Morphometric Analysis for Prioritization Lower Bhima Basin by using Geographic Information System

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Abstract- *Watershed prioritization is the scientific process of watershed delineation and monitoring. The Lower Bhima sub-watershed is located in Solapur and Osmanabad districts of Maharashtra which is one of the most drought affected region of the state. Lower Bhima basin is sub basin of Krishna river basin which also known as K6 sub basin . For prioritization, six sub-catchments of lower Bhima basin are delineated i.e. (CH1 , CH2 ,CH3 ,CH4, CH5 CH6) and parameters such as Bifurcation ratio , Drainage density, Stream frequency ,Form factor, Texture ratio ,Elongation ratio ,Circulatory ratio, Length of overland flow, Constant of Channel maintenance are calculated separately and prioritization has been done by using the Raster calculator option of Spatial analyst. The Lower Bhima basin covers an area of 3364 sq km and is an 5th order drainage basin with mainly dendritic drainage pattern. The analysis reveals that the stream order varies from 1 to 5 and the total number of stream segments of all orders counted as 821. Morphometry, Lower Bhima basin, earth observation data, geographical The basin has medium drainage density of 0.65 per km2.The length of overland flow values of the basin is 0.875, indicating medium relief. Prioritization of Lower Bhima basin is done by calculating compound parameter (Cp) of each aspects of morphometric parameters and sub catchments with lowest is given highest priority and vise versa . Sub-catchments of CH2, CH4 have been found to be under high priority.*

Keywords- Morphometry, Lower Bhima basin, earth observation data, geographical Information system(GIS).

I. INTRODUCTION

Morphometry is an essential means in geomorphic analysis of an area. Morphometry is defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimension of its landforms (Clarke, 1966). Morphometric analysis is a significant tool for prioritization of sub-watersheds even without considering the soil map (Biswas et al., 1999). Morphometric analysis requires measurement of the linear features, gradient of channel network and contributing ground slopes of the drainage basin. Many works have been reported on morphometric analysis using GIS such analysis aided in understanding the hydrological, geological and topographical characteristics of lower Bhima basin. The prioritization is based on Compound value (Cp) of Morphometric parameters evulated using ARC GIS. Morphometric analysis involves a set of parameters like; Aerial aspects, linear aspects, Relief aspects.

II. AIM AND OBJECTIVES

The aim of the study is Watershed management based on present land use land cover (LULC) and Morphometric analysis. The objectives of the study are following:

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

III. STUDY AREA

The study area lower Bhima basin is sub- basin of Krishna river basin and it is also known as K6 sub basin . The area falls under Lower Bhima basin is shown fig(1) i.e. 3564 sq km and bounded by latitude 17º20'00" to 18º10'00"N and Longitude : 75º55'00 " to 76º 35' 00" E . The geographical area of sub basin is 3564.00 Sq.km Culture able command area (C.C.A) of lower Bhima basin is 3439sq.km. The Lower Bhima basin covers two district wiz Osmanabad and Solapur district. Five talukas are covered partly.

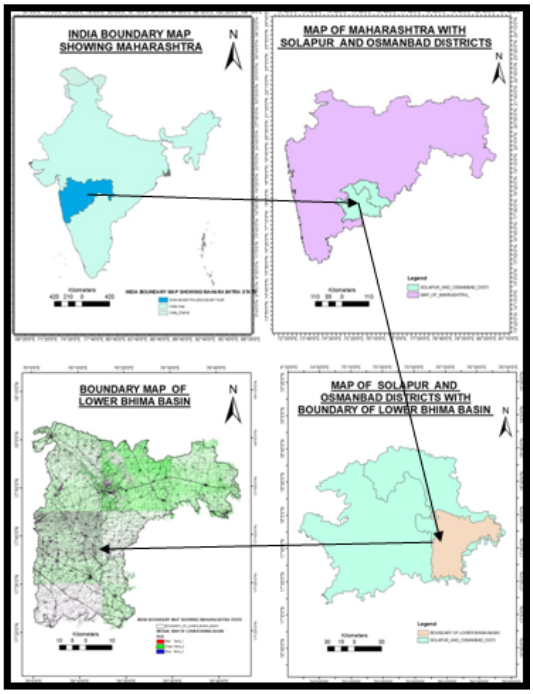


Fig. 1 – Location Map of Lower Bhima Basin

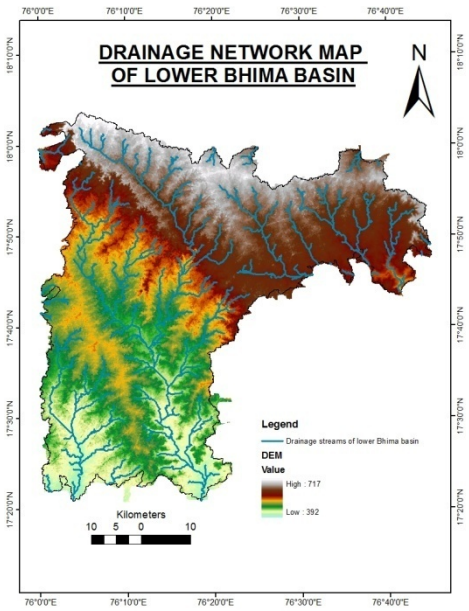


Fig. 2 – Drainage Map of Lower Bhima Basin

IV. MATERIAL AND METHODOLOGY

4.1 Material used:

1) Survey of India Toposheet (1:50000)
2) IRS-LISS 3 IMAGE
3) DEM (20m resolution)
4) Google Earth Image

