Vulnerability Assessment of Soil Erosion of Panchganga Basin Using Geoinformatic Technique

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***Abstract*-Water is a vital natural resource and at the same time very complex to manage. In order to meet the growing demand for food, fuel and fodder of ever increasing population, economic development, rapid urbanization, industrialization, land and water resources need to be optimally utilized. Watershed prioritization has gained importance in sustainable resource development. River basin Morphometric characteristics are an important aspect of the characterization of watershed. The present study aims to assess the prioritization of the panchganga basin. If has been done on the basis of morphometric characteristics and land use/land cover categories for its planning and sustainable development of water resources. The study area is about 2511 km^2 and lies between 16° 13' to 17°11' North latitudes and 73°41' to 74°42' E longitude. This basin covers some part of Shahuwadi, Radhanagri, Karveer,Hatkanangle and Shirol tehsil. The entire study region is divided into 09 sub-watersheds by demarcating its boundaries and named as PB-01 to PB-09 by using GIS software. Various River basin morphometric characteristics of the Panchganga basin have been assessed by applying GIS techniques and using CartoDEM data. Strahler's, Horton's and Schumm's methods have been employed to assess the fluvial characteristics of sub-watersheds. Final compound value for final ranking to each morphometric parameter &land use/land cover has been assigned by considering its role in priority for conservation and management of natural resources. The compound parameter values are calculated and the sub-watershed with lowest compound weight is given highest priority. The analysis reveals that PB-1, PB-2, and PB-3, sub-basins should be given highest priority, on the basis of land use/land cover analysis for conservation of natural resources as they are much more susceptible to soil erosion.**

Key words: Watershed, Geoinformatic, Morphometry, Prioritisation Land use /Land cover

I.INTRODUCTION

Water and land are the most important naturalresource of environment and society as a whole.We use air, water, soil, minerals, animals, plants etc. in our daily life.In view of ever increasing population, economic development, rapid urbanization, industrialization, land and water resources need to be optimally utilized& proper steps should be taken to manage & conserve them in time, we require various natural resources like soil, water, Plants, minerals etc for livelihood. In future, tremendous hardship will befaced by human beingwith respect to availability of resources.Watershed prioritization has gained importance in sustainable resource development. River basin Morphometric analysis is an important aspect of the characterization of watershed. Watershed is an ideal unit for management of natural resources i.e., land, water, forest, soil etc. Physiography, drainage, geomorphology, soil, land use/land cover are some of the important parameters which play a significant role in watershed planning. Watershed management involves properutilization of land, water, forest and soil resources of a watershed for optimum production with minimum hazard to natural resources (Biswas et al. 1999). Morphometric analysis requires measurement of linear features, areal aspects, gradient of channel network and contributing ground slope of the drainage basin (Nautiyal 1994).Shrimali et al., 2001 has presented studied of the Sukhana lake catchment in the Shiwalik hills for the delineation and prioritization of soil erosion areas by GIS and remote sensing. Katpatal et al. (2004) conducted study on remote sensing and GIS application for monitoring and management of Pioli watershed near Nagpur urban area. Balakrishna H B, 2008 carried out Morphometric analysis for Tippagondanahalli River basin for prioritization of sub watersheds.The present study aims to assess the prioritization of the panchgangabasin on the basis of morphometric characteristics and land use/land cover categories for its planning and sustainable development of water resources.

II. STUDY REGION:

The study area lies between 16°13' north to 17°11' north latitudes and 73°41' east to 74°42' east longitudes. This basin covers some part of Shahuwadi, Panhala, Radhanagri, Karveer, Hatkanangle and Shiroltahsils of Kolhapur district. The total area of the study region is 2511 sq. kmThe region has diversified physiography with complex geological structure. Minimum and maximum elevation of the area is 550 meter and 1020 meter respectively. North western part of the basin is hilly with rugged topography and plain surface is towards eastern part. The monsoon climate dominates the region.

