MORPHOMETRIC ANALYSIS AND PRIORITIZATION OF VASHISHTHI WATERSHED

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ABSTRACT

In this study, morphometric analysis and prioritization of the four sub catchments of Vashishthi Watershed located between Ratnagiri district in Maharashtra state, India is carried out by employing Remote Sensing and Geographic Information System (GIS) techniques using satellite imageries and topographic maps on a scale map of 1:50000. Vashishthi watershed has dendritic drainage pattern. The morphometric parameters are discussed about Linear, Aerial and Relief aspect. The drainage density of the study area varies from 0.730 to 0.742 Km/km^2 which observed that high permeable sub-soil. The bifurcation ratio varies from 1.9 to 2.6 which indicates geology is reasonable homogeneous and no structural disturbances. The morphometric analysis explains sub catchment 3 shows lower values of drainage density and stream frequency, and sub catchment 1 shows lower values of form factor, texture ratio and elongation ratio. The compound parameter values are calculated and the lowest compound parameter value is given the highest priority. The results of this analysis would be useful in distribution of streams network with respect to sub watersheds and determine the effect of characteristics of the catchments such as shape, size, slope.

Keywords: *GIS, Morphometric Parameters, Priority, Vashishthi Waterhsed*

I. INTRODUCTION

Watershed Management is a technique to protect and improve the quality of the water and also control erosion in the catchment area in a comprehensive manner. (Sahil Salvi et.al 2017). Morphology is the study of forms or structures which is quantitative determination of landform. Morphometric analysis is the measurement and mathematical evaluation of the earth's surface, shape and dimension of its landform (Agarwal , 1998; Obi Reddy et al, 2002). Morphometric analysis is very useful in drainage basin evaluation, silt erosion control, flood frequency analysis, watershed prioritization, natural resources management & conservation. Watershed prioritization is the scientific process of watershed delineation and monitoring (Kartic Bera et.al; 2013). The prioritizing of sub watershed based on linear aspect (La) Ariel aspects (Aa) & Relief Aspects (Ra) which are classified in three class i.e. high, medium, low. In recent years, development of GIS techniques helps the scientists and researchers to study a characteristics of basins and streams. The present study also has been done using GIS technique to analysis the Vashishthi Watershed.

II. STUDY AREA

The watershed area of Vashishthi river is 1900 Sq.kms., and located at Chiplun taluka, Ratnagiri district in Maharashtra State, India. The geographical location of drainage basin is from $73^{0}15^{'}$ E to $73^{0}45^{'}$ E and $17^{0}45^{'}$ N to $17^{0}15^{'}$ N. The study area falls in Survey of India (1:50000) toposheets No. 47G6, 47G7, 47G10, 47G11. There is only one main tributary of Vashishthi river which Jagbudi river.

