2 area having a perimeter of 418.6Km. The Birma river flows from south towards north direction and exhibits a fifth-order drainage system. The Geometric parameters of its Sub-watershed is shown in the Table-1. An Earthen dam Swami Bramha Nand Dam (Maudha Dam) is built on Birma River which is main source for irrigation and potable water supply in the area. Majhgawan tank and Bela Sagar reservoir are a part of Birma river basin. Birma river basin shows sub-dendritic to dendritic drainage pattern. The study area covers Survey of India Topographic sheet numbers 54O/6 to 54O/16.

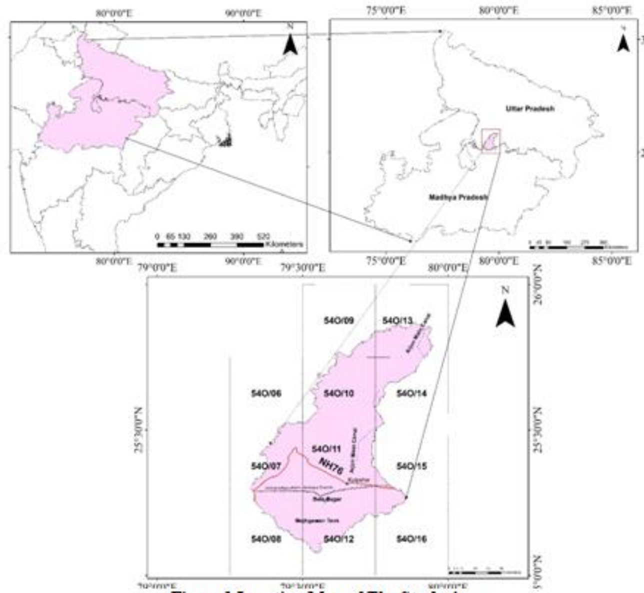

Figure 1 Location Map of The Study Area

III. DATA SETS USED

Survey of India toposheet numbers 54O/6 to 54O/16 are used to extract the Birma Watershed boundary. The shapefiles for lithological boundaries and structures were obtained from Geological Survey of India's Bhukosh portal. Sub-Watersheds of BW was delineated from Pour Point method. ASTER DEM with 30m resolution was downloaded from USGS and utilized in morphometric analysis. ArcGIS 10.4.1 software was used to extract linear, areal, relief parameters and to prepare various thematic maps.

IV. WEIGHTED SUM APPROACH (WSA)

Depending upon morphometric parameters, the prioritization of sub-watersheds is done by means of weighted sum approach. Here, preliminary ranking of sub watersheds is derived from areal, linear and relief parameters. Areal and linear parameters are ranked in descending order whereas relief is ranked vice versa. Correlation matrix is then computed of these parameters in MS excel. After this, weights (Wi) are allocated to individual variable and computed factor value is calculated using preliminary priority ranking and weighted value (Aher et.al. 2014). The following formula is used for compound factor –

$$WCF = PRi*Wi + \ldots\ldots + PRnth*W_n \qquad \ldots\ldots(1)$$

Where PR_n is the preliminary ranking of the nth variable and W_n is the weighted sum of the nth variable and WCF is weighted compound factor.

Depending upon their final compound factor value, sub-watersheds are classified as high, medium and low for the priority.

V. GEOLOGICAL SETUP

Geologically, the study area is a part of Bundelkhand Gneissic Complex (BnGC), which consists rocks of Archean-Proterozoic age. Dolerite dykes intrude variants of granitoids, gneisses and migmatites altogether constituting the BGC. Quaternary non-lithified sediments cover most of the northern half of the area. BGC is overlain by alluvium which is further classified into Older and Newer Alluvium. Older Alluvium comprises sediments of silt-clay with kankar and Newer Alluvium comprises of sediments - clay, silt and grey sand and at some places grey micaceous sand. Banda Alluvium represents Older Alluvium of early Pleistocene age. It consists of silt, clay with kankar along with red quartzo- felspathic sand. The Newer Alluvium is represented by Channel Alluvium and Terrace Alluvium of Holocene age and consists of clay, silt and grey sand along with grey micaceous sand. The width of Alluvium varies from 125 to 155 meters. The older supracrustals of Archean age consists of amphibolite. Two distinct physiographic regions near Hamirpur in the study area are:

1. The southern part plain area. The region is underlain by thin alluvial cover.
2. The northern part flat topography.

Near, Chhatarpur district, the study area consists of Bundelkhand Gneissic Complex comprising varieties of granites, gneisses etc. these rocks overlain by Bijawar group of rocks which includes breccia, stromatolites and dolomites. The Bijawar group of rocks were overlain by Vindhyan Supergroup which consists of sandstone, limestone shales.