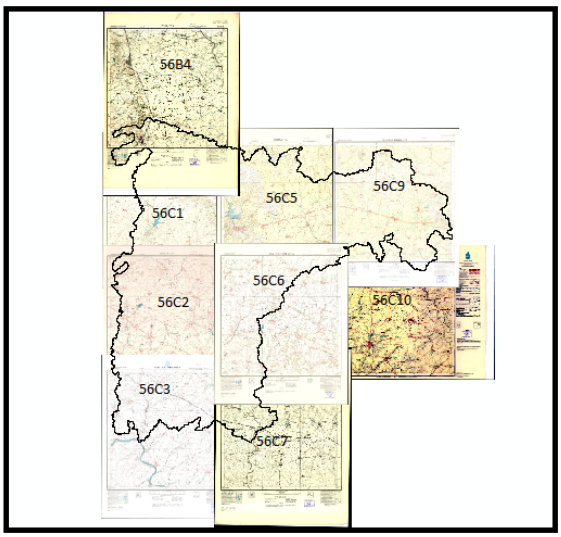


Fig 3- Mosaic Toposheets showing boundary of lower Bhima basin

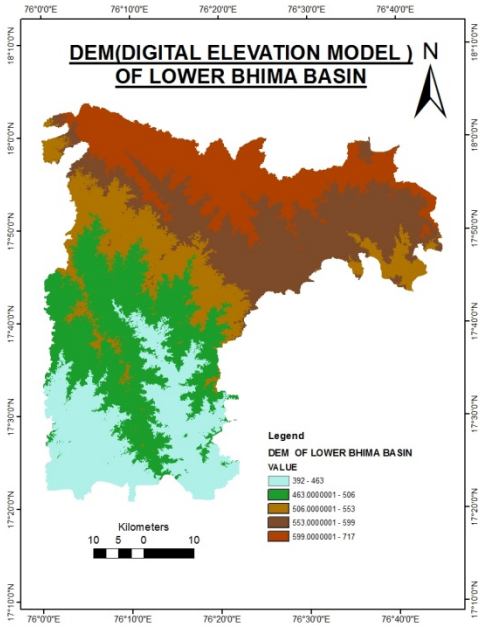


Fig 4- DEM of lower Bhima basin

4.2 Methodology:

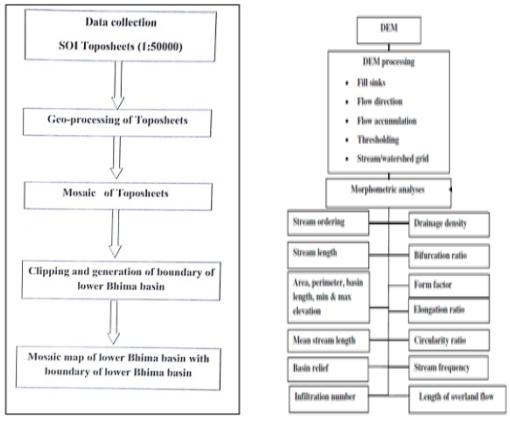
In the present study area covers of SOI Toposheets are 56B4, 56C1,56C2,56C3,56C5,56C6,56C7, 56C9,56C10. In present study the parameters considered for prioritization of sub-catchments are from the natural resources thematic data, including drainage density, irrigated area, forest cover and wastelands derived from imagery data. The thematic maps are derived from geo-referenced false color composite (FCC) satellite image of the Indian Remote Sensing (IRS) satellite series 1 – D(LISS III and PAN fused data) on 1:50000 scale with corresponding SOI toposheets as reference. For better accuracy of the thematic map, ground truth check is done for verification and necessary modifications are made in thematic

maps during post interpretation. The digitization of sub dendritic drainage pattern was carried out in GIS environment. The stream ordering is carried out using Horton's law. The fundamental parameters namely: stream length, area, perimeter, number of streams and basin length are derived from the drainage layer. The morphometric parameters for the delineated watershed area are calculated based on the formula suggested by (Horton, 1945),(Strahler, 1964), (Schumm, 1956), (Nookaratnam et al., 2005) and (Miller, 1953) given in table 1. Morphometric parameters like stream order, stream length, bifurcation ratio, drainage density, drainage frequency, relief ratio, elongation ratio, circularity ratio and compactness constant are calculated. Prioritization rating of all the six sub-catchments of lower Bhima basin is carried out by calculating the compound parameter values. The subwatershed with the lowest compound parameter value is given the highest priority.

