Prioritization of Sub Watersheds Based on Morphometric and Land use Parameters for Integrated Watershed Management of Vishav Watershed, Kashmir Valley

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ABSTRACT

Drainage morphometry and land use planning have become more important in the context of natural resource management. Morphometric analysis is widely used in the prioritization of watersheds. The present work utilizes remote sensing and geographic information system (GIS) approaches to prioritize sub-watersheds in the Vishav basin, J&K, India, based on morphometric and landuse parameters. The Vishav watershed has been divided into eight sub-watersheds (IEIC9a1 to IEIC9a8). Topographic maps of 1971on a 1:50000 scale were utilized to delineate the drainage system and Landsat 8 Operational Land Imager (30m) in Geographical Information System. The drainage morphometric and landuse/landcover (LULC) characteristics determined for each sub-watershed and prioritization was done by assigning ranks and generating a compound value. The sub-watersheds have been characterized into three categories as high, medium and low in terms of priority where IEIC9a5 and IEIC9a8 fall in high priority zone. The sub watershed IEIC9a5 is characterized by high drainage density (2.72 km^2), bifurcation ratio, and drainage texture (4.7km^2), whereas IEIC9a8 has got an alarming built up of 8.99 Km^2. The study calls for an immediate policy intervention in terms of prioritization of watersheds for possible land use planning and management plan.

Keywords: *Vishav, Watershed Prioritization, Morphometric Analysis, Landuse/Landcover, Remote Sensing, GIS.*

INTRODUCTION

Watershed prioritization is the practical application for conservation and management of soil and water resources (Mir *et al.,* 2021). River morphometry is a convenient technique to explain fluvially originated landforms (Barman *et al.,* 2021). Morphometry is the measurement and mathematical exploration of the earth's configuration, its surface, structure, and the dimension of its landforms (Varma *et al., 2020*, Clarke, 1996, Girma *et al., 2020*). A watershed is a geo-hydrological unit and represent a high land area that directs runoff towards a specific point. Because all hydrologic and geomorphic processes take place inside the watershed, morphometric properties reveal important information about its beginnings and growth (Singh *et al.,* 1997). The quantitative evaluation of morphometric features is considered very important in understanding fluvial geomorphology. The impact of morphometric attributes is found to be immense utility in watershed prioritization and natural resource management (Hajam *et al.,* 2013a; 2013b). Morphometry is important in hydrological investigations concerning environmental valuation, pedology and groundwater management (Hajam *et al.,* 2013b). A watershed morphometric analysis gives a numerical description of the drainage system, which is an essential part of characterization (Strahler, 1964). The assessment of linear properties, areal aspects, channel network gradient, and drainage basin contributing ground slopes is required for morphometric analysis (Nag, 1998). Morphometry is the study of measuring and analyzing the shape and scale of the earth's landforms, as well as the organization of the earth's surface (Agarwal, 1998; Obi Reddy *et al.,* 2002). They are, in reality, the most important elements of the fluvial environment, with the majority of study concentrating on geometric characteristics such as stream network design and quantitative descriptions of drainage texture, pattern, and shape (Abrahams, 1984). Landuse is an aggregate of physical, chemical, and biological systems and processes on one side, and human/social processes on the other (Meyer and Turner, 1994; Sekliziots, 1980). The existing geo-physical conditions of an area are largely determined by land cover (Meyer and Turner-II, 1991; Lambin *et al.,* 2001). As a matter of fact, each landuse and landcover class has a specific functionality resulting into the provision of ecosystem services and thus, prioritizing these intrinsic characteristics at the catchment scale is the crux of landuse planning and resource use appraisal. Prioritization is also critical in the broader framework of natural resources management since resource development plans are frequently carried out on a watershed basis (Vittala *et al.,* 2008, Hussan *et al.,* 2015, Nanda *et al.,* 2017). Drainage basin, catchment, and sub-catchments are the main units of land and water management, and have been recognised as convenient tools by the administration to protect natural resources (Moore *et al.,* 1977; Honore, 1999). The existing linkages between upland and lowlands is recognized in the watershed management concept encompassing landuse, geomorphology, slope, and soil aspects (Tideman, 1996). Subsequently for long-term development and management of natural resources, an integrated strategy is essential and inevitable (Khan *et al.,* 2001; Gosain *et al.,* 2004).

STUDY AREA

The Vishav drainage basin covers a geographical area of 1062.91 km^2 (10 percent of the Jhelum drainage basin), is located between 33^o 39′ and 33^o 65′ N latitude and 74^o 35′ and 75^o 11′ E longitudes, with majority of its area (80%) in the Kulgam and Shopian districts of Jammu and Kashmir, India (Nanda *et al.,* 2014b).

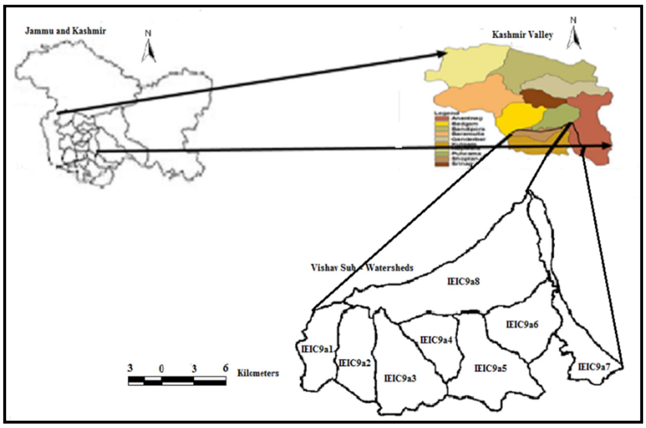


Fig. 1.1: Location map of the study area.