The study area represents subtropical climate characterized by extended summer, significant winter and moderate to high rainfall. It receives 95% of rainfall from southwest monsoon. The summer season starts from March to June then accompanied by south-west monsoon which lasts till September. The winter season starts from mid-October to February.

Table1. Stratigraphic Succession of Birma River Basin

Geological Unit	Lithology	Group	Age
Channel Alluvium	Grey micaceous sand, silt and clay	Newer Alluvium	Holocene
Terrace Alluvium	Grey micaceous sand, silt and clay		
Banda Alluvium	Silt clay with kankar & quartzo felspathic sand	Older Alluvium	Early to Late Pleistocene
Bundelkhand Granitic Complex	Granite and Gneiss		Archean to Proterozoic

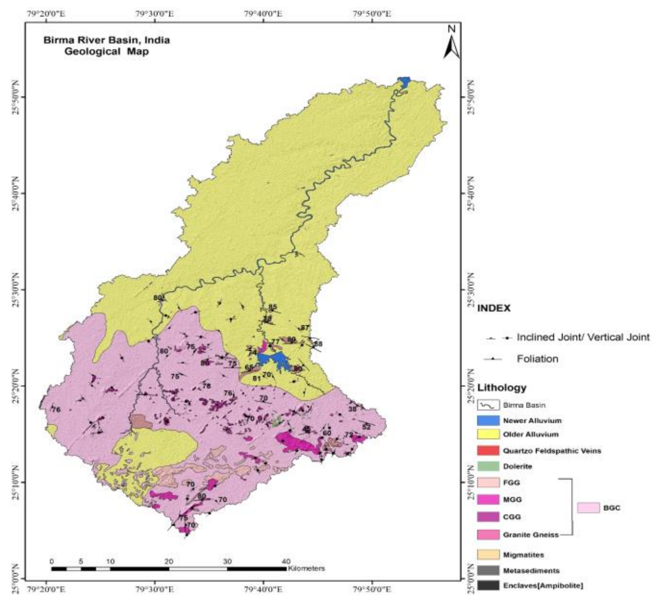

Figure 2. Lithological Map of Birma River Basin

VI. METHODOLOGY

ASTER DEM having 30 m spatial resolution was downloaded from USGS earth explorer and used for stream ordering, drainage density etc. and preparation of other thematic maps. Freely downloaded ASTER DEM is filled in surface raster using spatial analyst tool of ArcGIS to remove surface imperfections in the data. Using this filled DEM, flow direction and flow accumulation is generated. Based upon Strahler's method, stream network map is extracted using stream order tool. Birma and its sub watersheds is delineated by means of pour point method. Extracted watershed was cross verified using toposheets from Survey of India (SOI) viz. 54O/7, 8,9,10,11,12,13 & 14. Georeferenced toposheets were used as a base map for topographic features (highways, railways, ponds etc.). Morphometric parameters are calculated using Arc hydro tools. Different models and formulas that were used in morphometric analysis are mentioned in Table-2.

Table 2 Formulas For Computation Of Morphometric Analysis

Morphometric Parameter	Formulas	References
Basin Length (L_b) (Km)	-	-
Stream Order (U)	Hierarchial Rank	Strahler(1952)
Stream Number (Nu)	$Nu= N1+N2+N3+\ldots\ldots+Nn$	Horton(1945)
Stream Length (Lu) (Km)	$Lu= L1+L2+L3+\ldots Ln$	Strahler(1964)
Stream Length Ratio (Lur)	$Lur = Lu/(Lu-1)$	Strahler(1964)
Bifurcation Ratio (Rb)	$Rb= Nu/ Nu+1$	Strahler(1964)
Rho Coefficient(ρ)	$\rho=Lur/Rb$	Horton(1945)
Area (A) (Km^2)	-	-
Drainage Density(Dd) (Km/Km2)	$Dd= \Sigma Lu/A$	Horton(1945)
Stream Frequency(Lu) (Km-2)	$Fs= Nu/A$	Horton(1945)
Drainage Texture (T)	$T=Nu/P$, P= Perimeter of the basin	Horton(1945)
Length of Overland flow (Lg) (Km	$Lg= 1/2Dd$	Horton(1945)
Constant Of Channel Maintenance (C) (Km)	$C=1/Dd$	Schumm(1956)
Circularity ratio (Rc)	$Rc= 4\pi A/P2$	Miller(1953)
Elongation Ratio (Re)	$Re= 1.128\sqrt{A}/Lb$	Schumm(1956)
Basin relief (R) (Km)	$R= H-h$	Schumm(1956)
Relief ratio(Rr)	$Rr=R/Lb$	Schumm(1956)
Ruggedness number(Rn)	$Rn= R*Dd$	Strahler(1958)
Melton Ruggedness ratio (MRn)	$MRn= H – h/A^{0.5}$	Melton(1965)