Table 1 - Formulas of morphometric parameters

	Morphometric Parameters	Methods
LINEAR	Stream order (U)	Hierarchical order
	Stream length (Lu)	Length of the stream
	Mean stream length (Lsm)	Lsm = Lu/Nu where, Lu=Stream length of order 'U' Nu=Total number of stream segments of order 'U'
	Stream length ratio (Rl)	Rl=Lu/Lu-1; where Lu=Total stream length of order 'U', Lu-1=Stream length of next lower order.
	Bifurcation ratio (Rb)	Rb = Nu/ Nu+1; where, Nu=Total number of stream segment of order'u'; Nu+1=Number of segment of next higher order
RELIEF	Basin relief (Bh)	Vertical distance between the lowest and highest points of watershed.
	Relief ratio (Rh)	Rh=Bh/Lb; Where, Bh=Basin relief;Lb=Basin length
	Ruggedness number (Rn)	Rn = Bh × Dd Where, Bh =Basin relief; Dd=Drainage density
ARIAL	Drainage density (Dd)	Dd = L/A where, L=Total length of streams;A=Area of watershed
	Stream frequency (Fs)	Fs = N/A where, N=Total number of streams; A=Area of watershed
	Texture ratio (T)	T = N1/P where,N1=Total number of first order streams; P=Perimeter of watershed
	Form factor (Rf)	$Rf=A/(Lb)^2$;where, A=Area of watershed, Lb=Basin length
	Circulatory ratio (Rc)	$Rc=4\pi A/P^2$;where, A=Area of watershed, π=3.14, P=Perimeter of watershed
	Elongation ratio (Re)	$Re=2\sqrt{(A/\pi)}/Lb$;where, A=Area of watershed, π=3.14, Lb=Basin length
	Length of overland flow (Lof)	Lof = 1/2Dd where, Dd=Drainage density
	Constant channel maintenance (C)	Lof = 1/Dd where, Dd=Drainage density

4.3 Methodology Flow Chart



Flow chart Geo-processing of Toposheets and DEM processing

V. RESULT AND DISCUSSION

Morphometric analysis is done by using morphometric parameters these parameter are evaluated by using Arc Gis 9.3 and land use land cover map is generated using LISS 3 images and Geomatica 2013 software .For prioritization of lower Bhima basin study area is divided into sub catchments i.e. CH1,CH2,CH3,CH4,CH5,CH6.

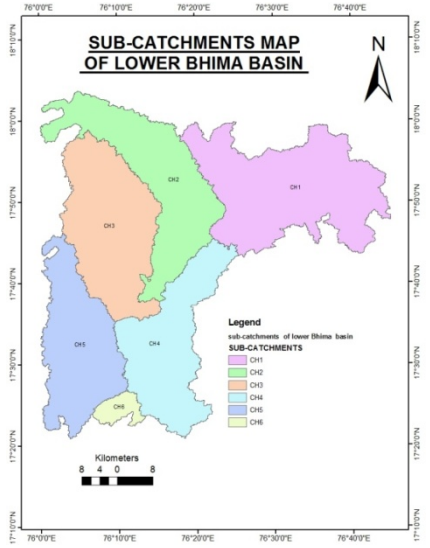


Fig 3 Sub-catchments map of lower Bhima basin

5.1 Linear Aspects :

Lower Bhima basin is fifth order basin having dendetric type drainage network**.** Stream order of lower Bhima basin varies from first to fifth order. Most of area of lower Bhima basin is covered by streams having 1st order .First order stream cover 933 sq.km area (i.e. 26%) of lower Bhima basin. More first order streams indicate more erosion of soil and high runoff . Mean stream length (Lsm) of lower Bhima basin is 1.87 indicates intermediate drainage network.

Table 2 Linear aspects of lower Bhima basin

Sr. No	Stream order (U)	Stream length(km) (Lu)	No of streams (Nu)
1	1	933.8	433
2	2	390.8	184
3	3	219.61	126
4	4	110.71	66
5	5	43.83	22