The Vishav stream is a perennial major left bank tributary of Jhelum River. Vishav stream originates from a glacier near the base of Kounsarnag called Teri, which then joins the underground stream at Mahinag, falling steeply north-northeast to arrive at the main strike valley till it amalgamates with Jhelum at Niayun, Sangam. The maximum discharge is observed in July, while the minimum is recorded in January (Raza *et al.,* 1978). The Vishav receives glacial melt water from two other headwater streams namely Chitti Nadi which rises in the vicinity of

Budil Pir Pass (4,264 m). On the other hand, Zaji Nar being a rises in the Gulalmarg and Zajimarg area and washes the Pir Panjal slopes from Dadi Gali (3,810m) in the east to Brahma Sakal Peak (4,706 m) in the west, draining the most important grassland area of Kongwatan. The united stream occupies a wide sandy bed and gets bifurcated into a number of channels owing to fall in channel gradient. This includes Reshinagar water channel, Sunaman Kol, the Kawal Kol and the Mau Kol. The Sunaman Kol and the Mau Kol (man-made canals) reunite and merge with the Rembiara near Niayun (Nanda *et al.,* 2015).

DATABASE AND METHODOLOGY

The survey of India toposheets of 1971 on a 1:50000 scale were utilized to delineate the drainage system, modified from digital elevation model and landsat satellite imageries. In addition to that landuse/landcover map was generated from Landsat 8 Operational Land imager (OLI 30m) of 2020 year. The Vishav watershed has been divided into eight sub-watersheds from IEIC9a1 to IEIC9a8 (Kango and Qadri 1982). The morphometric parameters such as stream length, bifurcation ratio, drainage density, drainage frequency, drainage texture, form factor ratio, circularity ratio, and elongation ratio were all calculated using standard procedures (Table 1.1). The LULC categories at NRSC level I such as forest, horticulture, agriculture, built-up, wasteland, and others (water bodies, snow/glacier, grassland and wetland) were considered for supervised classification of Landsat 8 OLI satellite data, 2020 substantiated by extensive ground truth validation. A comprehensive prioritization index was generated for conservation and management of these sub-watersheds. The drainage morphometric and LULC parameters determined for each sub-watershed were assigned ranks on the basis of their potential degradation. A compound value (CP) was generated for each sub-watershed by averaging the ranks assigned to them. Based on the CP value the sub-watersheds having the least score were assigned highest priority and vice versa. Finally, the sub-watersheds were categorized into three priority classes on the basis of the range of CP value as high (< 3.00), medium (3.00-4.00) and low (> 4.00) Shah *et al.,* 2018).

Table 1.1: Morphometric parameters with formulae

S. No.	Parameters	Formula	Reference
1	**Linear Morphometric parameters**		
1.1	Stream Order (Sμ)	Hierarchical rank	Strahler (1964)
1.2	Bifurcation Ratio (R_b)	$R_b = N\mu / N\mu +1$ Where, Rb = Bifurcation ratio, Nμ = No. of stream segments of a given order and Nμ +1= No. of stream segments of next higher order.	Schumn (1956)
1.3	Mean Bifurcation Ratio (R_{bm})	R_{bm} = Average of bifurcation ratios of all orders	Strahler (1964)

1.4	Stream Length (Lμ)	Length of the stream (kilometers)	Horton (1945)
1.5	Mean Stream Length (L_{sm})	L_{sm} = Lμ/Nμ Where, Lμ = Total stream length of order 'μ' Nμ = Total no. of stream segments of order 'μ'	Strahler (1964)
1.6	Stream Length Ratio (R_L)	R_L=L_{sm} / L_{sm}-1 Where, L_{sm}=Mean stream length of a given order and L_{sm}-1= Mean stream length of next lower order	Horton (1945)
1.7	Length of Overland Flow (L_g)	L_g=1/2D Km Where, D=Drainage density (Km/Km^2)	Horton (1945)
1.8	Basin Perimeter (P)	P=Outer boundary of drainage basin measured in kilometers.	Schumm (1956)
1.9	Basin Length (L_b)	L_b=1.312*A$^{0.568}$	Gregory and Walling (1973)
2	**Areal Morphometric parameters**		
2.1	Basin Area (A)	Area from which water drains to a common stream and boundary determined by opposite ridges.	Strahler (1964)
2.2	Drainage Density (D_d)	D_d = Lμ/A Where, Dd = Drainage density (Km/Km^2) Lμ = Total stream length of all orders and A = Area of the basin (Km^2).	Horton (1932)
2.3	Drainage Frequency (F_s)	F_s = Nμ/A Where, F_s = Drainage frequency. Nμ = Total no. of streams of all orders and A = Area of the basin (Km^2).	Horton (1932)
2.4	Drainage Texture (D_t)	D_t =Nμ /P Where, Nμ= No. of streams in a given order and P = Perimeter (Kms)	Smith (1950) & Horton (1945)
2.5	Form Factor Ratio (R_f)	R_f= A/L_b^2 Where, A = Area of the basin and L_b = (Maximum) basin length	Horton (1932)
2.6	Elongation Ratio (R_e)	R_e= √A /π / L_b Where, A= Area of the Basin (Km^2) L_b=Maximum Basin length (Km)	Schumm (1956)
2.7	Circularity Ratio (R_c)	R_c = 4πA/ P^2 Where, A = Basin Area (Km^2) and P= Perimeter of the basin (Km) Or R_c = A/ A_c Where, A = Basin Area (Km^2) and A_c = area of a circle having the same perimeter as the basin	Miller (1953)