VII. RESULTS AND DISCUSSIONS

1.1 Linear Parameters

1.1.a Stream Ordering

Drainage basin analysis begins with stream ordering. For this work, Strahler's procedure of stream ordering has been utilised. Assuming one is accessible to channel network map, the smallest fingertip tributary is selected as order 1. At the junction of two 1st order stream gives rise to 2nd order stream. Similarly, junction of two 2nd order stream gives, 3rd order stream and so forth. As mentioned earlier the Birma watershed shows fifth order drainage in the form of dendritic to sub-dendritic pattern(Figure 2). There are two hundred seventy-three 1st order streams, sixty-one 2nd order streams, eighteen 3rd order streams, four fourth-order streams, and one fifth-order stream out of the total 357 streams.

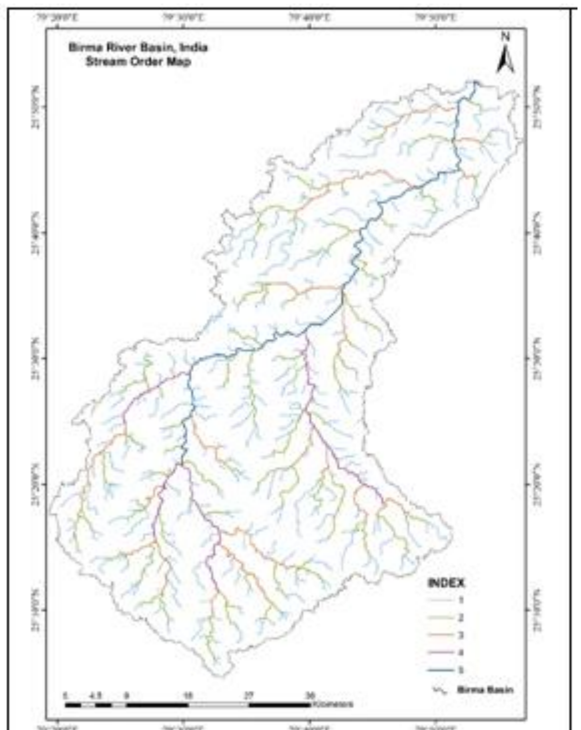

Figure 2 Stream Order Map of Study Area

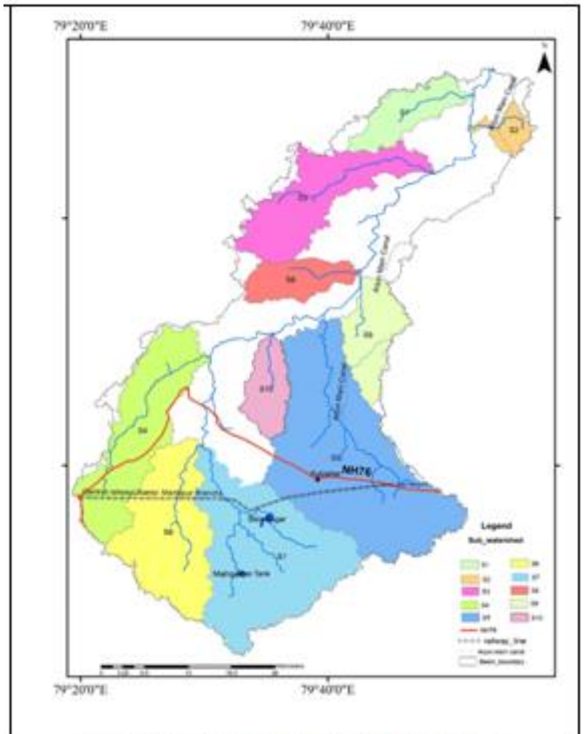

Figure 3 Sub-watersheds of Birma Basin

1.1.b Bifurcation Ratio

This ratio implies to the absolute count of streamlets of a certain order to the absolute count of streamlets of successive greater order. Strahler (1957) put forth that Rb values generally range from 3.0 to 5.0 which states that drainage patterns are not disrupted due to geological structures. Mean bifurcation ratio (Rbm) ranges between 3 and 5 when the impact of geological structures are insignificant within a basin (Verstappen 1983).