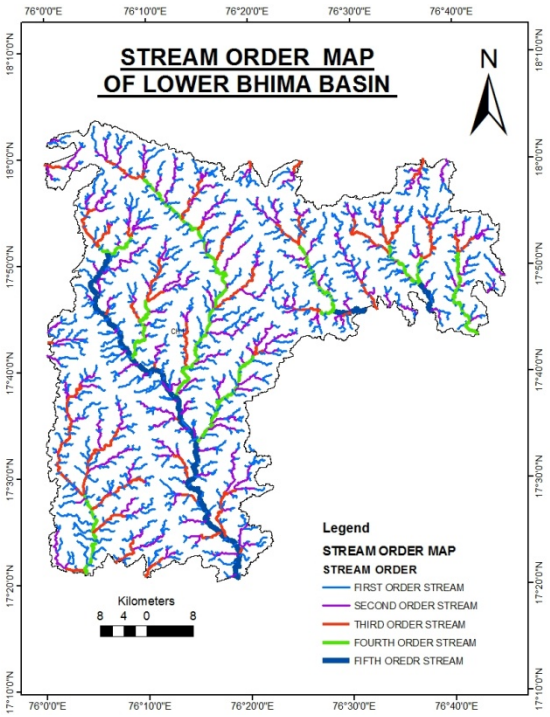


Fig 4 Stream order of lower Bhima basin

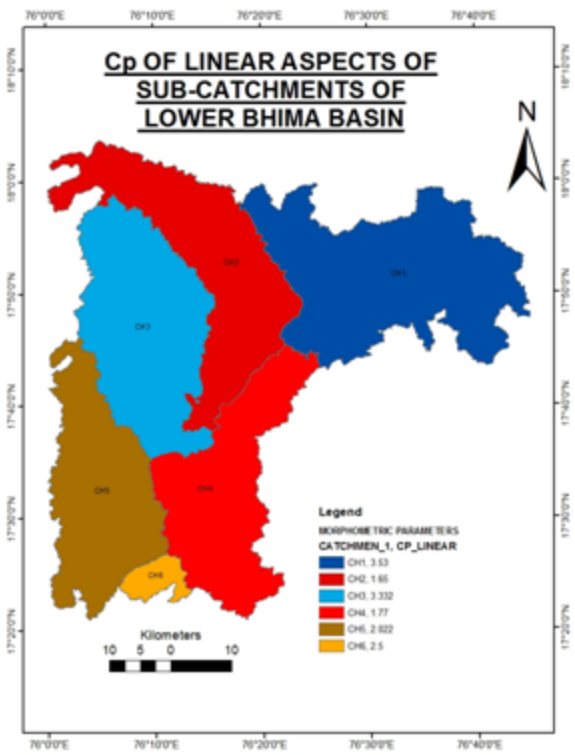


Fig 5 Cp value of linear aspect

5.1.1. Compound parameter (Cp) of linear Aspects:

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

Table 3 Compound parameter (Cp) of linear Aspects

Sub-catchments	CH1	CH2	CH3	CH4	CH5	CH6
Length of basin (km)	37.7	74.1	66.4	69.8	51.8	15.
Mean Stream Length (Lsm)	1.79	2.2	1.92	2.05	1.81	1.5
Bifurcation ratio (Rb)	3.53	1.65	3.33	1.77	2.02	2.5
Total linear Cp value	**3.53**	**1.65**	**3.33**	**1.77**	**2.02**	**2.5**

5.2. Aerial Aspects:

The areal aspect is the two dimensional properties of a basin. The Aerial morphometric parameters directly affect the size of the storm hydrograph and magnitudes of peck and mean runoff is the basin area. The maximum flood discharge per unit area is inversely related to the size of the basin. It is possible to delineate the area of the basin which contributes water to each stream segment (Stream).

5.2.1 Drainage density (Dd) :

Dd is a measure of the texture of the network, and indicates the balance between the erosive power of overland flow and the resistance of surface soils and rocks. The factors affecting drainage density include geology and density of vegetation. Overall Dd of lower Bhima basin is 0.65.As the value of Drainage density is less than 3 it is coarse type of drainage density indicates that moderately flat terrain and overall high infiltration capacity.

