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Research Article

MORPHOMETRIC ANALYSIS AND PRIORITIZATION OF WATERSHEDS FOR SOIL AND WATER RESOURCE MANAGEMENT IN WULAR CATCHMENT USING GEO-SPATIAL TOOLS

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ABSTRACT
The quantitative analysis of morphometric parameters is found to be of immense utility in watershed prioritization for soil and water conservation and natural resources management at micro level. The present work is an attempt to carry out a detailed study of linear and shape morphometric parameters in nineteen watersheds of Wular Catchment and their prioritization for soil and water resource management. Wular Catchment has an area of 1200.36 km^2 and lies between 34^{o}12′24.67″ and 34^{o}36′26.26″ N latitude and 74^{o}26′41.42″ and 74^{o}56′02.90″E longitude. Its altitudinal range is from 1580 meters near Wular Lake to about 4500 meters in Harmukh range. Topographic maps of 1961 on 1:50000 scale were utilized to delineate the drainage system, thus to identify precisely water divides using Geographic Information System (GIS). Following Strahler's stream ordering scheme, it has been found that in Wular Catchment the total number of streams is 2708 belonging to different stream orders with the highest order of 6. The study has shown that the Wular Catchment is in conformity with the Horton's law of stream numbers and stream lengths. The prioritization was carried out by assigning ranks to the individual indicators and a compound value (Cp) was calculated. Watersheds with highest Cp were of low priority while those with lowest Cp were of high priority. Thus an index of high, medium and low priority was produced. The highest priority zone consists of six watersheds, medium of six and low of seven watersheds. High priority indicates that these watersheds are susceptible to greater degree of erosion and application of soil conservation measures becomes inevitable to preserve the land from further erosion and to alleviate natural hazards.

Key Words**:** *Wular Catchment; Watershed; Morphometry; Prioritization; Drainage density*

INTRODUCTION

The quantitative analysis of morphometric parameters is of immense utility in river basin evaluation, watershed prioritization for soil and water conservation, and natural resources management at micro level. Geology, relief, and climate are the key determinants of running water ecosystems functioning at the basin scale (Frissel *et al.,* 1986). Morphometric descriptors represent relatively simple approaches to describe basin processes and to compare basin characteristics (Mesa 2006) and enable an enhanced understanding of the geological and geomorphic history of a drainage basin (Strahler 1964).

A watershed is an ideal unit for management of Natural resources like land and water and for mitigation of the impact of natural disasters for achieving sustainable development. The morphometric assessment helps to elaborate a primary hydrological diagnosis in order to predict approximate behavior of a watershed if correctly coupled with geomorphology and geology (Esper 2008). The hydrological response of a river basin can be interrelated with the physiographic characteristics of the drainage basin, such as size, shape, slope, drainage density and size, and length of the streams, etc. (Chorley 1969, Gregory and Walling 1973). Hence, morphometric analysis of a watershed is an essential first step, toward basic understanding of watershed dynamics.

Watershed prioritization is the ranking of different sub watersheds of a watershed according to the order in which they have to be taken for treatment and soil conservation measures. Morphometric analysis could be used for prioritization of micro-watersheds by studying different linear and aerial parameters of the watershed even without the availability of soil maps (Biswas *et al.,* 1999).

Thus, Watershed prioritization on the basis of morphometric parameters is essential in order to devise a sustainable watershed management plan. Remote sensing and GIS are the most advanced tools for studies on prioritization of micro-watersheds for their development and management. The contributions of Mather and Doornkamp, 1970, Gardiner, 1978, and Gregory, 1978 in terrain characterization studies, especially on spatial variability of morphometric parameters, are considered immensely important. In the Indian regional context, morphometric analysis was employed for characterizing watersheds {Nag, 1998, Vittal et al., 2004, Vijith, H and Satheesh, R 2006, Rudraiah, M et al., 2008, Thomas et al., 2009, Al Saud, M 2009, Rao, N.K et al., 2010}, for the prioritization of micro watersheds {Nooka Ratnam, K et al., 2005, Thakkar and Dhiman 2007, Javed, A et al., 2009, Mishra and Nagarajan, 2010, Londhe et al., 2010}

The present paper evaluates morphometric parameters of Wular Catchment in Western Himalayas to understand their hydrological behavior through Geographical Information System (GIS) techniques and prioritization of watersheds is carried on the basis of these morphometric parameters.

STUDY AREA

The study area falls in the three districts namely Baramulla, Bandipore and Ganderbal of Kashmir Valley. It has an area of 1200.36 km^2 and accounts for 7.6% of the total area of Kashmir valley. The study area lies between 34°12′24.67″ and 34°36′26.26″ N latitude and 74°26′41.42″ and 74°56′02.90″E longitude. The altitudinal range of the Study area is from 1580 meters near Wular Lake to about 4500 meters in Harmukh range. The location map of the study area is depicted in fig. 1. The major rivers apart from Jhelum in the study area are Madhmatti and Erin.