In the Birma watershed, the Rb ranges from 3.5 to 4.5. The lower value 3.5 indicates watershed which is not influenced by structural disturbances and that Rb value 5.0 shows that the drainage is structurally control over formation of pattern. Sub-watersheds S1, S2, S4, S5, S6, S7, S9 displays absence of structural control over drainage pattern, whereas S3, S8, S10 shows structural control. The Rb values is shown in table 3.

1.1.c Stream Length Ratio

This ratio implies to the steam length of certain order to the length of stream of prior order Horton (1945). A rising pattern of stream length ratio indicates geomorphic stage generally mature. In the Birma watershed, and its sub watersheds, rising pattern of the stream length ratio is seen, indicating mature geomorphic stage. The stream length ratio values are shown in the table 3

1.1.d Rho coefficient (ρ)

This ratio essentially obtained when stream length ratio is divided by bifurcation ratio. It signifies the drainage basin's storage capacity. The values of ρ coefficient are shown in the table 3. All the sub watersheds area of study shows lower values i.e. 0.02 to 0.08 which is less than 0.50, signifies lower hydraulic storage throughout the floods. Only S2 shows highest value of ρ coefficient, but that too is less than 0.50. Its value are shown in table 3.

1.2 Areal Parameters

1.2.1 Area

The Birma watershed has the area of 2589.74 Km^2. S8 is the smallest watershed having area of 68.9 Km^2 and S7 stands as largest watershed having an area of 361.9 Km^2.

1.2.2 Drainage Density

It is ratio between combined stream lengths of all orders to the basin area, Horton (1945). Dd provides us with enough data to inspect the numerical quantification of landscape study and run-off abilities (Reddy et al.2004; Yadav et al.2014). Dd is spatially categorized into four categories which are, less than 2 is considered as low, 2- 4 as moderate, 4-6 as high and greater than 6 as very high. Weak and impenetrable subsurface material, scanty flora and high relief is related to higher drainage density. Coarse drainage texture is related to lower drainage density whereas fine drainage texture is with erosional capacity of basin area, high run off is related to high drainage density. In the study area, Birma watershed shows low Dd of 0.49 Km/Km2 which indicates coarse drainage texture, dense flora, low relief and subsurface material is permeable. All the sub-watersheds also show low Dd i.e. <2. The Dd values in area of interest are mentioned in table 4 . The Dd map of Birma watershed is shown in figure 4.

1.2.3 Stream Frequency(Lu)

It is a combined count of streams of all orders to the basin area Horton (1945). High Fu specifies steep slope, little vegetation and less permeability, low stream frequency specifies gentle gradient, high permeability and low relief. In the study area, Birma watershed and its sub watershed shows low stream frequency which indicates gentle slope, high permeability. Low Fu and Dd indicates poor run-off and high infiltration of Birma watershed. The values of Fu are shown in table 4.

Table 3 Linear Parameters of Birma Basin											
Parameters	Sub-Watersheds										BW
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	
Perimeter(Km)	71.2	38.9	125.7	1240	1526	1062	1314	50.1	66.2	50.8	418.6
Basin Length (Km)	19.1	8.4	27.7	34.6	37.2	27.0	31.7	16.4	19.6	15.8	
Main Channel Length(Km)	23.6	11.2	38.9	40.2	49.8	32.2	39.2	20.3	21.1	16.7	136.4
Bifurcation Ratio(Rb)I/II	5.5	2.5	5.6	5.1	3.4	3.3	4.0	9.0	4.0	8.0	4.3
Bifurcation Ratio(Rb)II/III	2.0	2.0	3.0	3.5	3.0	4.0	3.0	-	2.0	-	3.5
Bifurcation Ratio(Rb)III/IV	-	-	-	2.0	5.0	2.0	3.0	-	-	-	4.5
Bifurcation Ratio(Rb)IV/V	-	-	-	-	-	-	-	-	-	-	4.0
Mean Rb (Rbm)	3.75	2.25	4.3	3.2	3.8	3.1	3.3	9.0	3.0	8.0	4.07
Stream Length Ratio II/I	0.07	0.33	0.12	0.36	0.47	0.63	0.42	1.1	0.78	0.69	0.46
Stream Length Ratio III/II	0.10	1.26	1.08	0.13	0.86	0.58	1.40	-	0.01	-	0.57
Stream Length Ratio IV/III	-	-	-	0.63	1.15	0.22	0.32	-	-	-	0.33
Stream Length Ratio V/IV	-	-	-	-	-	-	-	-	-	-	1.67
Mean Stream Length Ratio	0.08	0.79	0.6	0.37	0.82	0.47	0.71	1.1	0.39	0.69	0.75
Rho Coefficient(ρ)	0.02	0.35	0.13	0.11	0.21	0.15	0.21	0.12	0.13	0.08	0.18

