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PRIORITIZATION OF TIRTHAN WATERSHED

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ABSTRACT

The present study seeks to prioritize the Tirthan watershed for conservation and management of natural resources on the basis of morphological and land use/land cover characteristics. The study has utilized morphometric information derived from drainage layers computed from toposheets. The relief, slope, aspect and hypsometric parameters have been analysed using ASTER Digital Elevation Model (DEM) with 30 m spatial resolution. To generate the land use/ land cover information, the Google Earth images have been used. The characterization and prioritization of each sub-watershed has been done using 21 parameters related to morphometry and land use/ land cover. For the final prioritization, the arbitrary weightage method has been adopted to assign weight to the parameters on the basis of their resource degradation potential. Based on composite scores of parameters used the sub-watersheds have been ranked and ordered. Results of the study reveals that TSW-1 and TSW-2 fall in critical category of watershed prioritization.

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INTRODUCTION

Identification of suitable land for development is one of the critical issues of regional planning (Kumar and Kumar, 2011). Land and water are the two basic natural resources for the survival of living systems. These resources are limited and their judicious utilization is imperative especially in countries like India, where the size of land holdings is decreasing incessantly (FAO, 1985). Watershed is a geo-hydrological unit of land. These fundamental units of water resource region provide scope for the management of land and water resources. North West Himalaya (NWH) is one of the critical areas in terms of overall natural hazards as the area is susceptible to flash floods, snow avalanches, forest fires, mudflows and landslides (Dhote*et al.* 2019). The poor health of geo-hydrological unit also increases the tendency of natural hazards. The rates of denudation in the Himalayan region are very high in comparison to most other parts of the country (Pandey, 2010:190). Soil erosion is a serious problem in Himalayas and foothill ecosystem. Eighty percent of the sediment material delivered to the world's oceans each year comes from Asian rivers, and amongst these, Himalayan Rivers are the major contributors (Rawat *et al*, 2017:40). Sustainable use of mountains depends upon conservation and optimum use of soil and water resources (Ives & Messerli, 1989). Further, as farming/agriculture, especially subsistence agriculture is the main livelihood of people in the Himalayan region, which in turn is entirely dependent upon the health of soil resource. Additionally, Himalayan region experience higher potential soil loss. Thus, the watershed management is imperative to sustain the productivity and livelihood in this mountainous region. The watershed management concept recognizes the inter-relationships among the linkages between uplands and low lands, land use, geomorphology, slope and soil. The future of human beings is closely associated with the proper development and conservation of natural resources. In this regard, prioritization of watershed on the basis of quantitative analysis of morphometric parameters, land use and land cover characteristics are important to develop a sustainable watershed development strategy. Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of the watershed (Strahler, 1964 quoted in Biswas et al, 1999). This analysis has been commonly applied to prioritization of watershed. The various components such as stream segments, basin perimeter, basin area, elongation ratio, drainage density, slope and hypsometric analysis of land has been responsible for the natural development of basin. Data on land cover and land use are essential for observing and managing a range of key environmental and socio-economic trends, many of which are linked to the sustainable use of resources (Eurostat, 2011:158). The Tirthan watershed is a part of Lesser Himalaya which experiences heavy rainfall during monsoon season and dry spells during winter. Due to seasonal variations the region experiences flood events in monsoon, and is susceptible to meteorological, geological and hydrological hazards (Dhote*et al.* 2019). The topography of Tirthan watershed is rugged and provides less habitable land for different economic activities. In this regard prioritization of raises an academic curiosity to look into the matter and may provide better insights about optimum use of resources, their conservation as well as for the policy making. Therefore, the present study attempts to explore, various morphometric characteristics of Tirthan watershed, and land use/land cover pattern at micro level. Additionally, attempts have also been made to prioritize sub-watersheds on the basis of morphometric, and land use/land cover characteristics.

Study Area: The Tirthan watershed extending between 31º 30' 25" N and 31º 44' 02" N and 77º 13' 03" E and 77º 41' 14" E covers an area of about 682 sq Km. The watershed lies in the left bank of upper Beas River system in the lesser Himalaya.