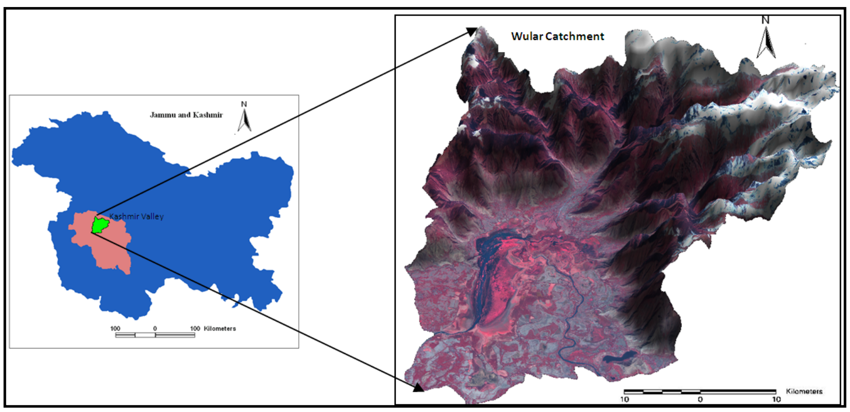

Figure 1: Location map of Study Area

MATERIALS AND METHODS

The Study was carried out on watershed level utilizing SOI toposheets, (1961). All the streams were digitized from Survey of India Toposheets, 1961 on 1:50,000 scale. The study was carried out in GIS environment utilizing Arcview 3.2a for digitization. The various steps employed in the study are given in fig. 2

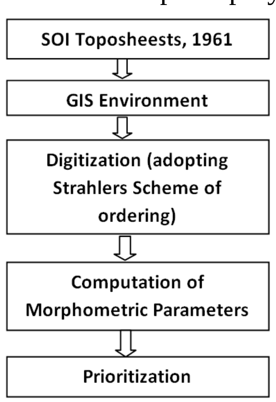

Figure 2: Steps of Methodology

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Strahler's system of stream analysis is probably the simplest, most used system and same has been adopted for this study. Each finger-tip channel is designated as a segment of the first order. At the junction of any two first-order segments , a channel of the second order is produced and extends down to the point where it joins another second order channel ,where upon a segment of third order results. The various morphometric parameters such as area, perimeter, stream order, stream length, stream number, bifurcation ratio, drainage density, stream frequency, drainage texture, length of basin, form factor, circulatory ratio, elongation ratio, length of overland flow, compactness coefficient, shape factor, texture ratio were computed using standard methods and formulae given in table 1.

Table 1: Formulae for the Computation of Morphometric Parameters

S.No.	*Parameter*	*Symbol/Formula*	*Description*	*Reference*
	Stream Order	Hierarchical Rank		**Strahler (1964)**
	Mean Stream Length (Lsm)	Lsm= Lu/Nu	Lu=Total stream length of order u; Nu=Total no. of stream segment of order u.	
	Stream length ratio (RL)	RL=Lu/ Lu-1	Lu-1=Total stream length of its next lower order	**Horton (1945)**
	Drainage Texture (Rt)	Rt=Nu/P	P= perimeter(Km)	
	Length of Overland Flow (Lg)	Lg=1/D*2	D=Drainage density	
	Bifurcation Ratio (Rb)	Rb=Nu/Nu+1	Nu+1=No. of segments of next higher order	**Schumm (1956)**
	Elongation Ratio (Re)	$Re=(2/Lb)*(A/Pi)^{0.5}$	Pi=π; A=Area of basin(Km^2)	
	Mean Bifurcation Ratio (Rbm)	Rbm=Average Rb of all orders		**Strahler (1957)**
	Drainage Density (D)	D=Lu/A		**Horton (1932)**
	Drainage Frequency (Fs)	Fs=Nu/A		
	Form Factor (Rf)	$Rf=A/Lb^2$		
	Circulatory Ratio (Rc)	$Rc=4*Pi*A/P^2$		**Miller (1953)**
	Basin Length (Lb)	$Lb=1.312*A^{0.568}$		**Nooka Ratnam et al. (2005)**
	Compactness Co efficient (Cc)	$Cc= 0.2821P/A^{0.5}$		
	Shape Factor	$Bs=Lb^2/A$		

The linear parameters such as drainage density, stream frequency, bifurcation ratio, drainage texture, length of overland flow have a direct relationship with erodibility, higher the value, more is the erodibility. Hence for prioritization of sub-watersheds, the highest value of linear parameters was rated as rank 1, second highest value was rated as rank 2 and so on, and the least value was rated last in rank. Shape parameters such as elongation ratio, compactness coefficient, circularity ratio, basin shape and form factor have an inverse relationship with erodibility (Nooka Ratnam *et al.*, 2005), lower the value, more is the erodibility. Thus the lowest value of shape parameters was rated as rank 1, next lower value was rated as rank 2 and so on and the highest value was rated last in rank. Hence, the ranking of the subwatersheds has been determined by assigning the highest priority/rank based on highest value in case of linear parameters and lowest value in case of shape parameters