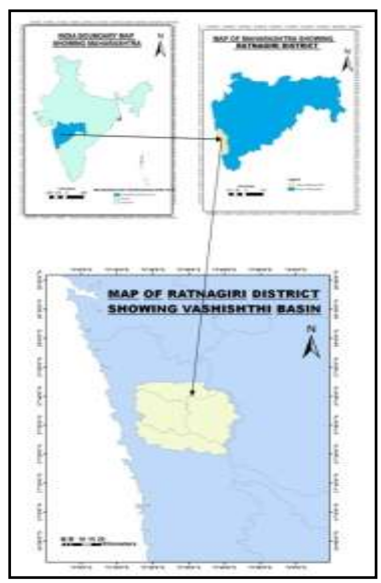


Fig. 1 Location Map of Vashishthi Basin

III. AIM AND OBJECTIVES OF THE STUDY

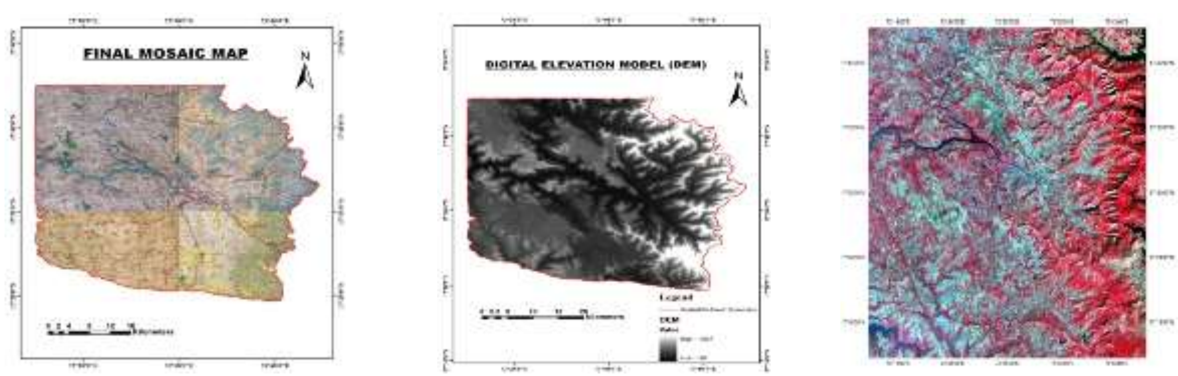
The main aim of the study is to maximize the benefits of water use based on watershed management by morphometric parameters & prioritization of sub basin for present land use.

The objectives of the study are following:

1. To study hydrological aspect of Vashishthi watershed and inter-relate with morphometric analysis.
2. To identify drainage bifurcation system and their nature.
3. To plot boundary of basin and sub-basin.
4. To delineate the watershed boundary up to mini watersheds wise with the help of the GIS software and GPS.
5. To study all morphomeric parameter of each sub-catchment and to do analysis with hydrological characteristic of basin.
6. To study IRS LISS-III image to generate map of land use land cover (LULC) of the Vashishthi watershed.
7. Final prioritization of the watershed through morphometric analysis and present land use land cover (LULC).

IV. DATABASE AND METHODOLOGY

Morphometric analysis and prioritization of sub catchments in Vashishthi watershed is carried out by using Remote Sensing and GIS techniques. Morphometric analysis of a drainage basin requires the delineation of all the existing streams and digitization of basin is carried out using ARC GIS 9.0 software. The topographical maps (toposheets) were georeferenced and mosaicked and total area was delineated with the help of ARC GIS 9.0 software assigning Universal Transverse Mercator (UTM) and World Geodetic System (WGS 1984) with 43 N zone projection system. Delineation of the Vashishthi watershed and the preparation of drainage map is based on Digital Elevation Model (DEM). The satellite image taken by 1RS-P6 (Resource Sat –I) having LISS III (medium resolution sensor) on 13 Jan 2013 were used for preparing Land use & Land cover data. The sub-catchments boundaries were demarcates on the basis of Slope, Contour value, No. of streams, Flow direction, Relief and the Vashishthi watershed divided into four sub catchments. Morphometric parameters such as Bifurcation Ratio, Drainage Density, Stream Frequency, Texture Ratio, Form Factor, Circulatory Ratio, Elongation Ratio, Length of Overland Flow, Constant Channel Maintenance Infiltration Number, Relief Ratio, Ruggedness No. were computed using standard formulae & methods (Horton, 1945; Strahler, 1964,1957; Schumn, 1956; Miller, 1953; Faniran, 1968).



(i) **(ii)** **(iii)**

Fig. 2 (i) Mosaic Toposheets showing boundary of Vashishthi basin; (ii) DEM of Vashishthi basin; (iii) LISS III Image of Vashishthi basin

Prioritization of all four sub catchments was carried out by calculating the compound parameter values & gave highest priority to lowest compound value.