Source: Compiled by the researchers.

RESULTS AND DISCUSSIONS

The measurement of linear characteristics of the drainage network, areal properties of the drainage basin, relief (gradient) aspects of the channel network, and contributing ground slopes are vital for a systematic description of the geometry of a drainage basin and its stream channel (Strahler, 1964, 1957). The morphometric analysis included parameters like stream order, stream length, bifurcation ratio, drainage density, drainage frequency, drainage texture, elongation ratio, circularity ratio, and form factor ratio, among others, with the results summarized in (Table 1.2 and 1.4). The drainage pattern of Vishav basin is dendritic in the upper part of the catchment, while it is more or less parallel in the lower section (Fig. 1.2).

Linear and Areal Morphometric Parameters Stream order

The stream order is defined as a measure of a stream's hierarchy position (Leopord *et al.,* 1969). The study area was 1062.91 km^2, with 2388 streams linked by six streams orders (Fig. 1.2). From Table 1.2, it is evident that the Vishav stream falls in the sixth order. As the stream order rises, it is seen that the stream frequency decreases (Strahler, 1964). First order streams account for 75.92 percent of all streams, whereas second order streams account for 18.34 percent. The third and fourth order streams account for 4.15 percent and 1.17 percent of all streams, respectively, whereas the fifth and sixth order streams account for just 0.42 percent of all streams. Overall, across the catchment, the law of lower order meant higher number of streams.

Bifurcation Ratio (Rb)

The term bifurcation ratio (Rb) is used to express the ratio of the number of streams of any given order to the number of streams in next higher order (Schumm, 1956). Bifurcation ratios normally range between 1.33 and 9.0, as illustrated in Table 1.2 (Strahler, 1964). The maximum Rb (9.0) is found between the third and fourth orders of IEIC9a8, indicating the strongest overland flow and discharge owing to mountainous hard rock formation and high slope arrangement. The mean bifurcation ratio in the research region ranges from 3.20 to 5.40, with lower values in IEIC9a4 and IEIC9a8 indicating geological heterogeneity, increased permeability, and lesser structural control in the area and higher values in IEIC9a8 indicating a structurally controlled drainage pattern (Nanda *et al.,* 2014a).

Table 1.2: Linear morphometric parameters of vishav sub-watersheds.

IEIC9a1 Stream order (Sμ)	Stream number (Nμ)	Bifurcation ratio (R_b)	Stream length (Lμ) (kms)	Mean stream length (L_{sm}) (kms)	Cumulative Mean stream length (L_{sm})	Stream length ratio (R_L)	Mean bifurcation ratio (R_{bm})
1st	184 (76.99)		135.93 (66.38)	0.73	0.73		
2nd	45 (18.83)	4.0	41.97 (20.49)	0.93	1.66	1.27	
3rd	08 (3.34)	5.62	15.37 (7.51)	1.92	3.58	2.06	**3.8**

4th	02 (0.84)	2.0	11.49 (5.62)	5.74	9.32	2.98	
Total	**239 (100)**		**204.76 (100)**				
	IEIC9a2						
1st	242 (76.82)		68.72 (83.84)	0.28	0.28		**3.3**
2nd	55 (17.48)	4.4	59.24 (37.80)	1.07	1.35	3.82	
3rd	11 (3.49)	5.0	15.84 (10.10)	1.44	2.79	2.06	
4th	04 (1.26)	2.75	4.49 (2.87)	1.12	3.91	1.40	
5th	03 (0.95)	1.33	8.45 (5.39)	2.81	6.72	1.71	
Total	**315 (100)**		**156.74 (100)**				
IEIC9a3							
1st	314 (77.53)		233.54 (63.57)	0.74	0.74		**4.3**
2nd	68 (16.78)	4.61	81.4 (22.16)	1.19	1.79	1.60	
3rd	19 (4.70)	3.57	34.27 (9.32)	1.80	3.69	1.51	
4th	03 (0.74)	6.33	3.55 (0.97)	1.18	4.87	0.65	
5th	01 (0.25)	3.0	14.61 (3.96)	14.61	19.48	12.38	
Total	**405 (100)**		**367 (100)**				
	IEIC9a4						
1st	177 (72.25)		141.11 (56.73)	0.64	0.64		**3.2**
2nd	50 (20.4)	3.54	42.46 (21.11)	0.84	1.48	1.31	
3rd	11 (4.50)	4.54	21.28 (10.58)	1.93	3.41	2.29	
4th	05 (2.04)	2.2	18.05 (8.98)	3.61	7.02	1.87	
5th	02 (0.81)	2.5	5.22 (2.60)	2.61	9.63	0.72	
Total	**245 (100)**		**201.12 (100)**				