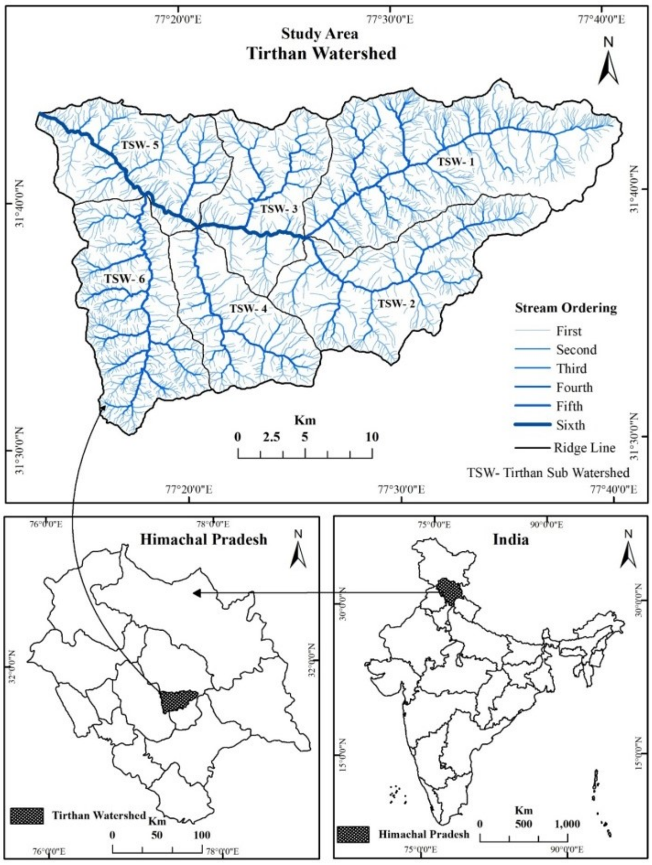
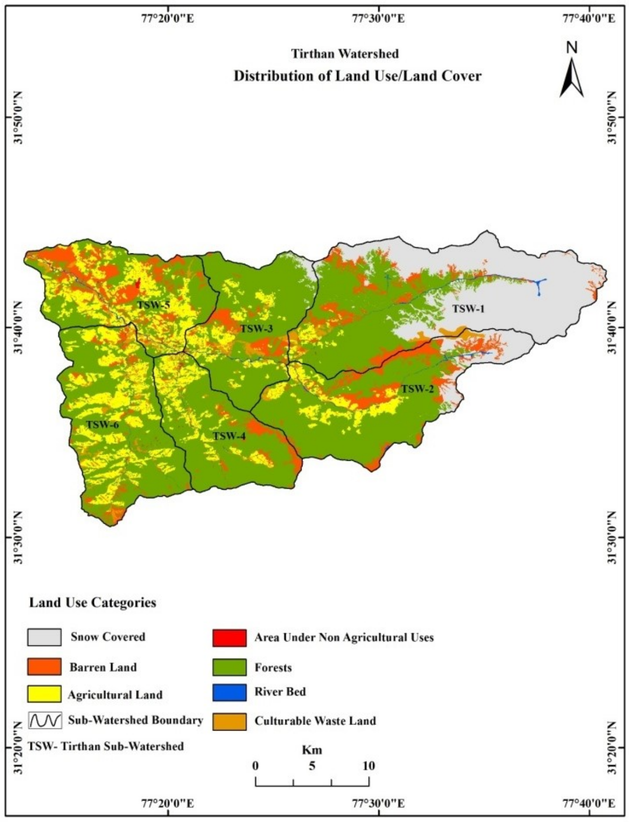


Figure 1.

It constitutes about 7.21% of total geographical area of Kullu and Mandi districts of Himachal Pradesh. Tirthan watershed is elongated in E-W direction (Fig.1). It is surrounded by Satluj basin in the south and southeast, Sainj watershed in north and Beas basin in west. Topographically, Tirthan watershed falls between lesser Himalaya (mostly below 3000 m) and the lower offshoots of Great Himalaya. The watershed presents a typical mosaic of moderate to high rugged topography with numerous mountainous peaks over 4500m. The altitude ranges from the lowest 929 m to the highest 5229 m above mean sea level. The major rock formations of the study area are crystalline in nature consisting of Quartzite, Phyllites, Slates and Schists.