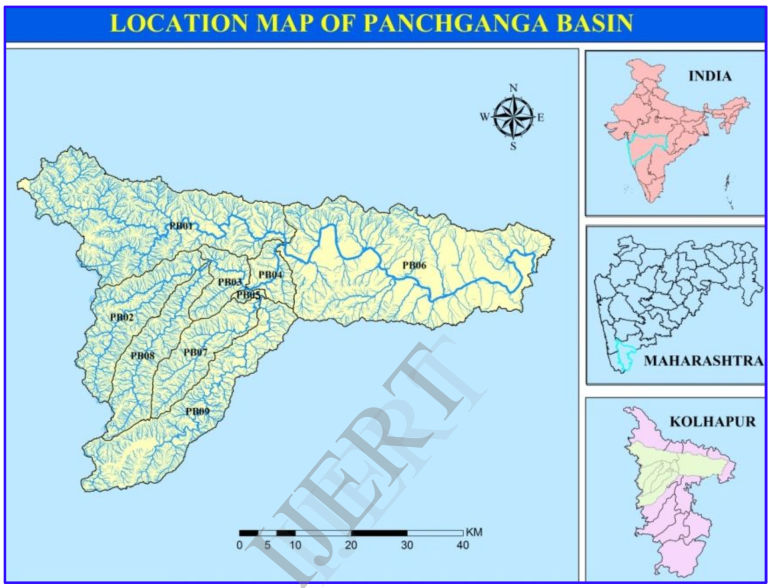

Fig.1: Location Map of Study Area

III. DATA & METHODOLOGY

For the present study, data from different sources has been integrated on a GIS platform, for watershed prioritization. The present study has integrated data from different sources and used different methods.For analysis this work is basically based on morphometric analysis & Land use/ Land cover analysis of Panchganga basin. At first, entire study area is delineated with the help of ArcSWAT software. Inlet and outlet are defined to demarcate Panchganga watershed. Sub-basins are also demarcated by using the same software to carry out the sub-basin wise Morphometric & Land use/ Land cover analysis. For base map preparation, four SOI toposheets on 1:50000 scale in paper format were used. The SOI toposheets and digital satellite data were geometrically rectified and georeferenced with the help of Arc-GIS &ERDAS IMAGINE software assigning WGS 1984/ UTM Zone 43 N projection system. Less than a pixel RMSE error was achived.Morphometric characteristics such as linear aspects and aerial aspects of the drainage basin were computed. The order was given to each stream by following Strahler (1964) stream ordering technique. The attributes were assigned to create the digital data base for drainage layer of the river basin. The map showing drainage pattern in the study area. The different morphometric parameters have been determined as per table no.1

Base map of the study area has been overlaid on satellite data to delineate various classes of land use/land cover. Land use and land cover map was prepared using knowledge based classification techniques with help of Erdas Imagine softwareand digital satellite remote sensing data i.e: IRS-P6 LISS-IV Data was also verifiedthrough standard visual image interpretation techniques based on photorecognition elements and field knowledge. The thematic maps weregenerated through satellite data.Weighted overlay technique has been used to assign weightage to Morphometric & LU/LC categories and sub-basin wise prioritization has been suggested for planning & sustainable development of water & land resources.

IV. BASIN MORPHOMETRY:

The drainage basin has been characterized with linear, areal and relief indices. These measures have been used to assess Morphometric characteristics of the basin.

STREAM ORDER (U)

The designation of stream orders is the first step in drainage basin analysis and expresses the hierarchical relationship between segments. Numerical ordering of streams begins with the tributaries at the stream assigned with the values. A stream segment has been resulted from joining of the two 1st order segments which was given as order II and so on using the method given by Strahler (1964). It has observed that the maximum frequency is in the case of first order streams. It has also noticed that there is a decrease in stream frequency as the stream order increases.