IEIC9a5							
1st	407 (76.36)		236.14 (59.49)	0.58	0.58		**3.4**
2nd	97 (18.20)	4.19	90.48 (22.80)	0.93	1.51	1.60	
3rd	20 (3.75)	4.85	35.19 (8.87)	1.75	3.26	1.88	
4th	06 (1.12)	3.33	15.59 (3.92)	2.60	5.86	1.48	
5th	02 (0.38)	3.0	15.98 (4.02)	7.99	13.85	3.07	
6th	01 (0.19)	2.0	3.55 (0.90)	3.55	17.40	0.44	
Total	**533 (100)**		**396.93 (100)**				
	IEIC9a6						
1st	268 (76.58)		149.70 (62.91)	0.55	0.55		**3.8**
2nd	63 (18)	4.25	52.38 (22.01)	0.83	1.38	1.50	
3rd	14 (04)	4.50	22.20 (9.33)	1.58	2.96	1.90	
4th	05 (1.42)	2.8	13.67 (5.75)	2.73	5.69	1.72	
Total	**350 (100)**		**237.95 (100)**				
IEIC9a7							
1st	98 (72.60)		55.39 (56.38)	0.56	0.56		**3.2**
2nd	27 (20)	3.62	20.07 (20.42)	0.74	1.30	1.31	
3rd	07 (5.18)	3.85	8.53 (8.69)	1.21	2.51	1.63	
4th	02 (1.48)	3.50	12.22 (12.43)	6.11	8.62	5.04	
5th	01 (0.74)	02	2.05 (2.08)	2.05	10.67	0.33	
Total	**135 (100)**		**98.26 (100)**				
	IEIC9a8						
1st	123		92.76	0.75	0.75		

	(74.09)		(68.69)				
2nd	33 (19.89)	3.72	27.85 (20.62)	0.84	1.59	1.12	**5 .4**
3rd	09 (5.42)	3.66	11.22 (8.30)	1.24	2.83	1.47	
4th	01 (0.60)	9.00	3.22 (2.39)	3.22	6.05	2.60	
Total	**166 (100)**		**135.05 (100)**				

Source: Computed from SOI toposheets on 1:50,000 scale, 1971, DEM and Landsat 8 OLI 2020.
Note: Figures in parenthesis show Percentage stream length contributed by different stream orders.

Stream Length ($L\mu$)

Stream length is one of the basin's most important hydrological parameters, since it shows surface runoff characteristics of streams with shorter lengths and is indicative of locations with steeper slopes and finer textures. IEIC9a5 sub watersheds have the longest total length (236.14) of stream segments, followed by IEIC9a3 and IEIC9a1. The stream length for the first four sub-watershed aggregates 41.36% while the subsequent four watersheds represent 59.64 percent as depicted in Table 1.2.

Drainage Density (D_d)

Horton (1932) suggested the drainage density (D) as an important indicator of the areal scale of landform characteristics in stream degraded terrain. It is defined as the ratio of total channel segment lengths for all orders in a basin to the basin area, expressed in per square kilometer. The drainage density reflects how closely channels are spaced, providing a numerical estimate of the average length of stream channel for the whole basin. The drainage density in the Vishav watershed ranges from 0.43 to 2.72 km/ km^2, as shown in Table 1.4, indicating that the watershed is underlain by extremely permeable material (Nag, 1998). IEIC9a5 contains the drainage density with the highest value, while IEIC9a8 has the least one.

Drainage Area (A)

A drainage area is a collection area from which water is channeled to a stream or river. The basin's area was delineated by translating the basin's combined geo-referenced and corrected SOI toposheets from 1971 at a resolution of 1:50,000 into polygon form. The basin's entire size is determined to be 1062.91 km^2, (Fig. 1.1).

Drainage Frequency (F_s)

The stream frequency values for the respective sub-watersheds are shown in table 1.4, and vary from 0.53 (IEIC9a8) to 3.89 (IEIC9a1). Sub-watersheds with lower stream frequency values have low relief and permeable subsurface material, whereas those with higher values feature with resistant/poor conducting subsurface material, sparse vegetation, and high relief. The highest drainage density and stream frequency in a basin results in faster runoffs, and so floods are more common in such basins (Kale and Gupta, 2001).

Drainage Texture (D_t)

Smith (1950) categorized drainage density into five separate drainage texture classes viz extremely coarse, medium, denoting moderate, denoting fine, and very fine drainage texture. Drainage texture ratings for sub-watersheds range from 1.47 (IEIC9a7) to 8.69 (IEIC9a5). The coarse drainage texture is produced by a low drainage density, whereas a fine drainage texture is produced by a high drainage density (Smith, 1939). The texture of the study region ranges from extremely coarse to coarse, indicating thereby that the area is more prone to weathering.