Source: Computed by Author from Google Earth Images

Figure 2

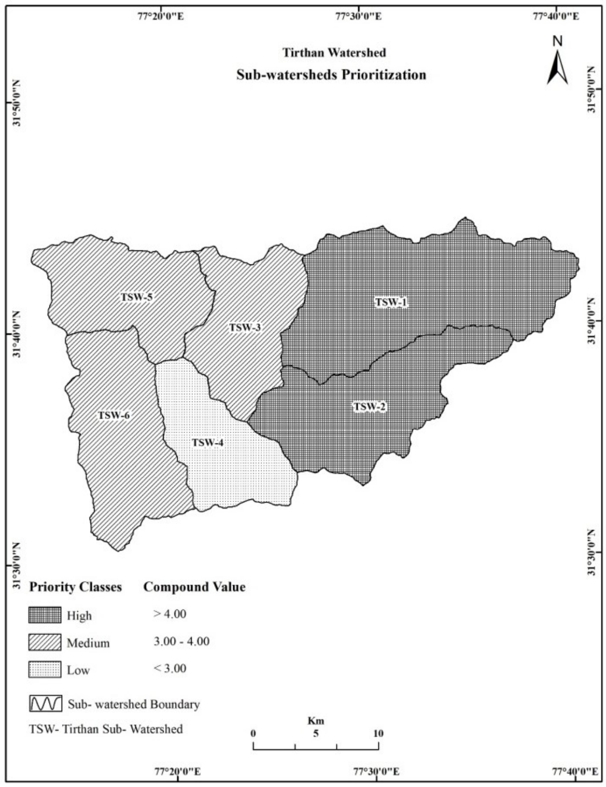


Figure. 3

In the study area, sandy skeletal, loamy skeletal soil, fine and coarse loamy soil and loamy soil are the classes of soil texture. The climate in the Tirthan watershed is typically the Western Himalayan warm temperate and alpine type. Precipitation is moderate over most of the year and abundant during monsoon from mid-June to mid-September.

The vegetation type of the study area ranges from sub-tropical to alpine type.

METHODOLOGY

The present study, primarily quantitative methods have been used. Data were collected from both published and unpublished collected from different sources. Topographical maps of the study area, produced by survey of India at 1:50,000 scales (*viz.*53 E/2, 53 E/6, and 53 E/10) were used for delineating boundaries, drainage network, extracting morphometric characteristics. For spatial analysis the Tirthan watershed has been divided into six sub-watersheds (Fig. 1). On the basis of five orders stream principle, five sub-watersheds (TSW-1, TSW-2, TSW-3, TSW-4 and TSW-6) and one sub-watershed (TSW-5) of all ordered stream have been delineated. The drainage network has been digitized through Arc-GIS 10. Relief, slope, aspect and hypsometric parameters have been analysed using, ASTER Digital Elevation Model (DEM) with 30 m spatial resolution. The land use/ land cover categories have been analysed at sub-watershed level. The land use/land cover information has been derived from Google Earth images by using Arc-GIS 10.3 software. The visual interpretation keys have been used to identify land use/land cover categories of the study area on these imageries, which were also verified by field observations. The arbitrary weightage method has been adopted to assign weight to the parameters on the basis of their resource degradation potential (Table 1). Based on weighted scores, the composite index has been calculated for each sub-watershed. Based on composite values of morphometric and land use/land cover attributes the sub-watersheds have been ranked and ordered. The sub-watershed having the highest composite value has been assigned rank-1 and next highest value has assigned rank-2 and so on.

RESULTS AND DISCUSSION

Morphometric Characteristics: The characterization of watersheds plays an important role in forecasting the hydrological behaviour and planning these geo-hydrologic units. In order to explain and compare the spatial variation of the elements of river basin some fundamental morphometric parameters are intensively used in geomorphology. Linear, areal, shape and relief attributes have been used to characterize the Tirthan watershed. It deals with the detailed investigation of certain morphometric properties at the sub-watershed level.

Linear Aspects: Table 2 reveals that Tirthan sub-watershed-1 (TSW-1) has the highest number of first ordered streams which constitute more than 28% of total first order streams of study area. TSW-3 and 4 have minimum share (9.8 and 8.88%) of first order stream. It may be attributed due to high vegetation cover in this region (Table 4).Mean stream length for the entire watershed is 2.90 km. At sub watershed level mean stream length ranges from 1.52 in the TSW-5 to 4.13 in TSW-6. A widely used topographical property of stream network is the bifurcation ratio. This is the ratio between the number of stream segments of one order and the number of the next highest order. The mean bifurcation ratio (Rbm) for each sub-watershed ranges from 3.73 to 5.06 for TSW-5 and TSW-6 respectively. The average Rbm in the watershed is 4.60 which is indication of higher range among stream segments in successive orders. It is evident from the study that the high mean bifurcation ratio (TSW-1, 6) is the result of large variation in stream frequency between successive orders. The Rbm also reflects indirectly the impact of underlying lithology and vegetation cover. The length of overland flow is one of the most important independent variables affecting both the hydrologic and physiographic development of drainage basins (Horton, 1945). It is the length of flow of water over the ground surface before concentrating in definite stream channels. The length of overland flow ranges from 0.14 to 0.22 in all across the sub-watersheds. Table 4 represent the length of overland flow for each sub-watershed. It has been found that variation in the length of overland flow is due to variable stream frequency and drainage density. It may be inferred that there is negative relationship between drainage density and length of overland flow.