The total number of 9846 stream are identified of which 7515 are 1st order stream, 1800 are 2nd order stream, 434 are 3rd order stream, 82 are 4th order stream, 11 are 5th order stream and 2 is indicating 6th order stream respectively. Drainage pattern of the stream network is dendritic type. All the streams of the watersheds of panchganga River basin have been designated according to the Strahler's system as shown in table 1.1.

STREAM LENGTH (L_U):

Stream length was computed on the basis of Horton law (1945), for the entire sub basins of the study area. Total lengths of stream segments aremaximum in first order streams and decreases as the stream order increases. In the present study, Stream length of sub-basin PB-01 has the highest length of first order stream that is around 1382.53 km. and the 7th order stream length is only 40.53km**.** The lowest stream length belongs to PB-05 sub-basin that is only 10.49 km for first order streams and 3.82 km for 4th order stream. In the Panchganga river basin total length of stream is 7062.16 km.

Fig 2: Stream Ordering of Panchganga River

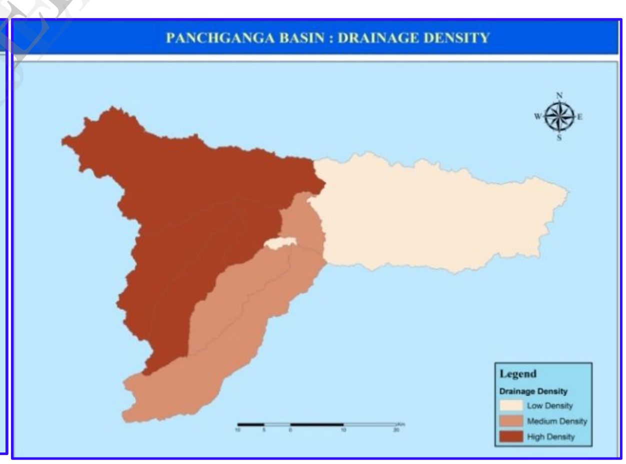

Fig 3: Drainage Density of Panchganga River

BIFURCATION RATIO (R_b):

Horton (1945) and Schumm (1956) considered the bifurcation ratio as an index of relief and dissection. Bifurcation ratio (Rb) is the ratio of the number of streams of order n to the number of streams of the next higher order (n+1). It is a dimensionless property and shows only a small variation for different regions with different environment except where powerful geological control dominates (Strahler, 1969). The lower values of Rb are characteristics of the watersheds or drainage basins, which have suffered less structural disturbances (Strahler, 1969) and the drainage pattern has not been distorted because of the structural disturbances (Nag, 1998). If Rbis high, that means the flow of energy is low, which in turn gives sufficient time for infiltration and groundwater recharge, as well as low probability of flooding and vice versa.

Bifurcation ratio values for the different sub-watersheds of the study area have been calculated. The mean bifurcation ratio of all orders varies from 1.23 to 8.67.The highest value of mean bifurcation ratio is found in PB-1, PB-9, PB-8, PB-6 and PB-3 suggesting structural control and low permeability. This relatively lower value of mean bifurcation ratio suggests the geological heterogeneity, higher permeability and lesser structural control in the area.

FORM FACTOR (F_F):

Quantitative expression of drainage basin outline form was made by Horton(1932) through a form factor ratio (RF).If is the dimensionless ratio of basin areato the square of basin length. Basin shape may be indexed by simple dimensionlessratios of the basic measurements of area, perimeter and length (Singh, 1998).

The form factor of sub-basins varies from 0.14 to 1.21 (Table No.1.2). This represents more or less elongated shape. The PB-09 watershed is having low value of F_f. The elongated basin with low form factor indicates that the basin will have a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier tomanage than of the circular basin. (Christopher et al., 2010).

ELONGATION RATIO (Re):

Schumm (1956) defined elongation ratio (Re) as the ratio of diameter of a circle of the same area as the drainage basin and the maximum length of the basin. It is a very significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin. Values near to 1.0 are typical of regions of very low relief (Strahler, 1964).