Elongation Ratio (R_e)

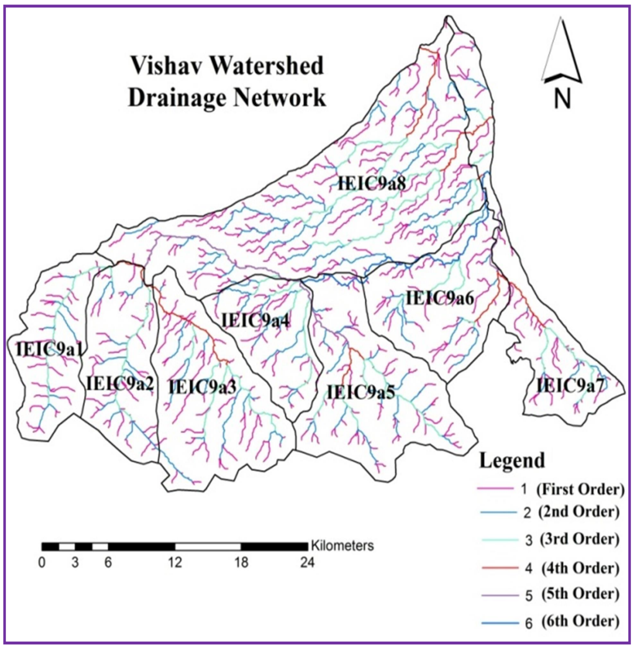
The elongation ratio (Re) was established by Schumn (1956) as the ratio of the diameter of a circle with the same area as the basin to the maximum basin length. The (Re) values of Sub-watersheds range from 0.16 (IEIC9a8) to 0.20 (IEIC9a2), suggesting significant relative relief of the topography and an extended drainage basin (Nanda *et al.,* 2014a), as depicted in table 1.4.

Circularity Ratio (R_c)

The Circularity Ratio is the ratio of a basin's area to the area of a circle with the same circumference as the basin's perimeter (Miller, 1953). The computed Rc values for the study area's sub-watersheds range from 0.15 (IEIC9a7) to 0.66 (IEIC9a4), indicating that the drainage basin is elongated in shape and has significant relative relief.

Form Factor Ratio (R_f)

To depict the quantitative form of drainage basin outline form, Horton (1932) employed a form factor ratio (R_f), which is the dimensionless ratio of basin area to square of basin length. As shown in Table 1.4, R_f values in the research region range from 0.01 (IEIC9a7) to 0.42 (IEIC9a2), showing that the majority of sub-watersheds have an extended shape with lower peak flows over longer periods of time. The basin will have a flatter peak of flow for a longer duration since it is extended and has a low form factor. The regulation of flood flows in such elongated basins is easier than in circular basins (Christopher *et al.,* 2010).



Source: Computed from survey of India toposheets 1:50000 and Aster DEM.

Figure 1.2: Drainage network of vishav sub-watersheds.

LAND USE LAND COVER ANALYSIS OF 2010

The LULC categories were taken for prioritization of sub-watersheds and includes, Forests, cultivated land, built up, wasteland and other category as shown in Fig. 1.3 (NRSC Level 1).

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Forests were found as dominant landcover category covering an area of 314.10 sq.kms (29.55 Percent), followed by cultivated area 447.10 sq.kms (42.06 percent), wastelands 57.51 sq.kms (5.41 percent), built-up 17.24 sq.kms (1.62 percent) and other category 226.96 sq.kms (21.35 percent), and is depicted in (Table 1.3 and as shown in Fig. 1.4).

Forests

The dominance of forests is a clear indication of ecosystem stability and strength. The forest covers the highest percentage under land cover category in Vishav watershed (30 percent) as given in Fig. 1.4. From (Table 1.3) it is evident that the lowest and highest area under forests was occupied by IEIC9a8 (8.41 percent) and IEIC9a3 (50.66 percent). The watershed with lowest percentage of forest cover was assigned rank one as high priority and vice-versa.

Cultivated land

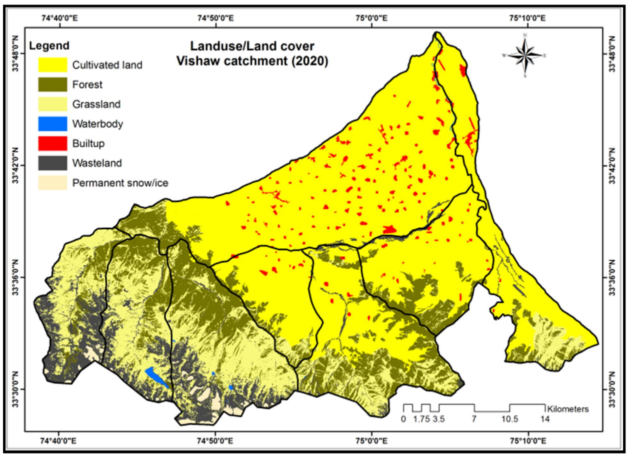
The sub-watersheds with lowest area under cultivation category which included horticulture and agriculture was assigned rank one as high priority and vice versa. Vishav watershed had an area of 447.10 km^2 (42.06 percent) under cultivation as shown in Figure 1.4. The highest percentage was found in IEIC9a8 (82.26 percent) and lowest percentage was found in IEIC9a5 (23.54 Percent), and is shown in Table 1.3.