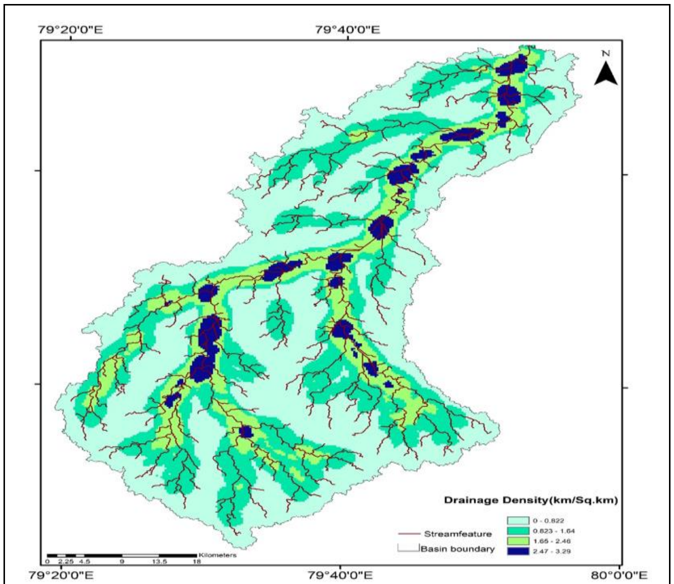

Figure 4 Drainage Density Map of Birma Basin

1.2.4 Form factor (Rf)

It implies as ratio of the basin area to the square of its maximal length. The Rf values spans from zero to one with one assigned to perfectly circular shape. Higher the Rf values, greater is the peak flow in short span of time while lower the Rf, poorer the peak flow in higher span (Chopra et al.2005). The Rf of Birma watershed shows an elongated shape of the drainage basin. All the sub watersheds also display low Rf value which indicates low peak flow for an extended time period. Values of form factor of Birma and its sub watersheds is shown in table 4.

1.2.5 Circularity ratio (Rc)

As defined by Miller (1953), Strahler (1964) Rc represents proportional relation among basin area to the area of a circle that has corresponding circumference as watershed's perimeter. Miller (1953) marked out Rc as a remarkable ratio indicating that watershed is at dendritic stage. Geomorphic phases watershed's life cycle is indicated by low to high values of Rc (Wilson et al. 2012). The values of Birma and its sub watersheds are mentioned in table 4 . Rc values of sub watersheds is of low to medium which is an indication of youth to mature stages. Birma basin shows low circularity ratio suggesting high relief along with permeable surface and subsurface.

1.2.6 Elongation ratio (Re)

It shows proportional relation of diameter of a circle which has equal basin area to the maximal basin length Schumm (1956). High elongation value designates better infiltration capacity and surface runoff. Strahler (1964) categorized elongation as: 0.9-1.0 is considered as circular, 0.8- 0.9 as oval, 0.7-0.8 as less elongated, 0.5-0.7 as elongated and <0.5 as more elongated. In the area of interest, Birma and its sub watersheds shows Re value in the ranges 0.5-0.7 which signifies elongated shape. The values of elongation ratio are shown in table 4.

1.2.7 Constant of channel maintenance (Cc)

The inverse of Dd, according to Schumm (1956), is the constant of channel maintenance. It gives an approximate information of reservoir's area in sq. Km required to perpetuate a Km. of a channel. High Cc values shows high permeability and low Cc values shows low permeability. In this study, shows high Cc values indicating high permeability. The values of Cc are shown in table 4.