The value Re in the study area was found to be 0.42 to 1.24 which indicates low relief and flat ground slope. Low elongation ratio is in PB-9 sub-basin and high is observed in PB-4 sub-basin as per Table No.1.2

CIRCULARITY RATIO (R_C):

Miller (1953) defines circularity ratio (Rc) as the ratio of the basin area to the area of a circle which is having the same circumference parameter as the basin. It is a dimensionless index to the form outline of drainage basins. The ratio is influenced by the length and frequency of stream, geological structure, vegetation cover, climate, relief, slope conditions and drainage pattern of the basin. High value of the Circularity ratio indicates old stage of topography. Circularity and elongation ratios may be of practical use in predicting certain hydrological characteristics of a drainage basin. The circularity ratio varies from 0.14 to 0.21 & if shows the sub-watersheds (Table no. 1.2) indicating mature stage of topography.

STREAM FREQUENCY (F_S):

Horton (1932) defined stream frequency as the total number of stream segment of all order per unit area. The stream frequency varies from basin to basin (Table No. 1.2). Stream frequency for watersheds of the study area has shown positive correlation with the drainage density. If indicate that stream population increases with the increase of drainage density in watershed. PB-1 sub-basin has maximum stream frequency that is 3.75 $km/km^{2.}$ The minimum stream density is 1.64 km/km^2 which is in PB-6 sub-basin.

DRAINAGE DENSITY (D_d):

Horton (1932) defines drainage density as a ratio between total length of stream of all order &drainage area. The significance of drainage density is recognized as a factor determining the time travel by water (Schumm,1956). On the one hand, Dd is a result of interacting which are factors controlling the surface runoff; on the other hand, it is itself influencing the output of water and sediment from the drainage basin (Ozdemir and Bird, 2009).In the present study, drainage density varies from 1.64 to 3.75 (Table No 1.2). Higher the value, higher would be the runoff and lower the drainage density lesser would be the runoff and higher the probability of groundwater potential zones.In the study region, PB-1, PB-2, PB-3 & PB-8 sub-basins have high drainage density while other sub-basins have medium to low drainage density.

DRAINAGE TEXTURE (Dt)

The drainage texture is considered as one of the important concept of geomorphology which shows the relative spacing of the drainage lines (Chorley, et al, 1957). In the present study, drainage texture varies from 16.49 to 0.76 (Table No: 1.2). Drainage density values are variable and suggest that the study area falls into very coarse to coarse texture category and indicates good permeability of sub-surface material in the study area except the first order streams.

V. LAND USE /LAND COVER CHANGE ANALYSIS:

Land use / land cover change analysis is a key to many diverse applications such as environment, forestry, hydrology, agriculture, geology and ecology. Various natural resource management, planning and monitoring programs depend on accurate information about the LU/LC in a region. When it comes to connecting earth science, land use / land cover is the major research activity, &this information at different scales is of utmost importance to many facets of the society.

Identification of land cover establishes the baseline from which monitoring activities (change detection) can be performed. If provides the ground cover information for baseline thematic maps. Land use refers to economic use of land, for example, recreation, wildlife habitat, or agriculture. Land use applications involve both baseline mapping and subsequent monitoring. Timely information is required to know which current quantity of land and which type of use and to identify the land use changes from year to year (Sabins, 1997; Read and Lam, 2002; Campbell, 2002). Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Timely and accurate change detection of Earth's surface features provides the foundation for better understanding the relationships and interactions between human and natural phenomena to optimize land resources. In general, change detection involves the application of multi-temporal datasets to quantitatively analyze the temporal effects of the phenomenon (Lu et al., 2004).

Land use/land cover mapping was prepared at sub -watershed level using IRS P6 LISS IV 2012 data. If also verified through visual image interpretation techniques led to the identification and delineation of land use/ land cover categories such as agriculture, fallow land, barren land, water body, cultivated land, forest& Settlement etc.Figure 4 shows land use/land cover map ofthe study area.