Built up

The watershed with the highest proportion of watershed area in the built-up category received highest priority, and vice versa. Built up covers an area of 17.24 km^2 in the watershed (1.62 Percent). Table 1.3 reveals that sub-watershed with highest percentage of built up includes IEIC9a7 (3.49 Percent) followed by IEIC9a8 (2.90 Percent) and IEIC9a4 (1.81 Percent), and is depicted in Table 1.3.

Wasteland

The watershed with maximum percentage are represented by wastelands IEIC8a6 (11.71 percent) followed by IEIC8a2 and IEIC8a3 (10.05 and 9.02 percent). Sub-watersheds having higher percentage of wasteland were given higher priority and vice versa are depicted in Table 1.3.



Source: Classified and Computed from Landsat 8 operational land imager 2020.

Fig. 1.3: Land use/land cover map -2020.

Other Category

The sub-watersheds with lowest area under other category which included waterbody and snow ice was assigned rank one as high priority and vice versa. Vishav watershed had an area of 226.96 km^2 (21.35 percent) under different category as shown in Fig. 1.4. From the Table 1.3 it is evident that the highest percentage was found in IEIC9a1 (80.62 percent) and lowest percentage was found in IEIC9a7 (1.24 Percent).

Table 1.3: Sub Watershed wise percentage of landuse/land cover of vishav stream (2020).

Sub Watershed (Codes)	**Forest (sq.kms)**	**Cultivated land (sq.kms)**	**Built Up (sq.kms)**	**Wasteland (sq.kms)**	**Other Categories (sq.kms)**	**Total (sq.kms)**
IEIC9a1	14.15 (17.37)	-	-	1.64 (2.01)	65.68 (80.62)	**80.85 (100)**
IEIC9a2	35.90 (38.24)	-	-	9.43 (10.05)	48.54 (51.71)	**93.39 (100)**
IEIC9a3	72.12 (50.66)	0.03 (0.02)	-	12.84 (9.03)	57.37 (40.36)	**141.47 (100)**
IEIC9a4	28.42 (38.57)	35.20 (47.77)	1.33 (1.81)	5.48 (7.44)	3.25 (4.41)	**74.11 (100)**
IEIC9a5	72.10 (49.46)	34.31 (23.50)	1.44 (0.99)	10.71 (7.34)	27.20 (18.63)	**145.61 (100)**
IEIC9a6	39.25 (35.93)	49.80 (45.58)	1.76 (1.61)	12.79 (11.71)	5.65 (5.17)	**109.79 (100)**
IEIC9a7	26.10 (24.47)	72.89 (68.33)	3.72 (3.49)	2.64 (2.47)	1.32 (1.24)	**107.20 (100)**
IEIC9a8	26.06 (8.41)	254.87 (82.26)	8.99 (2.90)	1.98 (0.64)	17.95 (5.79)	**310.49 (100)**
Vishav Watershed	314.10 (29.55)	447.10 (42.06)	17.24 (1.62)	57.51 (5.41)	226.96 (21.35)	**1062.91 (100)**
Sub Watershed (Codes)	**Forest**	**Cultivated land**	**Built Up**	**Wasteland**	**Other categories**	**Total**
IEIC9a1	14.15 (4.50)	-		1.64 (2.85)	65.68 (28.94)	80.85 (7.61)
IEIC9a2	35.90 (11.43)	-		9.43 (16.40)	48.54 (21.39)	93.39 (8.79)
IEIC9a3	72.12 (22.96)	0.03 (0.01)		12.84 (22.33)	57.37 (25.28)	141.47 (13.31)
IEIC9a4	28.42 (9.05)	35.20 (7.87)	1.33 (7.71)	5.48 (9.53)	3.25 (1.43)	74.11 (6.97)
IEIC9a5	72.10 (22.95)	34.31 (7.67)	1.44 (8.35)	10.71 (18.62)	27.20 (11.98)	145.61 (13.70)
IEIC9a6	39.25 (12.50)	49.80 (11.14)	1.76 (10.21)	12.79 (22.24)	5.65 (2.49)	109.79 (10.33)
IEIC9a7	26.10 (8.31)	72.89 (16.30)	3.72 (21.58)	2.64 (4.59)	1.32 (0.58)	107.20 (10.09)
IEIC9a8	26.06 (8.30)	254.87 (57.01)	8.99 (52.15)	1.98 (3.44)	17.95 (7.91)	310.48 (29.21)
Vishav Watershed	**314.10 (100)**	**447.10 (100)**	**17.24 100**	**57.51 (100)**	**226.96 (100)**	**1062.91 (100)**

Source: Classified and computed from Landsat 8 operational land imager 2020.

Note: Figures in parenthesis show percentage stream length contributed by different stream orders.