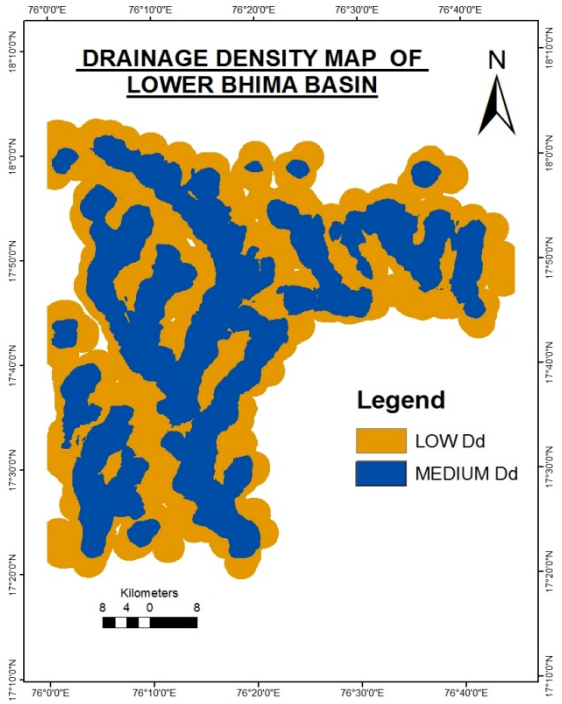


Fig 6 Drainage density map of lower Bhima basin

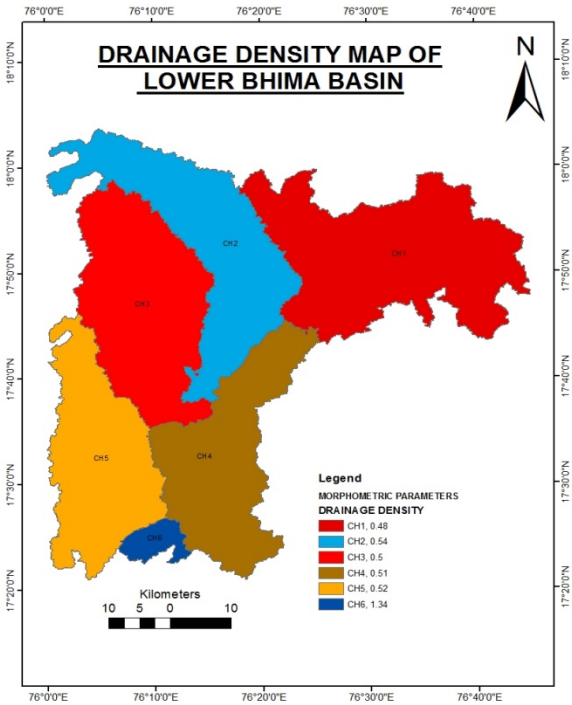


Fig 7 Drainage density map sub-catchment of lower Bhima basin

5.2.2 Stream frequency (Fs):

Drainage frequency may be directly related to the lithological characteristics. The number of stream segments per unit area is termed Stream Frequency or Drainage Frequency (Fs) Horton (1945). Fs of lower Bhima basin is 0.26

5.2.3 Form Factor (Rf):

Form factor (Rf) may be defined as the ratio of the area of the basin to the square of basin length (Horton, 1932). It is the quantitative expression of drainage basin outline form. Smaller the value of form factor, more elongated will be the basin. Form factor (Rf) value of the study area is 0.23

5.2.4 Drainage Texture (Rt)

Horton (1945) defined drainage texture is the total number of stream segments of all order in a basin per perimeter of the basin. Drainage texture is on the underlying lithology, infiltration capacity and relief aspect of the terrain. Rf of LB is 0.53.

5.2.5 Infiltration Number (If)

The infiltration Number is defined as the product of Drainage Density (Dd) and drainage Frequency (Fs) Infiltration no of lower Bhima basin is 0.182.

5.2.6 Elongation ratio (Re):

Elongation ratio (Re) is the ratio between diameter of the circle of the same area as the drainage basin and the maximum length of the basin. The elongation ratio value of the Lower Bhima basin is 0.48, which indicates that the major part of basin is of low relief.

5.2.7 Circulatory ratio (Rc):

Miller (1953) defined a dimensionless circulatory ratio (Rc) as the ratio of basin area to the area of circle having the same perimeter as the basin. Circulatory ratio (Rc) is mainly concerned with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin.In the study area, the Rc value is 0.11

5.2.8 Length of Overland Flow (Lg):

The term length of overland is used to describe the length of flow of water over the ground before it becomes concentrated in definite stream channels. Horton (1945) expressed it as equal to half of the reciprocal of Drainage Density (Dd).Lg of study area is 0.875.

5.2.9 Constant channel maintenance (C):

Schumm (1956) used the inverse of drainage density as a property termed constant of stream maintenance C. This constant, in units of square feet per foot, has the dimension of

length and therefore increases in magnitude as the scale of the land-form unit increases. The value of C is 1.74.

5.2.2 Compound parameter (Cp) of linear Aspects:

For prioritization of lower Bhima basin is based on compound value (Cp) of Aerial aspects. Compound parameter (Cp) of Aerial aspect depend on 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 lower Bhima basin = $Dd + Fs + Rt + If + Rf + Re + Rc + Lg + C$

Table 4 Areal parameter with Cp

Sub-Catchments	CH1	CH2	CH3	CH4	CH5	CH6
Dd	0.48	0.54	0.50	0.51	0.52	1.34
Fs	0.26	0.23	0.24	0.24	0.26	0.34
Rf	0.6	0.11	0.15	0.11	0.2	0.25
Rt	0.63	0.44	0.68	0.54	0.57	0.39
If	0.12	0.13	0.12	0.12	0.13	0.46
Re	0.87	0.38	0.43	0.37	0.5	0.28
Rc	0.08	0.07	0.14	0.11	0.11	0.17
Lg	1.02	0.92	1	0.98	0.95	0.37
C	2.04	1.85	2	1.96	1.89	0.74
Total Aerial Cp	**5.62**	**4.67**	**5.26**	**4.94**	**5.13**	**4.34**