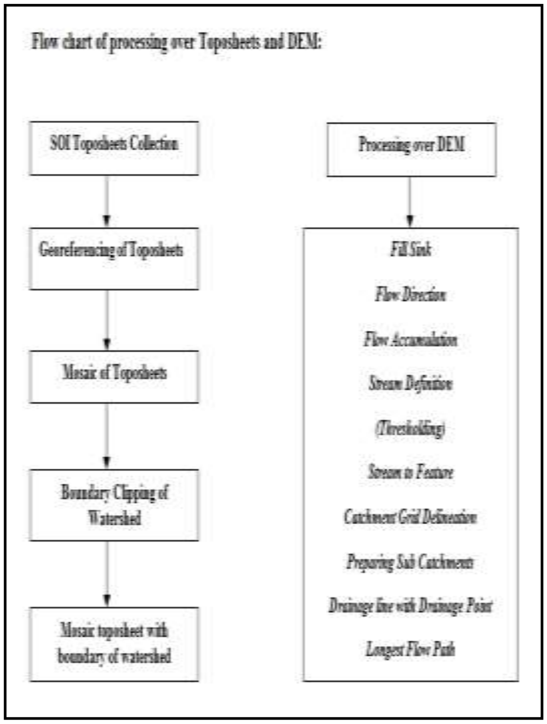


Table 1 The formula for computation of morphometric parameters

Aspects	Morphometric Parameters	Formula	References
LINEAR	Stream Order (U)	Hierarchical Order	Strahler, 1964
	Stream Length (Lu)	Length of the Stream in km	Horton, 1945
	Mean Stream Length (Lsm)	**Lsm = Lu/Nu** Where, Lu = Total stream length of order 'u'; Nu = Total no. of stream segments of order 'u'	Horton, 1945
	Stream Length Ratio (RL)	**RL = Lsm / Lsm-1** Where, Lsm=Mean stream length of a given order ; Lsm-1 = Mean stream length of next lower order	Horton, 1945
	Bifurcation Ratio (Rb)	**Rb = Nu / Nu +1** Where, Rb = Bifurcation Ratio ; Nu = No. of stream segments of a given order ; Nu +1 = No. of stream segments of next higher order	Schumm, 1956
AREAL	Drainage Density (Dd)	**Dd = Lu/A** Where, Dd = Drainage Density (1/km) ; Lu = Total stream length of all orders ; A = Area of the basin (km^2)	Horton, 1945
	Stream Frequency (Fs)	**Fs = Nu/A** Where, Fs = Stream Frequency ; Nu = Total no. of streams of all orders and ; A = Area of the basin (km^2)	Horton, 1945
	Texture Ratio (T)	**T = Nu /P** Where, Nu = No. of streams in a given order ; P = Perimeter of basin (km)	Horton, 1945
	Form Factor (Rf)	**Rf = A/Lb²** Where, A = Area of the basin ; Lb = Basin length	Horton, 1932
	Circulatory Ratio (Rc)	**Rc = 4πA/P²** Where, A = Basin area (km^2) ; P= Perimeter of the basin (km)	Miller, 1953
	Elongation Ratio (Re)	**Re= (A /π) / Lb** Where, A= Area of the basin (km^2) ; Lb= Basin length (km)	Schumm, 1956
	Length of Overland Flow (Lof)	**Lof = 1/ 2Dd** Where, Dd = Drainage Density	Horton, 1945
	Constant Channel Maintenance (C)	**C = 1/Dd** Where, Dd = Drainage Density	Horton, 1945
	Infiltration Number (If)	**If = Dd × Fs** Where, Dd = Drainage density ; Fs = Drainage frequency	Faniran, 1968
RELIEF	Relief Ratio (Rh)	**Rh = H / Lb** Where, H = Basin Relief (km) ; Lb = Basin length (km)	Schumm, 1956
	Ruggedness Number (Rn)	**Rn = H x Dd** Where, H = Basin Relief (km) ; Dd = Drainage Density	Schumm, 1956

V. ANALYSIS AND DISCUSSION

5.1 Linear Aspect:

Linear aspects of the watershed are mainly connected with channel patterns of drainage network where topological characteristics of the streams are analyzed. It include the Stream Orders (U), Stream Length (Lu), Mean Stream Length (Lsm), Stream Length Ratio (RL) , Bifurcation Ratio (Rb) were determined & presented in Table 3.