Table 4 Areal Parameters of Birma Basin

Parameters	Sub-Watersheds										
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	BW
AREA(Km^2)	81.5	129.9	185.5	227.6	152.6	232.7	361.9	68.8	96.4	69.7	2589.7
DD(Km/Km^2)	0.38	0.59	0.40	0.41	0.55	0.53	0.48	0.50	0.45	0.46	0.49
Lu(Km^{-2})	0.17	0.27	0.11	0.17	0.15	0.16	0.13	0.13	0.11	0.13	0.13
Rf	0.22	0.4	0.23	0.18	0.34	0.31	0.32	0.26	0.24	0.27	0.29
Rc	0.20	0.24	0.14	0.18	0.25	0.25	0.26	0.35	0.27	0.33	0.18
Re	0.5	0.7	0.5	0.4	0.6	0.6	0.6	0.5	0.5	0.5	0.6
Cc	2.6	1.29	2.5	2.4	1.8	1.8	2.08	2	2.22	2.17	2.04
Lo	1.3	0.84	1.25	1.23	0.9	0.9	1.04	1.0	1.11	1.08	1.02

1.2.8 Length of Overland Flow

It is the half of constant of channel maintenance i.e inverse of drainage density by Horton (1945). As per Horton (1945) it is the extent of water flowing atop land surface prior to getting enfolded into the primary channel which influences the hydrogeological parameters of the watershed. When the rainfall surpasses the infiltration capacity of the soil, the surplus water which flows atop of the land surface is termed as overland flow Suresh (2000). This is more noticeable in mini/micro watersheds as because of small areal extent, it takes lesser rainfall to produce large overland flow. In contrast to this, in large watersheds it takes sufficient amount of rainfall for overland flow to generate. The maximal extent of overland flow is marked by youth stage and depletion in overland flow is marked by old stage. The values of Lo of Birma and its sub watershed are shown in table 4.

1.3 Relief Parameters

1.3.1 Relief ratio (Rr)

It implies to the ratio when the basin relief is fractioned by the maximum lengthwise stretch of the basin Horton (1945). It evaluates altogether the gradient of a drainage basin and acts as an index of intensity of an erosion processes functioning at the basin's gradient. Rr shows steepness and intensity of erosive power in a watershed. High Rr suggests stream's high erosive power which results in excessive sediment loss and low relief ratio. The Rr values of the Birma and its sub watersheds is shown in table 5 , indicating gentle gradient, less sediment loss of the Birma river basin.

1.3.2 Basin Relief (R)

It is the elevation variance between the uppermost and the lowermost points of the drainage basin. Its a principal aspect for knowing about the denudational attributes of the river basin. The basin relief of the Birma watershed is 254m which indicates gentle slope. The basin relief values of Birma basin and its sub-watersheds is shown in table 5

1.3.3 Melton Ruggedness Number (MRN)

In accordance with Melton (1965), it is a slope index which suggests particularized presentation of relief ruggedness throughout the drainage basin. The values of MRN is shown in the table 5. In the study area, sub- watershed S2, S4, S10 indicates that the transport of sediment is controlled by bed loads in accordance with Wilford et al. (2004) classification. Birma watershed with MRN of 5.0 indicates that the transport of sediment is not controlled by bed loads.

1.3.4 Ruggedness Number (RN)

As suggested by Strahler (1958), it is a product of drainage density and basin relief. It shows roughness in a surface as a consequence of several erosive work in watershed. Low RN indicates that watershed has levelled surface with little disintegration of relief. It also shows that watershed attained penultimate stage of geomorphic cycle. The values of the RN are shown in the table 5 , which suggests that the Birma watershed has even terrain and less rugged with low gradient.

1.3.5 Gradient Ratio (Rg)

Being an index of channel gradient, it evaluates the run off volume (Sreedevi et al. 2014). The Rg values of Birma watershed is 0.002 indicating low relief of the basin with flat terrain. The sub watersheds also represent the same. The values of gradient ratio is shown in table 5.

Table 5 Relief Parameters of Birma Basin

Parameter	Sub- Watersheds										
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	BW
Rr	0.002	0.006	0.002	0.005	0.005	0.006	0.004	0.003	0.003	0.006	0.002
R	0.056	0.057	0.078	0.017	0.021	0.184	0.157	0.05	0.06	0.10	0.25
RN	0.02	0.03	0.03	0.07	0.11	0.09	0.07	0.02	0.02	0.05	0.12
MRN	6.2	10.5	5.7	11.7	9.6	10.2	8.2	6.5	6.2	13.0	5.0
Rg	0.006	0.002	0.002	0.002	0.005	0.005	0.006	0.004	0.003	0.003	0.002

1.4 Hypsometric Curve

According to Strahler (1952), hypsometry is well-defined as total gradient and shape of the drainage basin. Hypsometric curves are associated with soil mass volume in basin and erosion in a basin with respect to the remaining mass (Hurterz et al. 1999). In this study, hypsometric curve of the Birma watershed is similar to S-shaped curve shown in figure 5 which shows that the watershed experiences moderate erosion activities. The HI values of Birma watersheds ranges from 0.22 to 0.55 which shows mature stage of the landscape development. The values are shown in table 6.