FOREST:

The area under forest includes all lands which are under forest, whether private or state owned. There is close association between the nature of the terrain, the amount of rainfall received and the area under forests (Diddee, et al., 2002). The maximum area (22.63%) under forest can be seen in sub-watershed PB-08, whereas the minimum area is found in PB-09 (2.1%).

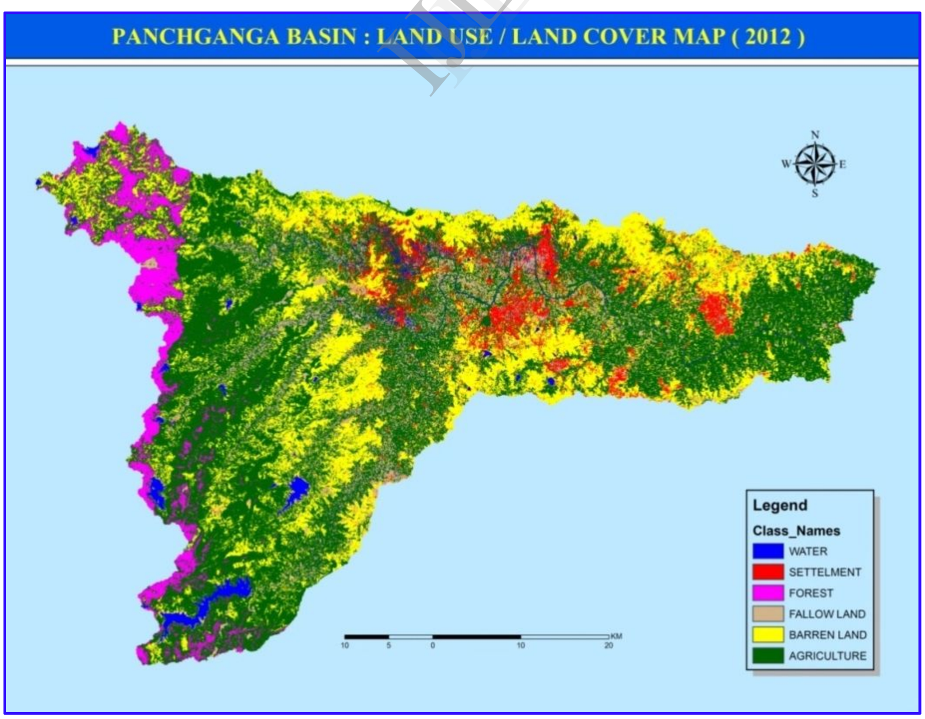

Fig.4. Land use/land cover analysis from IRS p6 LISS IV data of 2012

AGRICULTURAL LAND:

Agriculture is described as the backbone of Indian economy. Agricultural land may be defined broadly as land used primarily for production of food and fiber. Agricultural land use depends upon good suitable weather condition, water resources, topographical situation, technology, socio-economic and organizational factors. The Agriculture land cover is found from all the sub -watersheds of Panchganga river basin.Highest area under Agriculture land is reported from PB-04with 61.39%, while lowest area is reported from PB-08 with 19.93%.

Table 3.Land use/land cover analysis of Panchganga Basin

Land use/Land Cover Classes	Sub-basin wise Area (In Percentage)								
	PB-01	**PB-02**	**PB-03**	**PB-04**	**PB-05**	**PB-06**	**PB-07**	**PB-08**	**PB-09**
Forest	13.9	6.98	2.52	1.52	4.93	5.15	5.55	22.63	2.1
Agriculture	27.05	42.86	28.35	61.39	50.9	43.26	31.2	19.93	42.19
Barren Land	31.28	18.38	37.64	18.64	30.86	25.06	45.25	33.41	30.34
Fallow Land	26.39	28.75	28.09	16.66	10.96	8.06	12.55	22.81	18.95
Water	1.36	3.01	3.38	1.76	2.33	0.77	5.41	1.2	6.39
Settlement	---	---	---	---	---	17.67	5.55	---	---
TOTAL	100	100	100	100	100	100	100	100	100

BARREN LAND:

The Barren land cover is reported from all thesub -watersheds of Panchganga river basin.Highest area under barren land is reportedfrom PB-07with 45.25%, while lowest area is reported fromPB-02 with 18.38%. Higher priority has been given to thesub-watersheds having higher percentage of Barren land cover andvice versa.