Table 3 Linear aspect of the Vashishthi Watershed

Sr. No.	Stream Order	Stream Length (Lu)	Mean Stream Length (Lsm)	Cumulative Mean Stream Length (Lsm)	Stream Length Ratio (RL)
1	1	689.278	1.218	1.218	
2	2	344.865	1.311	2.529	1.076
3	3	218.704	1.272	3.801	0.970
4	4	95.568	1.309	5.11	1.029
5	5	49.003	1.195	6.305	0.91

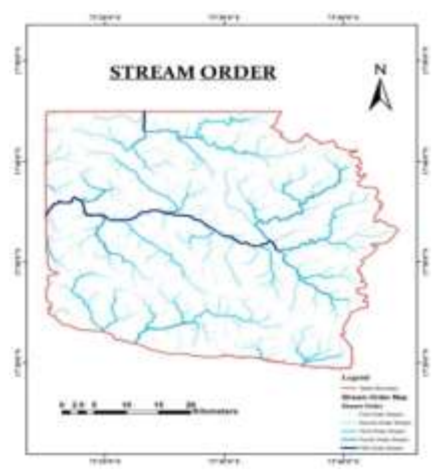


Fig. 5 Stream order of Vashishthi basin

5.1.1. Compound parameter (Cp) of linear Aspects :

Compound parameter of Vashishthi basin of linear aspects prominently affected by bifurcation ratio of streams in sub-catchments.

Table 4 Compound parameter of linear aspects of Vashishthi basin

Sub Catchments	CH1	CH2	CH3	CH4
Bifurcation Ratio (Rb)	2.59	1.93	2.28	2.5
Total Linear Cp Value	**2.59**	**1.93**	**2.28**	**2.5**

Fig. 6 Compound Parameter of Linear Aspect of Vashishthi basin

5.2. Aerial Aspects:

Area of a basin (A) and perimeter (P) are the important parameters in watershed analysis. Basin area directly affects the size of the storm hydrograph, the magnitudes of peak and mean runoff. The total area of the Vashishthi watershed is 1900 km^2. The Aerial aspects of the drainage basin such as basin drainage density(Dd), stream frequency (Fs), texture ratio (T), elongation ratio (Re),circularity ratio (Rc) and form factor ratio (Ff) were calculated and results have been given in Table 5**.**

5.2.1 Stream Frequency (Fs)

It is the ratio of total number of all stream segments of all orders per unit area (Horton, 1945). It depends on lithology of the basin. The stream frequency values of the study area varies from 0.551 to 0.611. Fs value shows positive correlation with drainage density indicating increase in stream population with respect to increase in drainage density.

5.2.2 Drainage Density (Dd)

It is the ratio of total length of streams of all orders to the area of basin (Horton 1945). It indicates closeness of spacing of channel and stream eroded topography. It is affected by factors like soil and rock properties, infiltration rate, vegetation cover, climate etc. Dd in the study area varies between 0.733 to 0.742 indicating low drainage density. This suggests that, it has considerably high permeable sub-soil, coarse drainage texture, good vegetation cover results in more infiltration capacity in watershed.

Fig. 7 Drainage Density of Vashishthi basin

5.2.3 Texture Ratio (T)

It is the total number of stream segments of all orders per perimeter of the area (Horton, 1945). T of Vashishthi watershed varies from 1.218 to 1.922 shows very coarser in drainage texture.

5.2.4 Form Factor (Ff)

It is the ratio of the area of the basin to the square of basin length (Horton, 1932). The value of form factor is in between 0.20-0.43. Smaller the value of form factor, more elongated will be the basin. The basins with low form factors have low peak flows of longer duration .