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Table 2: Description of Indicators of Prioritization

Parameter	***Characteristics***
	Linear
Stream Order	It is defined as a measure of the position of a stream in the hierarchy of tributaries
Mean Stream Length (Lsm)	The mean stream length is the characteristic property related to the drainage network and its associated surfaces. Generally higher the order, longer the length of streams is noticed in nature.
Drainage Texture (Rt)	It is the total number of stream segments of all orders per perimeter of the area
Length of Overland Flow (Lg)	Length of overland flow is the length of water over the ground before it gets concentrated into definite stream channels. This factor relating inversely to the average shape of channel is quite synonymous with the length of the sheet flow to a large degree. Generally higher value of Lg is indicative of low relief and where as low value of Lg is an indicative of high relief.
Bifurcation Ratio (Rb)	Bifurcation ratios characteristically range between 3.0 and 5.0 for basins in which the geologic structures do not distort the drainage pattern
Drainage Density (D)	Drainage density (Dd) shows the landscape dissection, runoff potential, infiltration capacity of the land, climatic conditions and vegetation cover of the basin.High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture.
Stream Frequency (Fs)	Stream Frequency is the total number of stream segments of all orders per unit area. Generally, high stream frequency is related to impermeable sub-surface material, sparse vegetation, high relief conditions and low infiltration capacity
Shape	
Form Factor (Rf)	Form factor is defined as ratio of basin area to the square of basin length The value of form factor would always be less than 0.7854 (for a perfectly circular basin) Smaller the value of form factor, more elongated will be the basin. The basins with high form factors have high peak flows of shorter duration, whereas, elongated watershed with low form factors have lower peak flow of longer duration.
Circulatory Ratio (Rc)	**It is** defined as the ratio of basin area to the area of circle having the same perimeter as the basin and is dimensionless. Circulatory Ratio is helpful for assessment of flood hazard. Higher the Rc value, higher is the flood hazard at the peak time at the outlet point.
Elongation Ratio (Re)	Elongation ratio (Re) is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. 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
Compactness Co efficient (Cc)	Compactness Co efficient (Cc) is used to express the relationship of a hydrological basin with that of a circular basin having the same area as the hydrologic basin.
Shape Factor	Basin Shape is the ratio of the square of basin length (Lb) to the area of basin (A)

The prioritization was carried out by assigning ranks to the individual indicators and a compound value (Cp) was calculated. Watersheds with highest Cp were of low priority while those with lowest Cp were of high priority. Thus an index of high, medium and low priority was produced. The various indicators which have been used in the prioritization of Wular Catchment are described in table 2

RESULTS AND DISCUSSION

The study carried out has been divided into three sections, the first section deals with applicability of Horton's laws of stream numbers and stream lengths in the study area. The second section deals with the various linear and shape morphometric parameters and the prioritization of watersheds is done in third section on the basis of these linear and shape morphometric parameters.

Stream Number and Order

The first and most important parameter in the drainage basin analysis is ordering, whereby the hierarchal position of the streams is designated. Following Strahler's scheme, it has been found that in Wular Catchment the total number of streams is 2708, out of which 2158 belong to 1st order, 427 are of 2nd order, 94 are of 3rd order, 25 are of 4th order, 3 of 5th, and 1 is of 6th order. In addition to this one more stream of 6th order i.e., Jehlum has been considered separately. The Watershed wise number and order is given in the table 3 and depicted in fig. 3. It reveals that the highest number of streams is found in 1EM2a (490), followed by 1EM1a (314) and 1EM2b (246), where as the smallest number of streams is found in 1EOb1 (31) followed by 1EW2b (36) and 1EOb1 (42). It is also revealed that the first order streams are highest in number in all watersheds which decreases as the order increases and the highest order has the lowest no of streams.