Areal Aspects of Tirthan Watershed: Areal properties express the overall plan form and dimensions of drainage basins (Summerfield, 1991:209). Drainage density is defined as the total length of stream segments per unit area. It is a valuable index of drainage basin processes as it helps to reflect several environmental factors like climate, topographical, lithological, pedological and vegetal controls (Prasad, 2007:116). Table4 exhibit the distribution of drainage density in the study watershed. Tirthan watershed has dense network of streams i.e., 2.7 km/km² area. It has been observed that the drainage density is the lowest in TSW-4 and is the highest in TSW-6. The elongation ratio has important hydrological consequences because precipitation occurred during a storm in highly elongated basins has to travel a wide range of distances to reach the basin outlet (Summerfield, 1991:209). Table 4 portrays the spatial distribution of elongation ratio with in Tirthan watershed. The values range from the lowest 0.56 in TSW-2 and the highest 0.75 in TSW-5. It is evident from the study that higher the value of Re, more circular is the shape of sub-watersheds. Circularity ratio is a dimensionless parameter which provides a quantitative index of the shape of the basin. The value of circularity ratio varies from 0 (a line) to 1 (a circle). In the study area, the value of circularity ratio ranges from 0.40 in TSW-2 and the highest 0.58 in TSW-4. Tirthan sub-watershed 1 and 2 has the values less than the average value for the study area. Remaining four sub-watersheds (TSW-3, 4, 5 and 6) have the values greater than the average value. The ratio of basin area to the square of basin length is called the form factor (Horton, 1932 quoted in Prasad, 2007). The value of 'R*f* varies from 0 (highly elongated shape) to the unity i.e., 1 (perfect circular shape). The form factor (R*f*) for Tirthan watershed is 0.34. This indicates that whole watershed of the Tirthan has elongated shape and suggest flatter peak flow for longer duration. The form factor values range from 0.24 in TSW-2 and 0.44 in TSW-3 and TSW-4.

Relief Aspects of Tirthan watershed: The relief aspect of the watershed is related to the analysis of three-dimensional feature of the hydro-geological unit involving area, volume and altitude of vertical dimension (Singh, 2012:375). Relief aspects analysed for present study are the relief ratio, relative relief, ruggedness number and hypsometry. Relative relief represents the difference in elevation between the highest and lowest points in any unit area. The relative relief of the Tirthan sub-watersheds has been studied by using Melton method (1957). The relative relief range from the lowest 40.16 m in TSW-6 to the highest 58.10 m in TSW-4.Relief ratio is a dimensionless variable which denotes the ratio between height and basin length. Relief ratio denotes the overall steepness of drainage basin and is an indicator of the intensity of degradation process operating on slope of that particular watershed (Singh, 2012:187-188). The average relief ratio of Tirthan watershed is 1.52. It varies between lowest 1.16 m/m in TSW-6 and the highest 1.77 m/m in TSW-3.Ruggedness number is the product of maximum basin relief (H) and drainage density (D*d*), where both parameters are in the same unit. The ruggedness number is extremely high in all the sub-watersheds of the study area. It ranges between lowest 5.31 in TSW-4 and highest 10.06 in TSW-1. It indicates that the whole watershed is almost extremely rugged with high basin relief and high drainage density. Such high values are characteristic of mountainous terrain.

Slope Analysis: One of the most important attributes of morphometric elements is the slope or the inclination of the terrain (Thakur, 2008:33). The study area has highly rugged and dissected terrain thus area under moderate slope provides favourable conditions for human subsistence and vegetative growth. More than 75% area has less than 40˚ slope, the share of this category varies from the lowest 72 percent in TSW-3 to the highest 84.5% in the TSW-6. Table 4 shows spatial variations of moderately sloping category at sub-watershed level. The variations in the sub-watershed are due to the lithology, relief and physical forces who work upon it.