5.2.5 Elongation Ratio (Re)

It is the ratio between diameter of the circle of the same area as the drainage basin and the maximum length of the basin (Schumn, 1965). The elongation ratio value of the Vashishthi watershed is in between 0.505-0.739. Values close to 1.0 are typical of regions of very low relief, whereas values in the range 0.6–0.8 are usually associated with high relief.

5.2.6 Circulatory Ratio (Rc)

It is the ratio of basin area to the area of circle having the same perimeter as the basin (Miller, 1953). It is mainly depend on the relief and slope of the basin, geological structures, land use/land cover, length and frequency of streams, climate. Rc value varies between 0.124 to 0.249 which shows elongated in shape and highly permeability of sub soil.

5.2.7 Infiltration Number (In)

The infiltration Number is defined as the product of Drainage Density and drainage Frequency (Faniran, 1968). Infiltration number of study area varies 0.4 to 0.45. If the infiltration number is high, low will be the infiltration with the higher runoff.

5.2.8 Length of Overland Flow (Lof)

Horton (1945) expressed it as equal to half of the reciprocal of Drainage Density (Dd). It is an important independent variable, which greatly affect the quantity of water required to exceed a certain threshold of erosion. Lof of study area varies 0.674 to 0.685.

5.2.9 Constant Channel Maintenance (C)

It is inverse of drainage density (Dd) (Horton, 1945). C of study area varies 1.348 to 1.370 indicates study area is under the influence of less structural disturbances and high relief in area.

5.2.2 Compound parameter (Cp) of linear Aspects :

Compound parameter (Cp) of Aerial aspect is the addition of Drainage density(Dd), Drainage frequency(Fs), Drainage Texture (Rt), Infiltration Number (If): Form Factor (Rf) Elongation Ratio (Re), Circularity Ratio (Rc), Length of Overland Flow (Lg), Constant channel maintenance (C) of each sub-catchments.

Cp of Aerial aspects of Vashishthi basin

$$= \boldsymbol{Dd + Fs + T + In + Ff + Re + Rc + Lof + C}$$

Table 5 Total Aerial Morphometric Parameter with Compound Parameter (Cp)

Aerial Morphometric Parameters	Sub-Catchments			
	CH1	CH2	CH3	CH4
Dd	0.738	0.742	0.730	0.733
Fs	0.604	0.598	0.551	0.611
T	1.218	1.751	1.922	1.266
In	0.446	0.444	0.402	0.448
Ff	0.20	0.21	0.29	0.43
Re	0.505	0.515	0.609	0.739
Rc	0.153	0.209	0.249	0.124
Lof	0.677	0.674	0.685	0.682
C	1.355	1.348	1.370	1.364
Total Aerial Cp	**5.896**	**6.491**	**6.808**	**6.397**

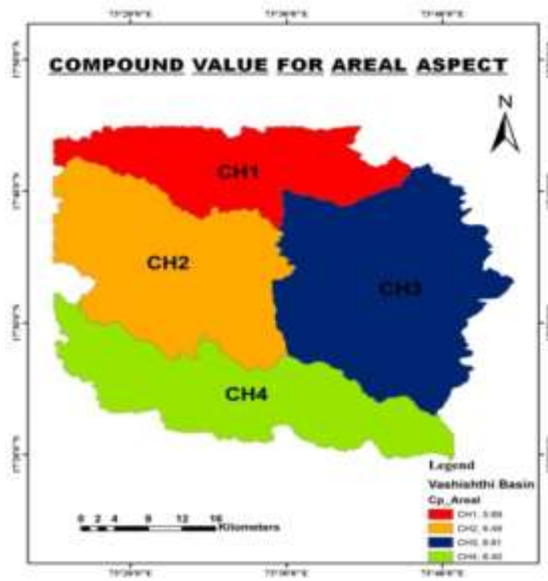


Fig. 8 Aerial Morphometric Parameter with Cp Map of Vashishthi basin

5.3 Relief aspects:

Basin relief, relief ratio and ruggedness number are the relief parameters. Relief aspect concerned with three dimensional features consists of the basin area, volume and altitude of landform which is used for analysis of terrain/geo-hydrology characteristics.