Table 6 Hypsometric Integral Values of Birma River Basin

Sub – Watersheds	Mean Elevation	Minimum Elevation	Maximum Elevation	Hypsometric Integral Value(HI)
S1	123.65	94	150	0.52
S2	125.3	96	153	0.51
S3	136.6	93	171	0.55
S4	178.3	134	311	0.25
S5	188.51	137	348	0.24
S6	204.2	162	346	0.22
S7	215.2	159	316	0.35
S8	150.6	122	177	0.52
S9	156.3	137	199	0.31
S10	168.2	138	246	0.27

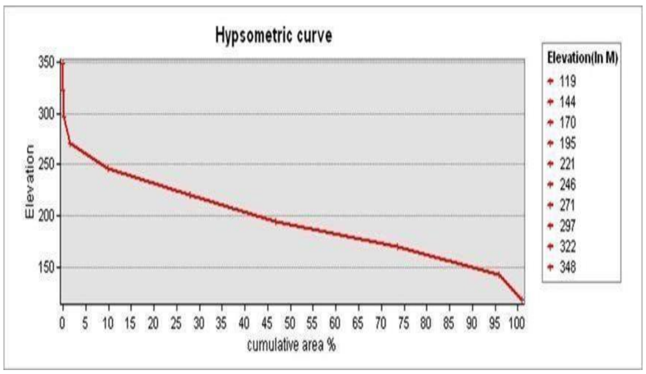

Figure 5 Hypsometric Curve Of Birma Watershed

1.5 Prioritization And Assortment Of Sub-Watersheds

Watershed prioritization postulates to categorizing watersheds utilising analysed morphometric parameters, giving priority ranks so that it can be taken into consideration for water and soil conservation methods. Table 7 represents preliminary ranking of sub watersheds by ranking of various morphometric parameters. As linear parameters are congruent with soil erosion, their uppermost value is graded first priority and the lowest value is assigned as the least priority. Shape parameters (Rc,Re, Rf etc.) are ranked in inverse form (Gajbhiye et al. 2014). Smallest value of shape parameters are assigned the first priority and highest value assigned the least priority. Same rank is given to parameters having same values. After the preliminary ranking is done using linear and shape parameters, compound factor value then computed of each sub watersheds using weighted Sum approach (WSA). A correlation matrix is generated between morphometric parameters is shown in table 8 . The formula for computation of WSA is shown in eq. 1 as described in chapter 3 under methodology adopted for morphometric analysis. From the table 8 , it is evident that Rbm and Rc (0.664), Dd and Fu (0.516), Dd and Rf (0.876), Dd and Re (0.827), Rf and Re (0.964) shows suggestively high positive correlation, whereas Lo and Re (-0.802), Dd and Lo (-0.99) shows low correlation. Further, Dd have mostly positive correlation with other parameters and Lo have negative correlation with other parameters. Figure 6 shows prioritization map of Birma basin.

Weighted compound factor value is calculated applying equation 1 with values ranging from 0.040 to 0.28, as shown in table 5.6. On the basis of priority, sub watershed S2 has the least value, 0.846, gets highest priority "I', whereas S3 has highest value of 9.285, hence given the least priority rank 'X'. S5, S6, S7, S8 are given II, III, IV, V ranks respectively. In addition to this, sub watersheds are correspondingly classified into medium, high and low groups to identify critical to sub critical areas which needs to be specified main priority for soil and water management methods. S2, S5, S6 have least compound factor value and comprises 515.2 Km2 area, hence are the most critical sub watersheds, S1, S3 are low in terms of critical zones, hence are low priority areas.

Table 7 Preliminary Ranking of Sub Watersheds

Sub watersheds	Rbm	Dd	DT	Fu	Rf	Lo	Rc	Re	Cc	Compound Factor
S1	5	10	6	2	9	1	8	5	10	9.16
S2	10	1	5	1	1	10	7	1	9	0.846
S3	3	9	9	9	8	2	10	5	1	9.285
S4	7	8	4	2	10	3	9	10	2	8.974
S5	4	2	1	5	3	8	5	2	7	1.709
S6	8	3	3	4	4	8	5	2	7	2.542
S7	6	5	2	6	2	6	4	2	5	2.878
S8	1	4	6	6	6	7	1	5	6	3.877
S9	9	7	9	9	7	4	3	5	3	7.04
S10	2	6	8	6	5	5	2	5	4	5.08