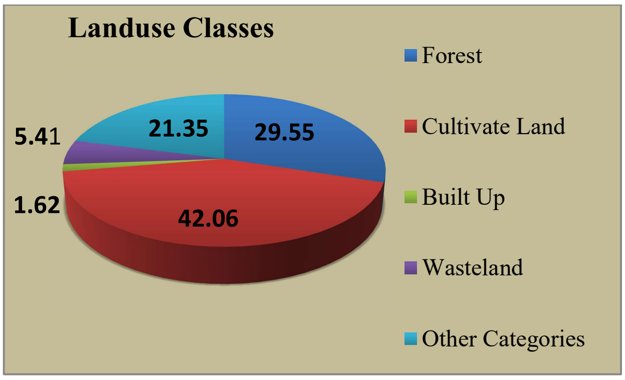


Fig. 1.4: Land use/land cover statistics-2020

PRIORITIZATION OF SUB-WATERSHEDS

Prioritization facilitates in the identification of watersheds that are severely degraded and require immediate care, besides providing a plausible justification for the degradedness in their actual natural settings. As mentioned earlier, prioritization is significant because it brings expected outcomes in a sustainable manner and targets long-term development since resource development programmes are frequently executed on a watershed basis (Vittala *el al.*, 2008).

Table 1.4: Areal morphometric parameters of vishav sub-watersheds.

Sub Watersheds	Drainage Area (A) (km^2)	Drainage Density (Dd) (km/km^2)	Drainage Frequency (Fs) (km^2)	Drainage Texture(Dt)	Form Factor Ratio (Rf)	Elongation Ratio (Re)	Circularity Ratio (Rc)
IEIC9a1	80.85	2.53	3.89	5.32	0.31	0.18	0.50
IEIC9a2	93.39	1.67	3.37	7.36	0.42	0.20	0.64
IEIC9a3	141.47	2.59	2.86	7.33	0.29	0.17	0.58
IEIC9a4	74.11	2.71	3.30	6.54	0.32	0.18	0.66
IEIC9a5	145.61	2.72	3.66	8.69	0.29	0.17	0.58
IEIC9a6	109.79	2.16	3.18	7.28	0.30	0.17	0.59
IEIC9a7	107.20	0.91	1.25	1.47	0.01	0.17	0.15
IEIC9a8	310.49	0.43	0.53	1.64	0.26	0.16	0.37
	1062.91						

Source: Computed from SOI toposheets, 1971, Aster DEM.

Table 1.5: Ranking of morphometric and LULC parameters of Vishav sub-watersheds

	Morphometric Parameters									Land use/ Land cover Category						
Sub Watersheds	Mean Bifurcation Ratio	Drainage Density	Drainage Frequency	Drainage Texture	Form Factor Ratio	Elongation Ratio	Circularity Ratio	CP Value	Priority	Forest	Cultivated Area	Wasteland	Built up	Other category	Cp Value	Priority
IEIC9a1	3	4	1	6	5	2	3	3.43	Medium	2	7	7	6	8	6.00	Low
IEIC9a2	5	6	3	2	7	4	6	4.71	low	6	7	2	6	7	5.6	Low
IEIC9a3	2	3	6	3	3	3	4	3.43	Medium	8	6	3	5	5	5.4	Low
IEIC9a4	6	2	4	5	6	2	7	4.57	Low	5	5	4	3	2	3.80	Medium
IEIC9a5	4	1	2	1	3	3	4	2.57	High	7	4	5	5	5	5.20	Low
IEIC9a6	3	5	5	4	4	3	5	4.14	Low	4	6	1	4	3	3.60	Medium
IEIC9a7	6	7	7	8	1	3	1	4.71	Low	3	5	8	2	4	4.00	Medium
IEIC9a8	1	8	8	7	2	1	2	4.14	Low	1	3	6	1	2	2.60	High

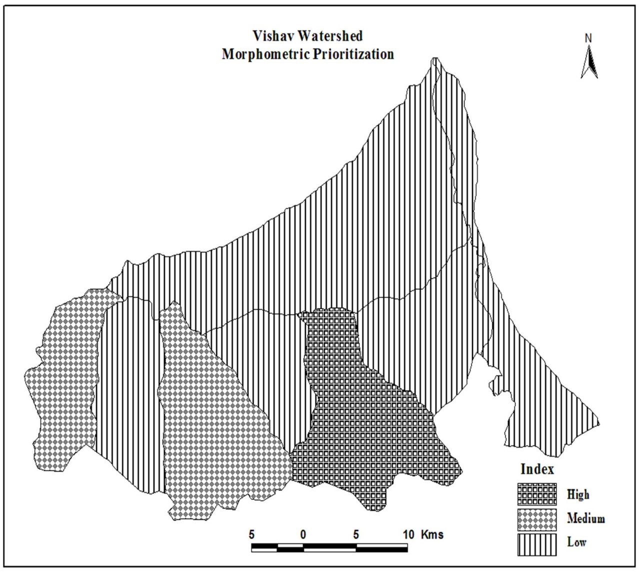
Source: Computed from SOI toposheets, 1971, Aster DEM and Landsat 8 OLI imager 2020.

The primary units of land and water management such as drainage basins, catchments, and sub-catchments are recognized as administrative planning units to safeguard natural resources (Moore *et al.,* 1977; Honore, 1999). The interconnectedness of upland and lowland linkages in their geo-environmental setting puts forward a watershed management concept (Tideman, 1996). As a result, for the long-term development and management of natural resources, an integrated strategy is essential (Khan *et al.,* 2001; Gosain *et al.,* 2004).