5.3.1 Basin Relief (H) :

Basin relief is the elevation difference of the highest and lowest point of the valley Floor.

5.3. Relief Ratio (Rh)

The relief ratio is the ratio of total relief of a basin to the longest dimension of the basin parallel to the main drainage line (Schumn, 1956). The Rh normally decreases with the increasing area and size of sub-basin of a given drainage basin (Gottschalk,1964). The relief ratio of study area varies from 0.006 to 0.029.

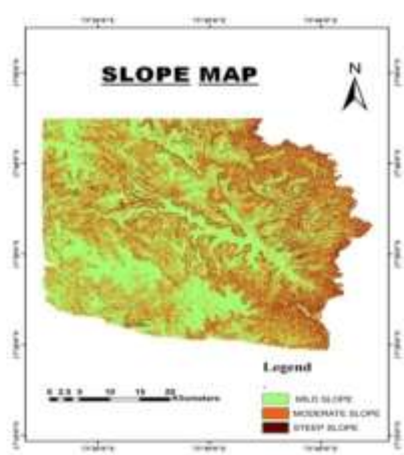


Fig. 9 Slope Map of Vashishthi basin

5.3.3 Ruggedness number (Rn)

It is the product of maximum basin relief (H) and drainage density (Dd), where both parameters are in the same unit. An extreme high value of ruggedness number occurs when both variables are large and slope is not only steep but long as well (Strahler,1956). Sub-catchment CH2 have value 0.227 indicates steeper slope and less time of concentration and high Runoff.

Cp of Relief Aspects of Vashishthi basin $= Rh + Rn$

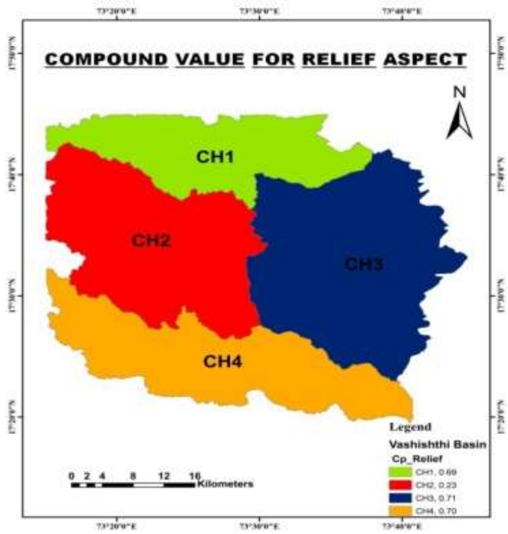


Fig. 10 Relief Morphometric Parameter with Cp Map of Vashishthi basin

5.4 Land Use and Land Cover

IRS-P6, LISS III image having spatial resolution 23.5m captured on 13 January 2013 was downloaded from BHUVAN site. It was processed in GEOMATICA 2015 digital image processing software for extracting the LULC map. The classification was done by using SOI TOPOSHEET and Google Earth image to get present LULC map. The LULC map is shown in Fig.12.

Table 7 Land use and Land cover of Vashishthi basin

Sr. No.	Land Use Classification	Area (km^2)	%	Description
1	Water	27.00	**1.02**	Blue
2	Forest	215.32	**8.14**	Green
3	Barren Land	570.09	**21.56**	Pale white
4	Residential Area	216.39	**32.57**	Red
5	Open Scrub	861.03	**32.56**	Yellow
6	Misc. Trees & Vegetation	109.89	**4.16**	Brown
Total		**1900**	**100**	-