Table 3: Order wise Stream Number, Length and Mean Length in Wular Catchment

Watershed Code	1st order			2nd order			3rd order			4th order			5th order			6th order		
	No	Length	Mean	No	Length	Mean	No	Length	Mean	No	Length	Mean	No	Length	Mean	No	Length	Mean
1EW1a	59	42.4	0.72	8	17.2	2.15	3	7	2.33	1	0.6	0.6	-		-	-	-	-
1EW1b	44	32.1	0.73	13	9.7	0.74	3	6.1	2.03	1	2.9	2.9	-		-	-	-	-
1EW2a	135	78.4	0.58	28	18	0.64	9	9.9	1.1	2	10.5	5.2	-		-	-	-	-
1EW2b	27	18.8	0.7	8	6.7	0.84	1	1.2	1.2	-	-	-	-		-	-	-	-
1EM1a	246	161.7	0.66	55	43.9	0.8	9	15.7	1.74	3	7.2	2.4	1	13.2	13.2	-	-	-
1EM1b	207	130.5	0.63	43	40.4	0.94	9	14.2	1.58	2	9.9	4.95	-	-	-	-	-	-
1EM2a	404	309.1	0.76	66	64.5	0.98	14	34.8	2.48	5	20.3	4.06	1	14.6	14.6	-	-	-
1EM2b	200	146.8	0.73	33	28.8	0.87	9	17.7	1.97	3	10.5	3.5	1	3.2	3.2	-	-	-
1EM2c	139	94.8	0.68	26	24.3	0.93	8	11.8	1.47	1	2.1	2.1	-	-	-	-	-	-
1EE1a	74	51.1	0.7	17	13.8	0.81	3	10.7	3.57	1	2.7	2.7	-	-	-	-	-	-
1EE1b	99	77.9	0.79	18	24.2	1.34	3	12.13	4.04	1	5.64	5.64	-	-	-	-	-	-
1EE1c	78	60.7	0.78	18	22.3	1.24	2	9.6	4.8	1	1.3	1.3	-	-	-	-	-	-
1EE2a	96	73.4	0.76	16	13.2	0.82	4	8.8	2.2	1	5.82	5.82	-	-	-	-	-	-
1EE2b	45	35.3	0.78	8	7.4	0.92	2	4.9	2.45	1	2.4	2.4	-	-	-	-	-	-
1EE2c	87	64.9	0.74	18	17.3	0.96	2	7.4	3.7	-	-	-	-	-	-	-	-	-
1EOa1	75	53.6	0.71	19	18.6	0.98	6	9.1	1.5	1	3.9	3.9	-	-	-	-	-	-
1EOa2	86	80.4	0.93	20	16.2	0.81	4	12.9	3.22	1	0.4	0.4	-	-	-	-	-	-
1EOb1	23	23.8	1.03	6	7.5	1.25	2	3.5	1.75	-	-	-	-	-	-	-	-	-
1EOb2	34	27.8	0.81	7	10.3	1.47	1	2.2	2.2	-	-	-	-	-	-	-	-	-
Wular Catchment			**0.72**			**0.95**			**2.12**			**3.44**			**16.24**			**15.5**
Cumulative mean length			**0.72**			**1.67**			**3.79**			**7.23**			**23.47**			**38.97**

***(Source:** Computed from SOI Toposheets, 1961)*

The Watershed wise length of streams in different orders, their total length and mean length is given in table 3. It is revealed that the drainage network of the Wular Catchment is characterized by total length of 2317.8 km while as that of Jehlum in it is 21.1 km. The watershed wise drainage length given in the table reveals that 1EM2a constitutes the highest proportion of drainage length of 443.3 km (19.4%), followed by 1EM1a which is 241.7 km (10.58 %), while the lowest contributors are 1EW2b and 1EOb1 contributing 26.7 km (1.17%) and 34.8 km (1.52%). The mean stream length is highest for 1EOb1 (1.12 km) followed by 1EE1b and 1EOa2, both of which have mean stream length of 0.99 km. While as the lowest mean length is found in 1EW2a (0.67 km), 1EW2b (0.74 km) and 1EM1b (0.75 km).

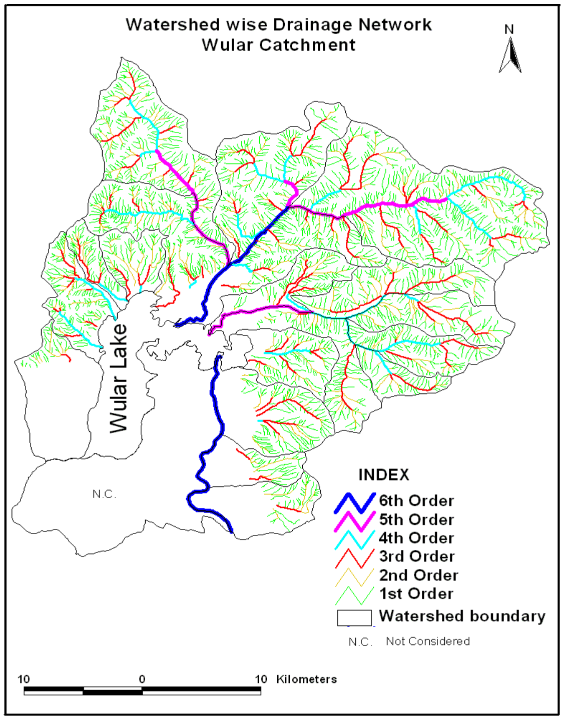

Figure 3: Stream Length
*(**Source:** Generated from SOI Toposheets, 1961)*

Relation between Stream order, Stream Number and Mean Stream Length and evaluation of Horton's law.