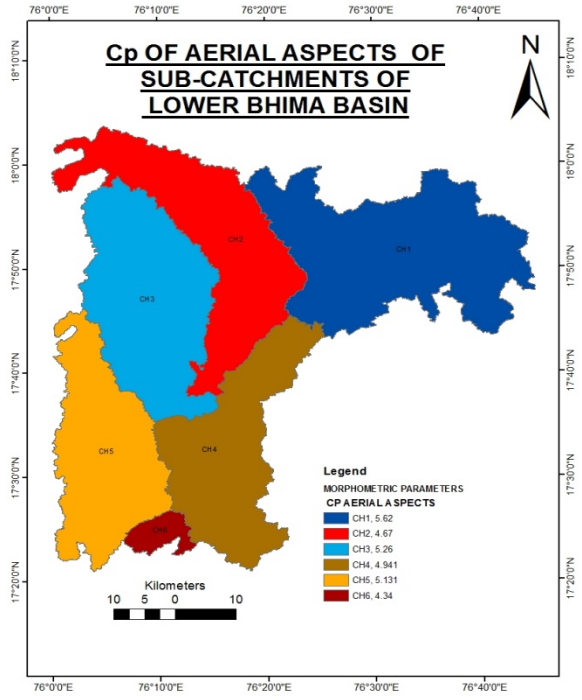


Fig 8 Cp of aerial aspects

5.3 Relief aspects:

Linear and areal features have been considered as the two dimensional aspect lie on plan. The third dimension introduces the concept of relief. By measuring the vertical fall from the head of each stream segment to the point where it joins the higher order stream and dividing the total by the number of streams of that order, it is possible to obtain the average vertical fall.

5.3.1 Channel Gradient:

Channel Gradient is the total drop in elevation from the source to the mouth of the trunk channels in each drainage basin.

5.3.2 Basin Relief (H):

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

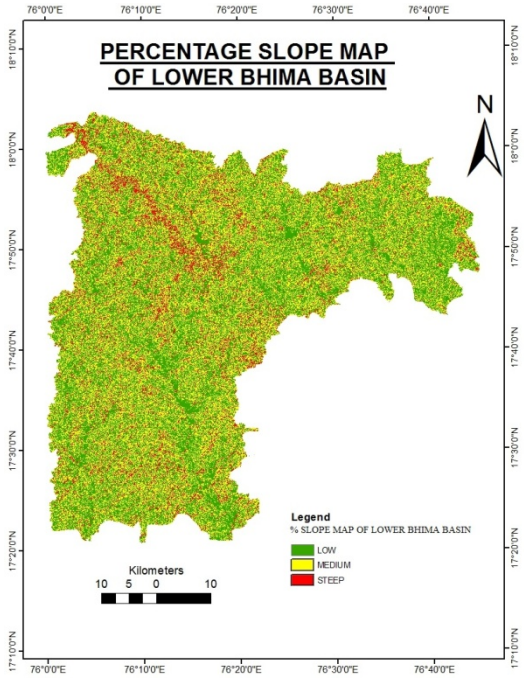


Fig 9 slope map of lower Bhima basin

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 steep (Strahler, 1956). The value of ruggedness number in Lower Bhima basin is 0.128.Subcathment CH6 have value 0.2 indicates steeper slope and less time of concentration and high Runoff.

Table 5 Relief parameter with Cp

Sub catchments	CH1	CH2	CH3	CH4	CH5	CH6
H(km)	0.18	0.27	0.22	0.24	0.16	0.15
Hd	0.08	0.14	0.11	0.12	0.08	0.2
Total Relief Cp	**0.08**	**0.14**	**0.11**	**0.12**	**0.08**	**0.2**

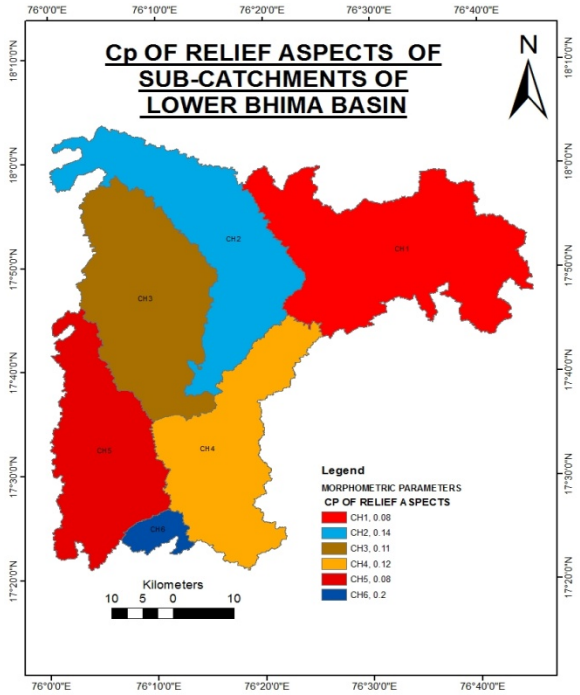


Fig 10 Total Cp of Relief Aspects

VI. LAND USE AND LAND COVER

From the boundary of study area and latitude and longitude downloaded LISS 3 image from BHUVAN site of FEB 2012 and it is clipped and rectified in GEOMATICA 2013.This rectified image is classified by using SOI TOPOSHEET and Google Earth image to get present LULC map