Hypsometric Analysis: Hypsometric curve and Hypsometric integral are considered important morphometric parameters in studying the stage of basin development.

Table 1. Tirthan Watershed: Weightage Criteria for Prioritization

Morphometric Parameters	Weightage Criteria	References
Mean Stream Length (Lsm)	More theMean Stream Length, More the Priority	Sharma and Thakur, (2016)
Basin Length (Lb)	More the Basin Length, More the Priority	Sharma and Thakur, (2016)
Stream Frequency (Fs)	More the Stream Frequency, More the Priority	Banerjee et al. (2011)
Length of Over Land Flow (Lg)	More the Length of Over Land Flow, More the Priority	Sharma and Thakur, (2016)
Drainage Density (Dd)	More the Drainage Density, More the Priority	Biswas et al. (1999)
Mean Bifurcation Ratio (Rbm)	More the Mean Bifurcation Ratio, More the Priority	Nooka Ratnam et al. (2005)
Ruggedness Number (Rn)	More the Ruggedness Number, More the Priority	Meshram and Sharma, (2017)
Relative Relief (Rr)	More the Relative Relief, More the Priority	Banerjee et al. (2011)
Relief Ratio (Rh)	More the Relief Ratio, More the Priority	Meshram and Sharma, (2017)
Erosional Integral (E.I.)	More the Erosional Integral, More the Priority	Mandal and Basu, (2011)
Elongation Ratio (Re)	Less the Elongation Ratio, More the Priority	Biswas et al. (1999)
Circulatory Ratio (Rc)	Less the Circulatory Ratio, More the Priority	Biswas et al. (1999)
Basin Shape (Bs)	Less the Basin Shape, More the Priority	Nooka Ratnam et al. (2005)
Form Factor (Fr)	Less the Form Factor, More the Priority	Nooka Ratnam et al. (2005)
Slope	Higher the Slope, More the Priority	Naqvi, et al. (2015)
LULC Parameters		
Forest Cover	Lower the Percentage of Forest Cover, More the Priority	Gajul, et al. (2016)
Agricultural Land	Lower the Percentage of Agricultural Land, More the Priority	Gajul, et al. (2016)
Builtup Area	Higher the Percentage of Built up area, More the Priority	Suji, et al. (2015)
Culturable waste Land	Higher the Percentage of Waste Land, More the Priority	Suji, et al. (2015)
Barren Land	Higher the Percentage of Barren Land, More the Priority	Naqvi, et al. (2015)
Protected Area	Less the Percentage of Protected Area More the Priority	

Table 2. Tirthan Watershed: Relationship between Stream Order and Stream Number

Stream Order and Stream Numbers *(Nu)*	Tirhtan Sub-watersheds (TSW)						Tirthan Watershed
	TSW-1	TSW-2	TSW-3	TSW-4	TSW-5	TSW-6	
1 *(Nu1)*	591 (28.08)	326 (15.40)	207 (9.83)	187 (8.88)	278 (13.21)	515 (24.47)	2104
2 *(Nu2)*	130	61	42	46	64	105	448
3 *(Nu3)*	32	14	10	12	11	24	103
4 *(Nu4)*	5	2	2	2	2	8	21
5 *(Nu5)*	1	1	1	1	1	1	6
6 *(Nu6)*	0	0	0	0	1	0	1

Source: Compiled by Author from Drainage Layer

Table 3. Tirthan Watershed: Distribution of Hypsometric and Erosional Integrals

Sub-watersheds	Hypsometric Integral in (%)	Erosional Integral in (%)	Landscape Stage of Development
TSW-1	54.30	45.70	Early Maturity
TSW-2	42.84	57.16	Middle Maturity
TSW-3	47.88	52.12	Middle Maturity
TSW-4	50.00	50.00	Early Maturity
TSW-5	39.88	60.12	Maturity
TSW-6	60.50	39.50	Late Youth
Tirthan Watershed	**43.04**	**56.96**	**Middle Maturity**

Source: Computed by Author from Digital Elevation Modal (DEM)