FALLOW LAND:

In thepanchganga basin some area is covered with fallow land.fallow lands are regular part of the cultivated land on which cultivation has been temporarily suspended due to some reasons like unfavourable climatic conditions, topographic & irrigation conditions etc. The maximum area (28.75%) under fallowlandcan be seen from PB-02, whereas the minimum area is can be seen from PB-06 (8.6%).

BUILT-UP LAND/SETTLEMENTS:

Built-up land/settlements are comprised of areas of intensive use with much of the land is covered by Structures. It is defined as an area of human habitation developed due to non-agricultural use and that which has a cover of Settlement, transport, Industries, Educational Institutes, utilities in association with water, vegetation and vacant lands. The maximum area (17.77%) under settlement has been shown from PB-06, whereas the minimum area is shown from PB-03.

VI. PRIORITIZATION OF SUB-WATERSHEDS ON THE BASIS OF MORPHOMETRIC ANALYSIS:

The morphometric parameters i.e. drainage density, stream frequency, mean bifurcation ratio, drainage texture, length of overland flow, form factor, circularity ratio, elongation ratio, basin shape and compactness coefficient, are also termed as erosion risk assessment parameters and those can be used for prioritizing sub-watersheds (Biswas et al. 1999). The linear parameters such as drainage density, stream frequency, mean bifurcation ratio, drainage texture, length of overland flow have a direct relationship with erodibility whereas shape parameters such as elongation ratio, circularity ratio, form factor, basin shape and compactness coefficient have an inverse relationship with erodibility (NookaRatnam et al. 2005).. Therefore, the higher value was rated as rank 1, second highest value was rated as rank second and so on. The sub watershed which got the highest Cp values were assigned last priority. The sub watershed were then categorized into three classes as high (**3.3 – 4.5**), medium (**4.6 – 5.6**), and low (5.**7 – 6.2**).Priorityhas been given range of cp values. On the basis of morphometric analysis, PB-01, PB-02, PB-03, fall in the high priority, PB-04, PB-06, PB-08 and PB-09 fall in medium priority and PB-05 & PB07 are in the low priority category

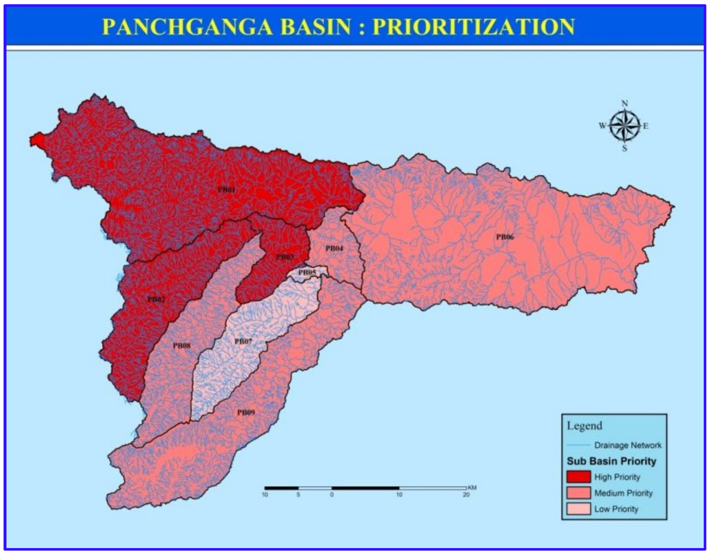

Fig 5. Priority of sub-watershed based on Morphometric Analysis

VII. PRIORITIZATION OF SUB-WATERSHEDS ON THE BASIS OF LAND USE/LAND COVERS ANALYSIS:

The land use depends upon the soil, topography, weather condition and water resources. Therefore, the agricultural activities of man are restricted as per land. The sub-watersheds were classified into three classes as high (4.0– 4.8), medium (4.9 – 5.2) and low (5.3 –6.6) priority. Out of 09 sub-watersheds, PB-01, PB-02, PB-03 and PB-07, fall under high priority, PB-05, PB-08 and PB-09 sub-watersheds indicate a medium priority.Whereas, PB-04, and PB-06 fall under low priority category .Figure no.6 shows priority of sub-watersheds based on land use/land cover analysis.