Prioritization Based on Morphometric Analysis

Morphometric parameters such as the bifurcation ratio (Rb), mean bifurcation ratio (Rbm), perimeter (P), drainage density (Dd), stream frequency (Fs), drainage texture (Rt), form factor (Rf), elongation ratio (Re), and circularity ratio (Rc) have been widely used to prioritise sub-watersheds for erosion risk assessment (Biswas *et al.,* 1999). Drainage density, stream frequency, and drainage roughness are all area parameters that have a direct relationship with erodibility, higher the value, higher the erodibility. As a consequence, the highest value of areal parameters received rank 1, and vice versa. A shape parameters including form factor ratio, elongation ratio, and circularity ratio are inversely proportional to erodibility; the lower the number, the higher the erodibility (Nooka *et al.* 2005). As a result, the sub-watersheds were ranked by assigning the highest rank based on the highest value for areal characteristics and the lowest value for form parameters shah *et al.,* 2018 (Table 1.5). The sub-watershed which got the highest Cp value was assigned least priority. The sub-watersheds were then categorized into three classes on the basis of the range of Cp value as high (< 3.00), medium (3.00-4.00) and low (>4.00) as depicted in Table 1.6.

Hence, on the basis of morphometric analysis, sub-watersheds IEIC9a5 is included in the high priority zone, while IEIC9a1, IEIC9a3, fall in medium priority zone, and IEIC9a2, IEIC9a4, IEIC9a6, IEIC9a7 and IEIC9a8 fall into the low priority zone, as shown in Fig.1.5.



Source: Computed from morphometric Parameters.

Figure 1.5: Prioritization based on morphometry of vishav sub watersheds.

Prioritization Based on Landuse/Landcover analysis

Forests, cultivation, built up, wasteland, and other landuse categories were examined for sub-watershed priority based on landuse/landcover LULC analyses in all eight sub-watersheds. The percentage area under each landuse category was taken into account, and a ranking were assigned as per the total area under each landuse category (Table 1.5).

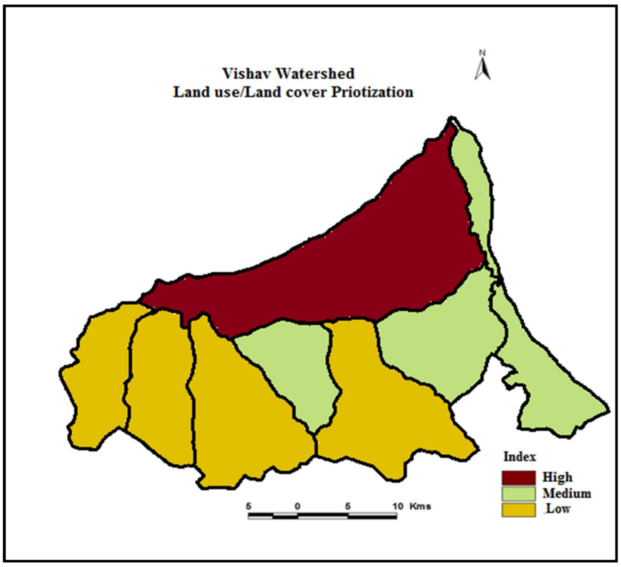
The larger the percentage area in a sub-watershed for cultivation, built-up and wasteland categories, the higher the rank, i.e. rank 1 and vice versa. Conversely for forest class, cultivation, and other categories, the lower the area, the higher the rank was awarded. Finally, the Cp value was calculated by adding the aggregated scores under each land use category. On the basis of the range of Cp values, the final priority/ranking was determined by categorizing the highest and lowest range of Cp values into three classes: high (3.00), medium (3.00-4.00), and low (> 4.00) as depicted in Table 1.6.

Table 1.6: Prioritization values and category in vishav sub watersheds.

Morphometry		Land use/Land cover	
High (< 3.0)	1	High (< 3.0)	1
Medium (3.0-4.0)	2	Medium (3.0-4.0)	3
Low (> 4.0)	5	Low (> 4.0)	4
Total	8	Total	8

Source: Computed from SOI toposheets 1971, Aster DEM and Landsat 8 OLI 2020.

Consequently on the basis of LULC analysis, IEIC9a8 fall into the high priority zone, while IEIC9a4, IEIC9a6, IEIC9a7 fall in medium priority zone, and rest sub-watershed are fall in low priority zone as shown in Fig. 1.6.



Source: Generated from Landsat 8 OLI 2020.

Figure 1.6: Prioritization based on Landuse/landcover of vishav sub watersheds.

CONCLUSION

Prioritization of the watershed is one of the most essential components of planning for the development and maintenance of the healthy watershed. The sub-watersheds have been classified into three categories as high, medium and low in terms of priority where IEIC9a5 and IEIC9a8 fall in high priority zone. The sub watershed IEIC9a5 is characterized by high drainage density (2.72 km^2), bifurcation ratio (3.3km^2), and drainage texture (4.7km^2), whereas IEIC9a8 has got an alarming built up of 8.99 km^2. The sub-watersheds IEIC9a1, IEIC9a3, IEIC9a4, IEIC9a6 and IEIC9a8 were placed in medium priority. To speed up the rehabilitation process and generate an authentic database in each natural resource unit, these prioritized sub-watersheds could be subjected to detailed surveys for soil and water conservation measures, water resources development, scientific land-use planning, preservation of eco-diversity, and an integrated study for the development of natural and social resources.

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