Fig. 11 Google Earth Image of sub-catchments boundary

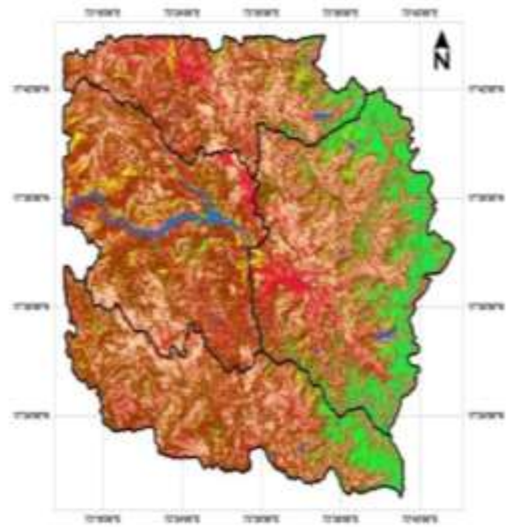


Fig.12 Land use and Land cover map

5.5 Final prioritization of sub-catchments of Vashishthi basin:

Final prioritization of Vashishthi watershed is done by using compound value of all Linear, Areal, Relief aspect and present land use and land cover. Based on total Cp compound value final ranking is allotted to each sub catchments of Vashishthi watershed and final prioritization is done.

Table 8 Sub-catchment wise Total Compound parameter (Cp)

Sub-Catchments	CH1	CH2	CH3	CH4
Total compound parameter (Cp) of Linear Aspects	2.59	1.93	2.28	2.5
Total compound parameter(Cp) of Aerial Aspects	5.90	6.49	6.81	6.40
Total compound parameter (Cp) of Relief Aspects	0.69	0.23	0.71	0.70
Total Compound parameter (Cp)	**9.18**	**8.65**	**9.8**	**9.6**

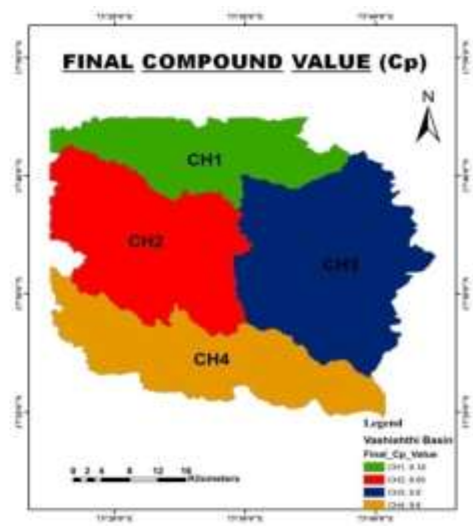


Fig. 13 Total Compound Value Map of Vashishthi basin Sub-catchments wise

Table 9 Sub-catchment wise Final priority based on Total Cp

Sub-Catchments	Total (Cp) value	Ranking	Final priority
CH1	9.18	2	MEDIUM
CH2	8.65	1	HIGH
CH3	9.8	4	LOW
CH4	9.6	3	MEDIUM

Fig 14 Prioritization Map of Vashishthi basin

VI. CONCLUSION

The present study demonstrates the usefulness of remote sensing and GIS techniques in prioritizing sub watersheds based on morphometric analysis. Following conclusions can be obtained from the present work on Vashishthi watershed.

1. The given study shows that DEM data with GIS techniques, proved to be a effective tool in morphometric analysis to understand terrain parameters such as the infiltration capacity, surface run off which helps in better understanding the status of land form, drainage planning and management.
2. Study area has fifth order basin with dendritic type of drainage pattern .
3. Study of morphometric parameters of sub catchments of Vashishthi watershed shows that sub catchment CH2 have less geological structural control and overall drainage density of study area is coarse type indicates high permeable soil.
4. From the Prioritization and analysis of study area, it has been found that CH2 and CH3 micro-watershed falls into a high to low priority category based on the water holding capacity in relation to morphometric analysis.
5. Highest priority indicates greater degree of erosion in that mini watershed and thus soil conservation measures structures such as nala bunds, percolation tank, contour trenches, recharge shaft, check dams, bench terracing etc. can first be applied to mini watershed area CH2 and then to the other mini watersheds depending upon their priority.

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