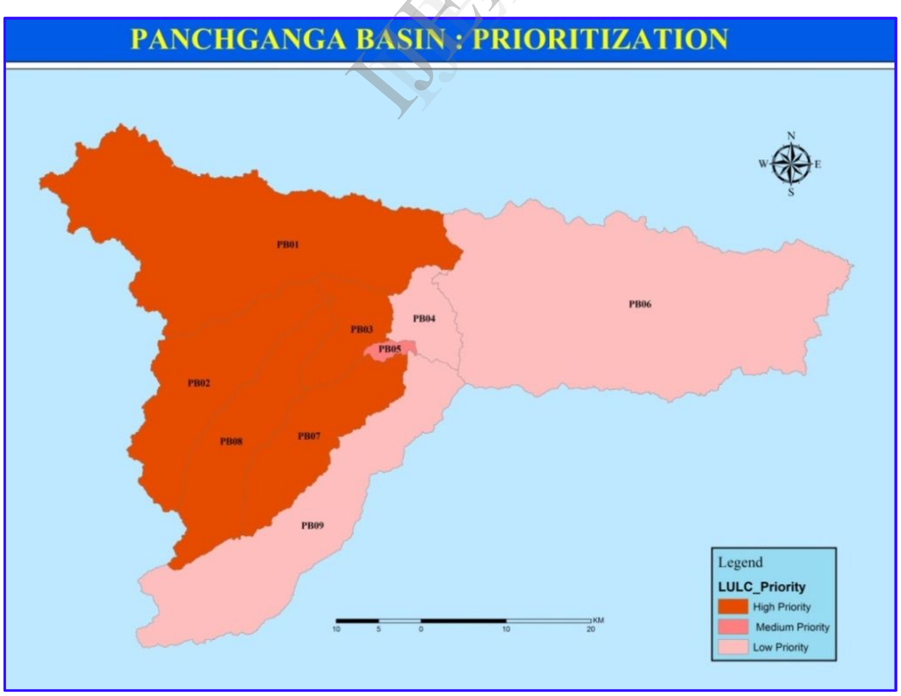

Fig 6. Priority of sub-watershed based on Land use/land cover analysis

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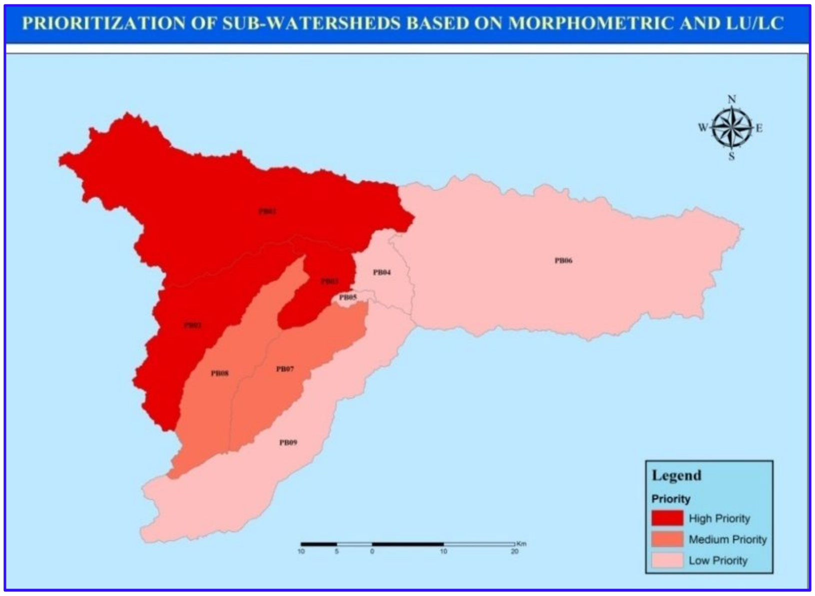