Fig 11 Google Earth Image of sub-catchments boundary

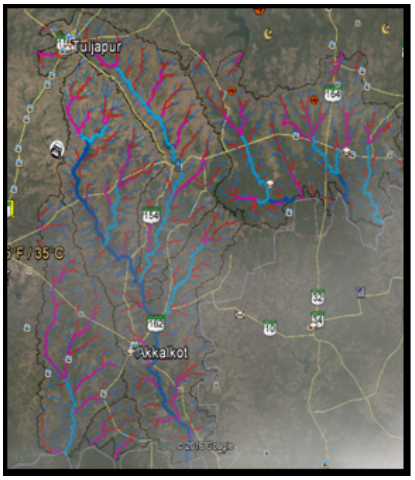


Fig 12 Google Earth Image of sub-catchments boundary and streams with order

Table 6.17 Land use Land cover of lower Bhima basin

Sr. No	Land use Land cover (LULC)	% Area Covered	Area in sq.km
1	Vegetations	52	1853
2	Barren land	30	1089
3	Habitat	8	286
4	Water bodies	10	356
	Total	**100**	**3564**

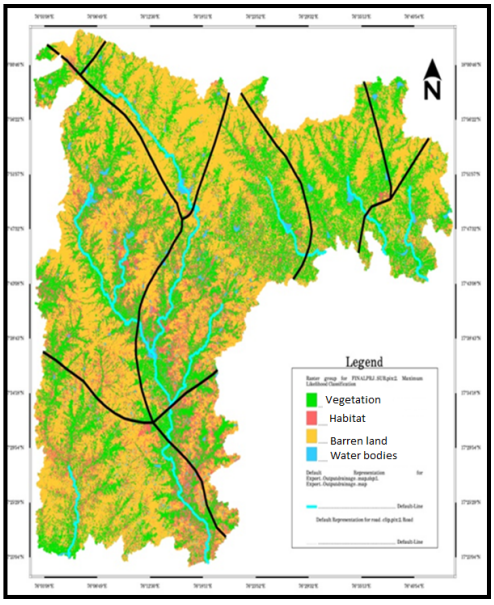


Fig 13 Final Land use and Land cover map

VII. PRIORITIZATION OF LOWER BHIMA BASIN

Prioritization of lower Bhima basin is done by using compound value of all linear , aerial , relief aspect and present land use and land cover. Based on total Cp compound value final ranking is allotted to each sub catchments of lower Bhima basin and final prioritization is done.

Table 7 Final compound value (Cp) for Lower Bhima basin

Sub-Catchments	CH1	CH2	CH3	CH4	CH5	CH6
Total (Cp) of Linear Aspects	3.53	1.6	3.33	1.77	2.02	2.5
Total (Cp) of Aerial Aspects	5.62	4.67	5.26	4.94	5.13	4.34
Total (Cp) of Relief Aspects	0.08	0.14	0.11	0.12	0.08	0.2
Total (Cp)	9.23	6.46	8.7	6.83	7.23	7.04

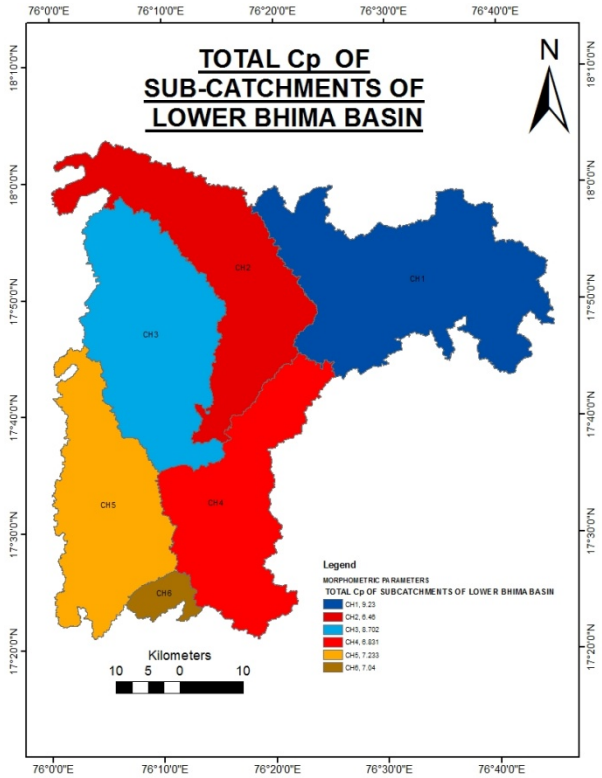


Fig 14 Final Compound value for all morphometric parameter.