Table 8 Correlation Matrix of Sub-watersheds

	Rbm	Dd	DT	Fu	Rf	Lo	Rc	Re	Cc
Rbm	1	-0.091	-0.335	-0.410	-0.229	0.046	0.664	-0.349	0.142
Dd	-0.091	1	0.404	0.516	0.876	-0.990	0.440	0.827	0.096
DT	-0.335	0.404	1	0.052	0.390	-0.424	-0.057	0.303	0.035
Fu	-0.410	**0.516**	0.052	1	0.498	-0.423	-0.139	0.559	-0.358
Rf	-0.229	**0.876**	0.390	0.498	1	-0.858	0.292	0.964	-0.043
Lo	0.046	-0.990	-0.424	-0.423	-0.858	1	-0.504	-0.802	-0.127
Rc	**0.664**	0.440	-0.057	-0.139	0.292	-0.504	1	0.149	0.069
Re	-0.349	0.827	0.303	0.559	**0.964**	-0.802	0.149	1	-0.180
Cc	0.142	0.096	0.035	-0.358	-0.043	-0.127	0.069	-0.180	1
Sum of correlations	0.436	3.078	1.368	1.294	2.890	-3.083	1.912	2.472	0.633
Grand Total	11.002	11.002	11.002	11.002	11.002	11.002	11.002	11.002	11.002
W (Weight)	0.040	0.280	0.124	0.118	0.263	-0.280	0.174	0.225	0.058

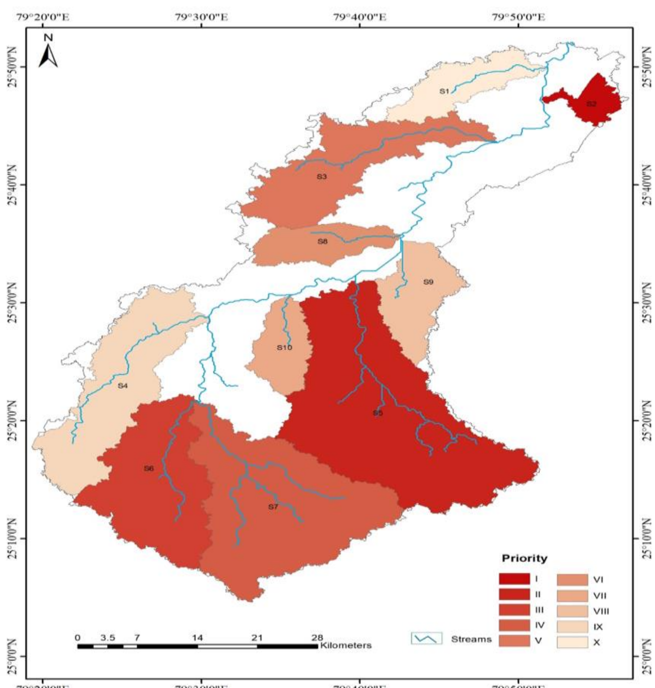

Figure 6 Prioritization of Sub-watersheds of Birma Basin

VIII. CONCLUSION

In this research, detailed analysis of morphometric parameters of Birma river basin are evaluated for better understanding of geomorphological and hydrogeological features. These parameters have been further utilized for prioritization of sub watersheds to identify critical to sub critical zones for soil conservation. From morphometric analysis, it is concluded that Birma watershed have fifth order basin. Its mean bifurcation ratio suggests that most of its sub watersheds shows lack of structural control. Its drainage density shows it has coarse drainage texture, dense flora, low relief and its subsurface material is permeable. Its shape factor i.e. Rc, Re, Rf, suggests that it is elongated in shape. The basin relief and ruggedness number show that basin has gentle slope and smooth terrain with less rugged surface. The S- shaped hypsometric curve indicates that watershed experiences moderate erosion and its hypsometric integral (HI) value suggests mature geomorphic stage of the basin.

The area being a hard rock terrain, where groundwater is confined to weathered and fractured zones, prioritization of watersheds could aid in proper development and management of ground water potential zones to narrow down the water scarcity of the area. Sub watershed covers maximum area percentage of, which recommends that it is most susceptible to soil erosion and therefore requires more attention for its management and conservation measures. Area occupied by watershed S8 and S10 is only 8%, which is least susceptible to erosion and requires little attention. The geospatial technology can be used in groundwater recharge, rainwater harvesting, slope analysis, LU/LC, along with advance geospatial technology. Applications of prioritization of sub watersheds includes management and conservation of soil and aquatic resources from base level. It also gives a better perspective of groundwater condition for policy and decision makers.

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