1. Horton's law of stream numbers

The number order relationship can be best explained by Horton's law of stream numbers which states "*that the number of stream segments of successively lower orders in a given basin tend to form a geometric series beginning with the single segment of the highest order and increasing according to constant bifurcation ratio.*"

The law of stream numbers is expressed in the following form of negative exponential function mode. $N\mu = R_b^{(k-\mu)}$

Where $N\mu$ = number of stream segments of a given order

R_b = constant bifurcation ratio

$^{\mu}$ = basin order

k = highest order of basin

In Wular Catchment, k = 6 and R_b = 4.93.

It is clear from table 4 that the computed value of stream numbers almost match with the actual values of stream number The regression line plotted on semi log graph (fig 4a) validates Horton's law of stream numbers as the coefficient of correlation is -0.76 and the percentage variance is 57.76%

2. The mean length – order relationship is explained by Horton's law which States "*that the cumulative mean lengths of stream segments of successive higher orders increase in geometrical progression starting with the mean length of the 1st order segments with constant length ratio*". The following positive exponential function model of stream length has been suggested.

$Lu = L_1R_L^{(\mu - 1)}$; Where Lu is the length of the given order, L_1 is the mean length of the first order, R_L is the constant length ratio and µ is the given order.

For the given values of $R_L = 2.17$, $L_1 = 0.72$, The calculated mean cumulative lengths are closely related to the mean cumulative length of the Wular Catchment (Table 4). The regression line drawn on the basis of cumulative mean stream lengths and stream order, plotted on a semi log graph paper (4b) validates the Horton's law of stream lengths as the coefficient of correlation is 0.90 and percentage variance explained is 81%.

Table 4: Order-wise actual and Calculated number of streams and actual and calculated mean Stream length

Stream Order	Stream Number		Mean Stream Length		Calculated Cumulative Mean Stream Length
	Actual Stream Numbers	Calculated Stream Numbers	Actual Mean Stream Length	Mean Cumulative Length	
1	2158	2912.29	0.72	0.72	0.72
2	427	590.73	0.95	1.67	1.56
3	94	119.82	2.12	3.79	3.39
4	25	24.3	3.44	7.23	7.36
5	3	4.93	16.24	23.47	15.96
6	1	1	15.5	38.97	34.64
Total	2708	3653.07			

***(Source:** Computed from SOI toposheets, 1961)*

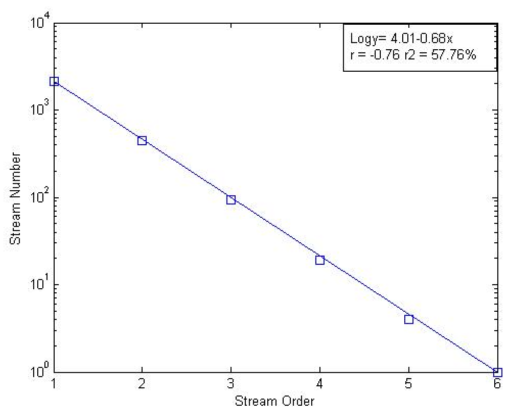

Figure 4a

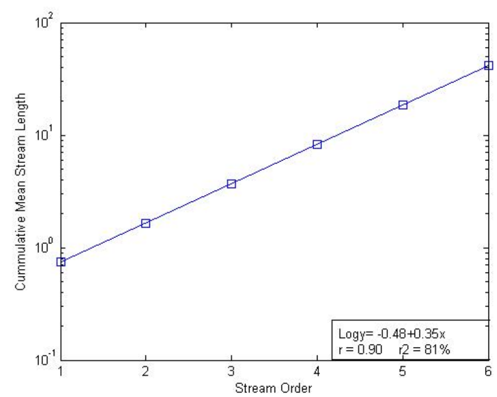

Figure 4b

The various morphometric parameters are given in table 5. These are broadly divided into linear and shape factors.

Linear Parameters

The Linear Parameters include Drainage Density (Dd), Stream Frequency (Fs), Bifurcation Ratio (Rb), Drainage Texture (Rt), Length of overland flow (Lg). The drainage density in the Wular Catchment exhibits a wide range in its values from 0.45 (lowest) in 1EW2b to 3.29 (highest) in 1EW1b. The high value of drainage density (2.39) indicates that the region is composed of impermeable sub-surface materials, sparse vegetation and high mountainous relief. In Wular Catchment the lowest stream frequency is in 1EW2b (0.61), followed by 1EOb2 (1.08) and 1EOb1 (1.15). The highest stream frequency is found in 1EW2a (4.65).High stream frequency is indicative of high relief and low infiltration capacity of the bedrock pointing towards the increase in stream population with respect to increase in drainage density. The watersheds having large area under dense forest have low drainage frequency and the area having more agricultural land have high drainage frequency. High value of drainage frequency produces more runoff in comparison to others. The mean