Table 7 Final ranking and priority

Sub-catchments	Total (Cp) value	Ranking	Final priority
CH1	9.23	6	LOW
CH2	6.46	1	HIGH
CH3	8.70	5	LOW
CH4	6.83	2	HIGH
CH5	7.23	4	MEDIUM
CH6	7.04	3	MEDIUM

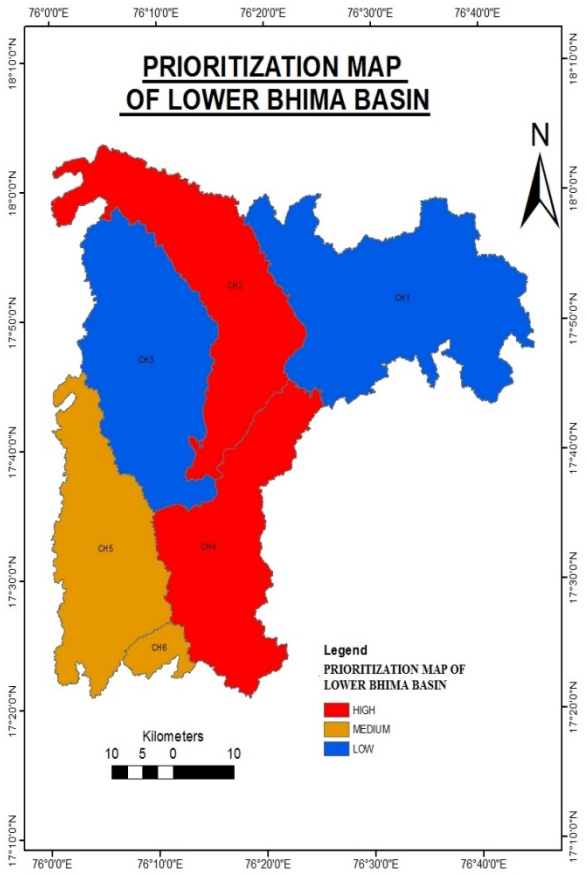


Fig15 Final prioritization map of Lower Bhima basin

VIII. CONCLUSION

Drainage Morphometry of a sub-watershed reflects hydro-geologic maturity of that river. Satellite remote sensing has an ability of obtaining the synoptic view of a large area at one time, which is very useful in analyzing the drainage Morphometry.GIS has proved to be an efficient tool in drainage delineation and this drainage has been used in the present Basin and sub basin boundary delineated by using Arc Gis 9.3.1 and area of Lower Bhima basin divided into six sub catchments. Lower Bhima basin is fifth order basin with dendritic type of drainage pattern. Study of morphometric parameters of sub catchments of lower Bhima basin shows that sub catchment CH1,CH3 have less geological structural control and overall drainage density of lower Bhima basin is coarse type (0.65) indicate high infiltration capacity and less runoff . From the Prioritization and analysis of lower Bhima Basin it has been found that CH2 and CH4 micro-watershed falls into a very low to high priority category based on the water holding capacity in relation to morphometric analysis. The morphometric parameters evaluated using GIS have helped us to understand various terrain parameters such as nature of bedrock, infiltration capacity, surface runoff, etc. This morphometric analysis and geological study will give location for groundwater recharge location. This sub-

catchments may be taken for conservation measures by planners and decision makers in the watershed management.

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REFERENCES

[1] V. B. Rocha, A. V. George and M. Rita, 2011 Morphometric Analysis and Micro-watershed Prioritization of Peruvanthanam Sub-watershed, the Manimala River Basin, Kerala, South India", International journal. of Geomatics and Geosciences ,vol.3, 2011.

[2] Sangita Mishra.S, Nagarajan.R,2010, Morphometric analysis and prioritization of sub-watersheds using GIS and Remote Sensing techniques: a case study of Odisha, India International journal. of Geomantic and Geosciences ,vol. 1, 2010.

[3] Sridhar. P, Chandra Bose. A.S, Giridhar. M.V.S.S, Viswanadh. G.K ,2012 Prioritisation of mini-watersheds based on Morphometric analysis using GIS", Internatonal journal . of Geomatics and Geoscience ,vol. 3, 2012.

[4] Jenita Mary Nongkynrih, Zahid Husain,2012, Morphometric analysis of the Manas river basin using earth observation data and Geographical Information System, International journal. of Geomatics and Geoscience ,vol. 2, 2011

[5] T.A.Kanth1 and ,Zahoorul Hassan,2012, Morphometric analysis and prioritization of sub-watersheds for soil and water conservation by using geospatial tools, International Journal of Geology, Earth and Environmental Sciences,2012.

[6] ARC HYDRO manual 2.0