Such analysis allows the calculation of hypsometric integral which summarizes the form of a drainage basin in a single value (Summerfield, 1991:210). Graph 1 portrays the hypsometric curves computed as per Strahler's technique, for the Tirthan sub-watersheds. In the present study, hypsometric integrals have been calculated with the help of the percentage hypsometric curve. It is expressed in percentage, the landmass of watersheds which has not been eroded yet. Table 3 shows hypsometric curves for all six sub-watersheds of study area. It is evident from the Graph 1 that hypsometric curves have witnessed regional variations due to variable intensity of erosion, geology and vegetation cover. Hypsometric integral ranges from lowest 39.88% in TSW-5 and highest 60.50% in TSW-6 indicating mature and late youth stages respectively. TSW-1 and TSW-4 have 54.30% and 50.00% integral value respectively which indicate the early maturing stage of landscape development. The TSW-2 and TSW-3 show the middle mature stage of landform development. There are no any sub-watersheds in early and middle youth stages. Thus, this analysis suggests that the whole Tirthan watershed has witnessed significant regional variation in hypsometric integral at sub-watershed level. These variations may be attributed to the level of vegetation cover, type of soil texture, geology of the area, amount of rainfall and level of human interventions.

Pattern of Land use and Land Cover: The land use/cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Information on land use/cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare (Kumar and Kumar, 2011:790). In the present study, nine-fold classification of land use/land cover by Ministry of Land Revenue Department, Government of India has been adopted. For the convenience at sub watershed level, these nine classes have been further clubbed into five categories Table 4.

Land Use and Land Cover Classification: Tirthan watershed shows different LULC categories. The Tirthan watershed has a little more than half of watershed area under forest cover. Results of the study reveal that the central and south eastern parts of Tirthan watershed have high proportion of vegetal cover. The Great Himalayan National Park and other conservation measures have led to higher forest cover. The study reveals that about 17% of Tirthan watershed is under permanent snow. The large proportion of snow cover is due to high absolute relief. There is about 14% of total land under agriculture with higher share in the western parts.

Table 4. Tirthan Watershed: Quantitative Representation of Morphometric and LULC Characteristics

Tirthan Sub-watersheds	Morphometric Parameters															Per cent area under Land Use/Land Cover categories					
	L*s*	L*sm*	L*b*	F*s*	L*g*	D*d*	R*bm*	R*n*	R*r*	R*h*	E.I.	R*c*	R*e*	F*f*	Slope (below 40°)	Forests	Non-Agricultural Land	Agricultural Land	Culturable Waste Land	Barren Land	Protected Areas
Tsw-1	521.36	3.78	25.05	4.05	0.17	2.78	5.00	10	52.15	1.44	45.70	0.48	0.61	0.29	73.21	32.59	0.07	2.11	2.42	8.64	100.00
Tsw-2	319.43	3.30	22.34	3.27	0.19	2.59	4.60	8.9	55.89	1.53	57.16	0.40	0.56	0.24	74.82	58.85	0.32	9.39	2.79	13.88	93.55
Tsw-3	210.60	2.28	14.04	3.01	0.21	2.42	4.00	6.0	54.10	1.77	52.12	0.51	0.74	0.44	72.00	70.16	0.45	11.58	7.97	7.07	52.88
Tsw-4	173.56	3.28	15.37	3.22	0.22	2.25	3.90	5.3	58.10	1.53	50.00	0.58	0.64	0.32	79.13	73.85	1.01	15.56	2.69	6.60	0.00
Tsw-5	263.20	1.52	14.45	3.81	0.17	2.81	3.73	6.9	53.41	1.70	60.12	0.56	0.75	0.44	75.12	40.63	1.42	30.52	6.66	19.49	0.00
Tsw-6	381.34	4.13	17.98	5.74	0.14	3.35	5.05	7.0	40.16	1.16	39.50	0.51	0.66	0.35	84.50	61.83	1.05	27.31	5.05	4.29	0.00
Total	1869.49	2.90	46.54	3.81	0.18	2.70	4.60	7.4	30.6	1.52	56.96	0.50	0.66	0.34	76.15	52.58	0.62	14.29	4.20	27.64	51.56