Fig 7. Priority of sub-watershed based on Morphometric and Land use/land cover analysis

VIII. CONCLUSION

Watershed prioritization is one of the most important aspects of planning for implementation of development and management of natural resources programmes. The present study demonstrates the usefulness of Remote Sensing &GIS techniques for morphometric analysis and land use /land cover prioritization of the sub-watersheds of Panchganga River basin. Result of prioritization of sub-watershed shows that PB-01, PB-02, and PB-03, sub-basins should be given highest priority, on the basis of Morphometric & land use/land cover analysis for conservation of natural resources as they are much more susceptible to soil erosion.

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Table No 1.1: Total Stream Numbers of Panchganga River

Sub-Basins	Stream Number in Different Order							
	1	2	3	4	5	6	7	8
PB-1	2574	629	154	33	5	2	1	0
PB -2	971	232	54	8	2	0	0	0
PB -3	225	61	13	1	0	0	0	0
PB -4	138	28	6	3	0	0	1	0
PB -5	14	3	1	1	0	0	0	0
PB -6	1047	269	64	18	1	0	0	1
PB -7	529	112	25	3	1	0	0	0
PB -8	738	169	43	5	1	0	0	0
PB -9	1279	297	74	10	1	0	0	0

Table No 1.2 : Sub-basin wise derived morphometric parameters of the Panchganga River basin

Morphometric Analysis of Panchganga Basin										
Sub-Basins	Area km^2	Stream Frequency (km/km^2)	Basin Length (km)	Form Factor	Elongation Ratio	Circulatory Ratio	Perimeter (km)	Drainage Density (Dd)	Drainage Texture(T)	Compactness Constant(C_c)
PB-1	590	5.75	50.36	0.23	0.54	0.17	206	3.75	16.49	2.39
PB -2	227	5.58	31.01	0.24	0.55	0.19	123	3.73	10.30	4.25
PB -3	81	3.70	13.91	0.41	0.73	0.23	66	3.09	4.54	2.07
PB -4	66	2.65	7.38	1.21	1.24	0.21	63	2.18	2.77	2.18
PB -5	10	1.90	4.25	0.55	0.83	0.20	25	1.91	0.76	2.23
PB-6	820	1.70	48.79	0.34	0.66	0.21	222	1.64	6.30	2.18
PB -7	165	4.06	28.15	0.20	0.51	0.21	99	2.94	6.76	2.17
PB -8	196	4.87	36.26	0.15	0.43	0.16	124	3.51	7.70	2.49
PB -9	358	4.63	49.70	0.14	0.42	0.14	178	2.97	9.33	2.65

Table No.1.3: Final Prioritization of Panchganga Basin

Prioritization of sub-watershed based on Morphometric and Land use/land cover analysis				
Sub-Basins	CP In Morphometry	CP In Land use / Land cover	Sum of CP Priority	Final Priority
PB-1	3.37	4.25	07.62	1
PB -2	3.75	4.25	08.00	1
PB -3	4.50	4.50	09.00	1
PB -4	5.12	6.00	11.12	3
PB -5	6.00	5.25	11.25	3
PB -6	5.37	6.00	11.37	3
PB -7	6.12	4.50	10.62	2
PB -8	5.12	4.25	09.37	2
PB -9	5.62	6.00	11.62	3

Prioritization Classes	
Compound Values	**Priority Class**
7.62– 9.00	**High Priority**
9.01– 10.62	**Medium Priority**
10.63 – 11.62	**Low Priority**