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bifurcation ratio of the Wular Catchment is 4.93. The lowest Rb is found in 1EOa2 (3.33) whereas highest Rb of 6.92 is in 1EE2c. Low Rb value indicates less structural disturbance and the drainage patterns have not been distorted whereas high Rb value indicates high structural complexity and low permeability of terrain. The hypothesis that the bifurcation ratios within a given region tend to decrease with increasing order does hold good except the bifurcation ratio of 4th and 5th order where it registers the highest bifurcation ratio of 8.33 in any order. The lowest Drainage Texture of 1.05 is in 1EW2b, while as the highest is in 1EM2a (7.85).The Drainage Texture of the watersheds in Wular Catchment ranges from very course to course. The Length of overland flow of Wular Catchment is 0.84. It is highest in 1EW2b (4.39), while as lowest is found in 1EW1b (0.61). Higher value of Lg is indicative of low relief and where as low value of Lg is an indicative of high relief.

Shape Parameters

The shape parameters include Form Factor (Rf), Shape Factor (Bs), Circulatory Ratio (Rc), Elongation Ratio (Re) and Compactness Coefficient (Cc).Wular Catchment has a Form Factor of 0.23. Form Factor is highest in 1EW1b (0.40), and lowest in 1EM2a (0.29), indicating them to be elongated in shape and suggesting flatter peak flow for longer duration. Shape Factor is lowest in 1EW1b (2.50), while as it is highest in 1EM2a (3.45). Wular Catchment has a Shape Factor of 4.38. 1EE2c has the lowest Circulatory Ratio of 0.21, and it is highest in 1EOa2 (0.64) indicating that all the watersheds represent an elongated shape. 1EW1b and 1EE2b have the highest Elongation Ratio of 0.71 and the lowest of 0.61 is found in 1EM2a. Wular Catchment has an Elongation Ratio of 0.54 which indicates high relief and steep ground slope. Compactness Coefficient is highest in 1EE1a (1.98) and lowest in 1EOa2 (1.25). The Compactness Coefficient for the Wular Catchment is 1.89.

Watershed Prioritization

The Watersheds have been broadly classified into three priority zones according to their compound value (Cp) - High (<8.4), Medium (8.4-11) and Low (11and above). The watershed wise prioritization ranks are given in table 6 and the final prioritized map of the study area is shown in figure 5.

Table 5: Watershed wise Morphometric Parameters in Wular Catchment

Microwatershed Code	Area(A) km2	Perimeter (P)km	Length of basin (L_b)km	Stream frequency (Fs) km/km2	Drainage Density (Dd)	Form factor (Rf)	Elongation ratio (Re)	Circulatory Ratio(Rc)	Bifurcation Ratio (Rb)					Mean	Drainage Texture(T)	Length of overland flow(Lg)	Compactness coefficient (Cc)	Shape Factor (Bs)
									(Rb1/2)	(Rb2/3)	(Rb3/4)	(Rb4/5)	(Rb5/6)	(Rb)				
1EW1a	24.54	22.68	8.08	2.89	2.74	0.38	0.69	0.60	7.38	2.67	3.00	0	0.00	4.35	3.13	0.73	1.29	2.66
1EW1b	15.42	20.95	6.21	3.96	3.29	0.40	0.71	0.44	3.38	4.33	3.00	0	0	3.57	2.91	0.61	1.51	2.50
1EW2a	37.37	33.41	10.26	4.66	3.13	0.36	0.67	0.42	4.82	3.11	4.50	0	0	4.14	5.21	0.64	1.54	2.82
1EW2b	58.59	34.3	13.25	0.61	0.46	0.33	0.65	0.63	3.38	8.00	0	0	0	5.69	1.05	4.39	1.26	2.99
1EM1a	83.99	52.85	16.25	3.74	2.88	0.32	0.64	0.38	4.47	6.11	3.00	3	0	4.15	5.94	0.69	1.63	3.14
1EM1b	73.2	53.18	15.03	3.57	2.66	0.32	0.64	0.33	4.81	4.78	4.50	0	0	4.70	4.91	0.75	1.75	3.09
1EM2a	164.78	62.39	23.83	2.97	2.69	0.29	0.61	0.53	6.12	4.71	2.80	5	0	4.66	7.85	0.74	1.37	3.45
1EM2b	79.96	45.04	15.80	3.08	2.59	0.32	0.64	0.50	6.06	3.67	3.00	3	0	3.93	5.46	0.77	1.42	3.12
1EM2c	54.4	50.82	12.70	3.20	2.44	0.34	0.66	0.26	5.35	3.25	8.00	0	0	5.53	3.42	0.82	1.94	2.96
1EE1a	30.26	38.69	9.10	3.14	2.59	0.37	0.68	0.25	4.35	5.67	3.00	0	0	4.34	2.46	0.77	1.98	2.74
1EE1b	45.91	42.94	11.53	2.64	2.61	0.35	0.66	0.31	5.50	6.00	3.00	0	0	4.83	2.82	0.77	1.79	2.90
1EE1c	40.62	33.78	10.76	2.44	2.31	0.35	0.67	0.45	4.33	9.00	2.00	0	0	5.11	2.93	0.87	1.50	2.85
1EE2a	33.46	31.72	9.64	3.50	3.03	0.36	0.68	0.42	6.00	4.00	4.00	0	0	4.67	3.69	0.66	1.55	2.77
1EE2b	17.98	22.25	6.77	3.11	2.78	0.39	0.71	0.46	5.63	4.00	2.00	0	0	3.88	2.52	0.72	1.48	2.55
1EE2c	44.34	51.04	11.31	2.41	2.02	0.35	0.66	0.21	4.83	9.00	0	0	0	6.92	2.10	0.99	2.16	2.88
1EOa1	34.61	28.8	9.82	2.92	2.46	0.36	0.68	0.52	3.95	3.17	6.00	0	0	4.37	3.51	0.81	1.38	2.79
1EOa2	56.51	33.3	12.98	1.96	1.94	0.34	0.65	0.64	4.30	5.00	4.00	0	0	3.33	3.33	1.03	1.25	2.98
1EOb1	26.84	24.99	8.50	1.15	1.30	0.37	0.69	0.54	3.83	3.00	0	0	0	3.42	1.24	1.54	1.36	2.69
1EOb2	39.02	29.26	10.51	1.08	1.03	0.35	0.67	0.57	4.86	7.00	0	0	0	5.93	1.44	1.93	1.32	2.83
Wular Catchment	**961.8**	**208**	**64.91**	**2.82**	**2.39**	**0.23**	**0.54**	**0.00**	**5.05**	**4.54**	**3.76**	**8.33**	**3.00**	**4.93**	**13.02**	**0.84**	**1.89**	**4.38**