Table 5. Final Prioritization of Tirthan Watershed

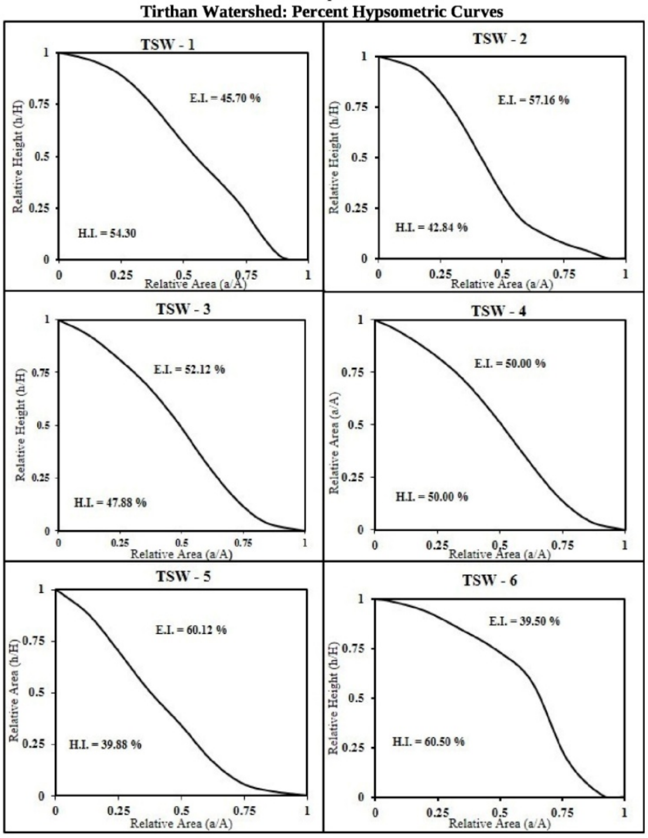
Tirthan Sub-Watersheds	Morphometric Parameters															Land Use/Land Cover categories						Compound Average	Final Priority
	L*s*	L*sm*	L*b*	F*s*	L*g*	D*d*	*Rbm*	R*n*	R*r*	R*h*	E.I.	R*c*	R*e*	F*f*	Slope	Forests	Non-Agricultural Land	Agricultural Land	Culturable Waste Land	Barren Land	Protected Area		
Tsw-1	6	5	6	5	3	4	5	6	2	2	2	5	5	5	5	6	1	6	1	4	1	4.04	High
Tsw-2	4	4	5	3	4	3	4	5	5	4	5	6	6	6	4	4	2	5	3	5	2	4.23	High
Tsw-3	2	2	1	1	5	2	3	2	4	6	4	4	2	2	6	2	3	4	6	3	3	3.19	Medium
Tsw-4	1	3	3	2	6	1	2	1	6	4	3	1	4	4	2	1	4	3	2	2	4	2.80	Low
Tsw-5	3	1	2	4	3	5	1	3	3	5	6	2	1	2	3	5	6	1	5	6	4	3.38	Medium
Tsw-6	5	6	4	6	1	6	6	4	1	1	1	4	3	3	1	3	5	2	4	1	4	3.38	Medium

Table 6. Tirthan Watershed: Classification of Sub-watersheds for Prioritization

Priority Class	**Name of Sub-watersheds**	**Area**	**Index Score**
High	TSW-1 and TSW-2	310.65 (45.56)	> 4.00
Medium	TSW-3, TSW-5 and TSW-6	294. 27 (43.16)	3.00-4.00
Low	TSW-4	76.85 (11.27)	< 3.00
Total	6	681.77	-

Figures in parentheses show the Percent to total area.

Graph 1
Tirthan Watershed: Percent Hypsometric Curves



Source: Compiled by Author from Digital Elevation Model

The share of area under non- agricultural uses i.e., settlements, roads, institutions etc. contributes merely 0.62% of the total study area. Among all the sub-watersheds, forest cover ranges from about one third of total area in sub watershed-1 (the lowest) to about three fourth in sub watershed-4 (the highest). The two sub-watersheds namely TSW-3 and TSW-4 occupy more than 70% forests. The variation in forest cover is due to interplay of different physical and social factors. Additionally, there is a huge variation in the proportion of agricultural land ranging from the lowest 2.11% in TSW-1 to the highest 30.52% in TSW-5. The results of the study reveals that Tirthan watershed has a little more than half of watershed area under protected lands which includes national park, wildlife sanctuary and eco-development zone. Three eastern sub watersheds (TSW-1, 2 and 3) are protected by Great Himalayan National Park Conservation Area.The area under forests is highly concentrated in central parts due to the favourable slope, aspect and altitude. The higher share of area under agricultural uses in the western parts of the watershed is due to favourable relief features and hospitable climate for agriculture. This region is also the part of unprotected area, where there are no restrictions on human activities. The study reveals that the high concentration of area under non-agricultural uses has spread over western parts of the study area (TSW-4, 5 and 6). It could be attributed to large area under agricultural land, moderate forest cover, hospitable climatic conditions and favourable slope and aspect.

Priority Classification of Sub-Watersheds

The compound parameter values of all six sub-watersheds of Tirthan watershed have been calculated and prioritization rating is shown in Table 6. The sub-watersheds have been broadly classified into three priority zones according to their composite value.

- Sub-watersheds with high priority (>4.00)
- Sub-watersheds with medium priority (3.00 to 4.0)
- Sub-watersheds with low priority (< 3.00)
- A brief explanation of each priority class is given below:
- **Sub-Watersheds with High Priority:** It is evident from the Table 5 that 2 sub-watersheds namely TSW-1 and TSW-2 have been identified more severe and prone to resource degradation based on morphological and land use characteristics. These watersheds have registered compound score > 4.00 hence kept in high category of priority for planning and management of natural resources i.e., land, water and forests. These two sub-watersheds together constitute about 45.56% area of the watershed (Table 6). Fig. 3 shows that both TSW-1 and 2 are located in the eastern part of the Tirthan watershed. These sub-watersheds lay in the altitudinal zone where the absolute relief exceeds 1500 m above mean sea level. Among the morphological characteristics viz. basin length, length of overland flow and steep slope and weightage assigned to them make these two units more vulnerable to resources deterioration. The land use/land cover properties such as forest cover, agricultural land and non-agricultural land show very low proportion under these categories hence need more attention. The large proportion of barren and culturable waste lands in these sub-watersheds also necessitates to accord more priority to the protection and conservation of resources. The study reveals that most of the area of these two sub-watersheds has been under protected zone, which is the part of great Himalayan national park conservation area (GHNPCA). Despite a sizeable area under this region seeks higher attention for protection, treatment and conservation of resource based on morphometric and land use/land cover parameters.
- **Sub-Watersheds with Medium Priority:** Table 6 and Fig. 3 exhibit that sub-watersheds namely TSW-3, 5 and 6 have been observed in medium category of watershed prioritization. These sub-watersheds have registered the compound score ranging between 3.00 to 4.00. In all, these sub-watersheds accounts for about 43.16% of total watershed area (Table 6). The study reveals that characteristics namely mean stream length, stream frequency, mean bifurcation ratio, drainage density, slope, length of overland flow; barren land and culturable waste land have shown high to moderate effect on the overall ecological health and soil loss in these three sub-watersheds. Fig. 3 portrays that these sub-watersheds are located in the west and north western part of the study area.
- **Sub Watersheds with Low Priority:** Table 6 and Fig. 3 reveals that only 1 sub-watershed falls in low priority category indicating the good environmental and ecological health. This sub-watershed is TSW-4 with less than 3.00 compound score. This sub-watershed shares about 11.27% area of the total watershed. Sub-watershed lies in south central part of the Tirthan watershed. This sub watershed is associated with low stream length, low stream frequency, low drainage density, high circularity ratio, low ruggedness value, low slope, large share of forest cover, small patches of wasteland and barren land. It is evident from proceeding discussion that watershed prioritization is considered one of the most important aspects of planning and development of natural resources for conservation measures.

CONCLUSION

The study concludes that out of 15 morphometric parameters, twelve have positive relationships with soil loss risk. The remaining three have negative relation with erodibility. The land use/ land cover attributes have both positive and negative relationships with soil loss risk and related ecological fragility. The study reveals that the compound score ranges from the lowest 2.80 to the highest 4.23 in the Tirthan watershed. TSW-1 and TSW-2 have been identified in critical category of watershed prioritization based on the inputs derived from morphometry and land use/ land cover characteristics. These two sub watersheds account about 45 % area of watershed. Therefore, the relevant conservation practices and measures need to be identified and implemented in these areas. The 3 sub-watersheds (TSW-3, 5 and 6) have been identified in medium category of prioritization for conservation and development of natural resources. These three sub-watersheds occupy about 43 % area of watershed. The study investigates that one sub-watershed (TSW-4) has been occupying about 11% of total watershed area is safe. Its categorization in low priority class may be attributed to low drainage density, low stream length, low ruggedness number, high circularity ratio and large vegetation cover. The analysis of all parameters reveals that sub-watershed with low priority shows low risk of resource degradation in the area. The present study used both traditional and modern inputs to prioritize the sub-watersheds within the Tirthan watershed. It would be useful for future research working in the field of watershed management and conservation of resources in the Himalayas. However, detailed field investigation, use of more variables, computation of soil loss and sediment yield index would improve and add new information to this work.

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