***(Source:** Computed from SOI Toposheets, 1961)*

Research Article

1. **High Priority**: The watersheds which fall in high priority category are 1EW1b, 1EM1a, 1EM1b, 1EM2c, 1EE2a and 1EE2b. These watersheds generally consist of steep slopes, high drainage density, high stream frequency, low form factor and low elongation ratio. These can be classified under very severe erosion susceptibility zone Thus need immediate attention to take up mechanical soil conservation measures gully control structures and grass waterways to protect the topsoil loss.

Table 6: Prioritization of Watersheds in the Wular Catchment on the basis of Morphometric Parameters

	Linear Parameters					Shape Parameters						
Microwatershed Code	Drainage Density (Dd)	Stream frequency (Fs) kM/kM2	Mean Bifurcation Ratio (Rb)	Drainage Texture(T)	Length of overland flow(Lg)	Form factor (Rf)	Shape Factor (Bs)	Circulatory Ratio(Rc)	Compactness coefficient (Cc)	Elongation ratio (Re)	Cp	Final Priority
1EW1a	6	11	12	11	15	18	1	17	3	16	11.0	Low
1EW1b	1	2	15	8	8	8	12	11	9	7	8.1	High
1EW2a	2	1	17	18	2	13	10	2	11	15	9.1	Medium
1EW2b	19	**12**	5	6	14	14	6	5	14	8	10.3	Medium
1EM1a	4	3	3	19	7	4	17	15	1	11	8.4	High
1EM1b	8	8	4	3	1	19	**19**	6	6	4	7.8	High
1EM2a	7	9	13	7	11	11	9	3	2	18	9.0	Medium
1EM2b	10	7	16	10	12	15	13	8	17	17	12.5	Low
1EM2c	13	5	8	9	10	9	4	18	4	1	8.1	High
1EE1a	11	13	9	15	9	16	3	9	18	14	11.7	Low
1EE1b	9	6	10	14	5	5	15	13	19	19	11.5	Low
1EE1c	14	15	11	12	6	2	7	14	7	12	10.0	Medium
1EE2a	3	19	**6**	2	18	12	5	7	8	2	8.2	High
1EE2b	5	4	14	16	4	3	14	1	10	6	7.7	High
1EE2c	15	10	7	4	16	7	16	19	16	3	11.3	Low
1EOa1	12	14	1	13	17	17	8	12	12	10	11.6	Low
1EOa2	16	16	19	**1**	19	1	2	10	15	9	10.8	Medium
1EOb1	17	17	18	17	3	6	18	16	5	5	12.2	Low
1EOb2	18	18	2	5	13	10	11	4	13	13	10.7	Medium

Source: *Computed from SOI Toposheets, 1961*

2. **Medium Priority**: There are six watersheds falling in medium priority. These include 1EW2a, 1EW2b, 1EM2a, 1EE1c, 1EOa2 and 1EOb2. These watersheds consist of moderate slopes, moderate values of drainage density, stream frequency, drainage texture and moderate to high form factor, circulatory ratio and elongation ratio.
3. **Low Priority**: This category has been attained by 1EW1a, 1EM2b, 1EE1a, 1EE1b, 1EE2c, 1EOa1 and 1EOb1. These watersheds consist of lower slopes, very low drainage density, stream frequency, texture ratio, high form factor, circulatory ratio and elongation ratio. These watersheds can be categorized under very slight erosion susceptibility zone and may need agronomical measures to protect the sheet and rill erosion.

CONCLUSION

Watershed prioritization is one of the most important aspects of planning for implementation of its development and management programs. The present study demonstrates the usefulness of GIS for morphometric analysis and prioritization of the watersheds of Wular Catchment. The morphometric characteristics of different watersheds show their relative characteristics with respect to hydrologic response of the watershed.

The study has shown that the Wular Catchment is in conformity with the Horton's law of stream numbers and stream lengths. The high value of drainage density (2.39) indicates that the region is composed of impermeable sub-surface materials, sparse vegetation and high mountainous relief causing higher surface run off, and a higher level of degree of dissection. The Rb values characterize highly dissected mountainous watersheds with mature topography and higher drainage integration. A high proportion of first order streams (80%) indicates structural breaks, chiefly as, lineaments, and fractures of

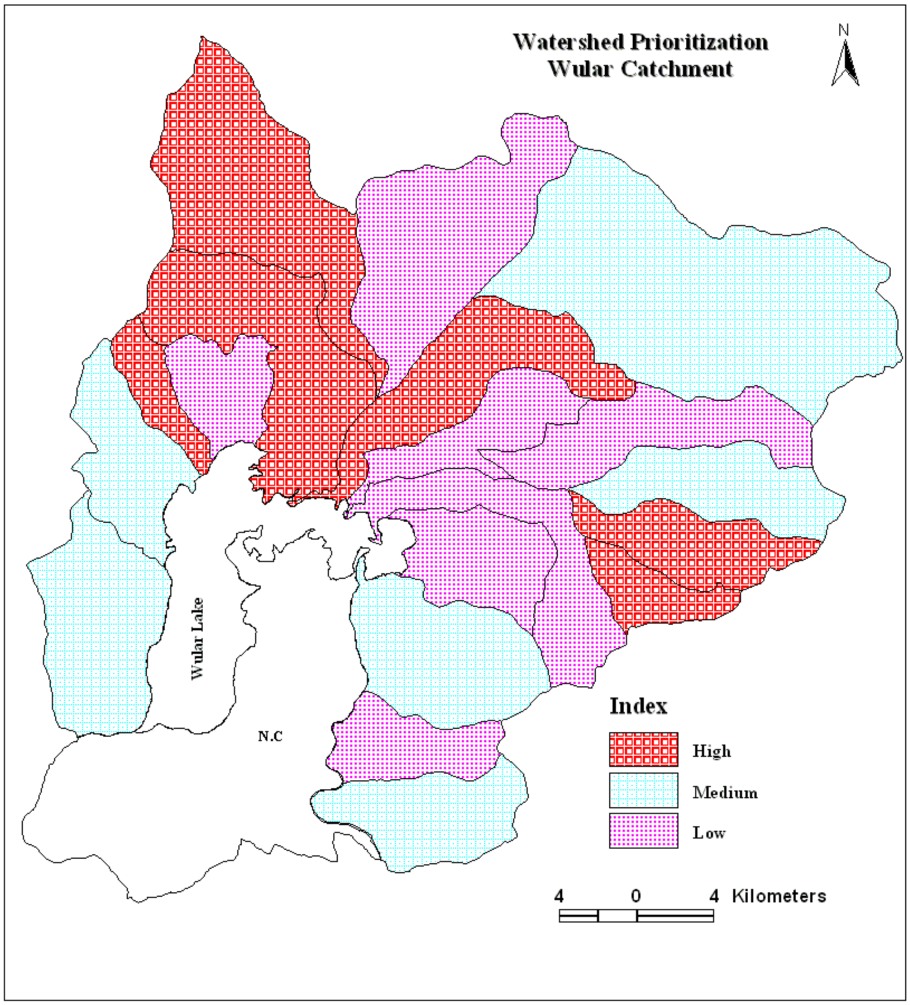

Figure 5: Source: Generated from SOI Toposheets, 1961

rocky basement of the watershed. The watersheds which fall in high priority category are 1EW1b, 1EM1a, 1EM1b, 1EM2c, 1EE2a and 1EE2b. These watersheds generally consist of steep slopes, high drainage density, high stream frequency, low form factor and low elongation ratio. High priority indicates the greater degree of erosion in the particular watersheds and it becomes potential candidate for applying soil conservation measures. Therefore, immediate attention towards soil conservation measures is required in these watersheds to preserve the land from further erosion and to alleviate natural hazards.

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