Environment and Ecology 40 (4D) : 2787—2794, October—December 2022
ISSN 0970-0420

Prioritization of Watershed Using GIS Technique

Nidhi Mishra, Nivedita Singh, Mukesh Seetpal

Received 29 August 2022, Accepted 14 October 2022, Published on 14 December 2022

ABSTRACT

The present study was undertaken in the Dangri River watershed, Panchkula District, Haryana (India), describing the importance of morphometric parameters in the field of water and soil conservation with main objective of prioritizing watersheds based on geomorphological parameters. The drainage characteristics of the watershed were evaluated using topographic map 55 F/2 at a scale of 1:50,000. In the study, four sub watersheds were prioritized and morphometric parameters evaluated in each sub-watershed includes analysis of bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circularity ratio, elongation ratio. Out of all the sub-watersheds, SW4 has the highest bifurcation ratio (6.56), which suggests that the drainage is well controlled structurally. The maximum value of circularity ratio and elongation ratio are 0.87 of SW2 and 0.26 of SW1, respectively. The form factor values are in the range of 0.103 to 0.49, indicating a relatively strong peak flow with a short period in the Dangri river watershed. The study demonstrates that sub-watershed classification and prioritising are extremely relevant, helpful and important in the watershed where there is great variation in agricultural techniques, soil texture and land cover. The four watersheds in the Dangri river basin were ranked in order of priority after the compound parameter values were calculated. Priority is given to the watershed with the lowest compound parameter value. The SW4 is most likely to experience the highest levels of soil erosion since it has a minimum compound parameter value of 1.57. The watersheds shall adopt the necessary soil and water conservation measures in accordance with the given priority.

Keywords GIS, Morphometric, Priority, Watershed.

INTRODUCTION

The development of water resources necessitates resolving crucial concerns related to the storage, conservation and later use of surface and sub terranean water. So, management of these resource are necessary for proper development. The fundamental focus of sustainable development is the effective management and preservation of natural resources. The area of the Earth known as a river basin is one that is depleted by a stream and its tributaries. Highlights of the river basin include its tributaries, watershed,

Nidhi Mishra [1]*
School of Agriculture, ITM University, Gwalior 474002, India

Nivedita Singh [2], Mukesh Seetpal [3]
[2, 3] Assistant Professor, School of Agriculture, ITM University, Gwalior 474002, India

Email: nidhimishra2426@gmail.com
*Corresponding author

junction, source and mouth. The goal of the current study is to identify the geomorphic features and then prioritization of the Dangri river watershed.

A watershed is an area of land that drains out all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay or any place along a stream channel. The information's on watershed features regarding hydrological or morphological studies are very important in addition to the type of watershed falling in particular area. There are various important features of watershed concerns, that are size, topography, drainage divide, soil type. Watershed management tries to bring about the best possible balance in the environment between natural resources and human and other living beings. The ranking of various sub-watersheds in order to determine which watersheds should get varied levels of conservation measures is known as watershed prioritization. Prioritizing watersheds is a necessary step before implementing any large-scale project because it enables planners and policymakers to take a selective approach while taking into account the size of the catchment area, the severity of the issues, the financial limitations and the labour requirements of the local and political system. To identify environmentally challenged sub-watersheds areas, a number of scientific criteria based on soil loss, sediment yield, topographic, or morphological variables have been used in the past (Gupta and Uniyal 2013, Gajbhiye *et al*. 2013, Singh 2021, Uddin *et al*. 2016, Khanday and Javed 2017).

The layout of the earth's surface, as well as the size, shape and location of its landforms, are all subject to measurement and quantitative study. In order to achieve sustainable development of watershed, several attempts have been made to rank them based on their priority. Morphometric parameters are the key elements in determining the quantitative estimation of watershed characteristics (Singh *et al*. 2014, Singh and Singh 2017, Bhattacharya *et al*. 2019). Morphometric analysis has been frequently practiced to prioritization of watersheds. A geographical information system (GIS) is a computer-based system designed to store, process and analysis geo-referenced spatial data and their attributes. By using GIS, the topographic and geomorphometric analysis may be carried out efficiently and different information system (using traditional and remotely sensed data) have already been proved to play a very important role in analyzing soil erosion and sediment yield, as evident from recent studies in the Indian peninsula and South-East Asia (Gajbhiye *et al*. 2013, Trikey *et al.* 2013, Khadse *et al*. 2015, Tamene *et al*. 2017). Combining geomorphological and GIS methods set the stage for attaining optimum planning and execution of water resource projects.

Study area

Dangri River watershed which lies within the Markanda River catchment, which is a main tributary of the Ghaggar river is situated in Raipur Rani block of Panchkula District in Haryana (India), covers an area of 32.202 km^2 between 75.01 E to 77.99 E longitude and 29.59 N to 30.69 N latitude with elevation range minimum 238 to maximum 1169 m above MSL (Mean Sea Level). The river Dangri rises in the lower Shivalik at the foothills of the Himalayas and joins river Ghaggar. River Ghaggar disappears in the desert of Rajasthan after a run of about 280 km. The average annual rainfall is 1057 mm. Dangri River Watershed situated at the Northernmost region in Panchkula District of Haryana. Fig. 1 shows the location map of the study area.

Data used

Base map of the study area was prepared using the Survey of India (SOI) toposheet on scale of 1:50000. Toposheet no. 53-F/2 was georeferenced for making base map. Further processing was done in the widely used GIS product with the most expandable features is called ArcGIS. It has all the features of ArcView and Arc Editor plus additional complex geoprocessing and data conversion tools. For all facets of data creation, modelling, analysis and map presentation on screens and output, professional GIS users utilize Arc info. Most spatial data files are created, modified and edited using Arc Catalog (ESRI). To evaluate the morphological parameters GIS software Arc GIS 10.4 was used here.

MATERIALS AND METHODS

Toposheets map on 1:50,000 scale of the study area

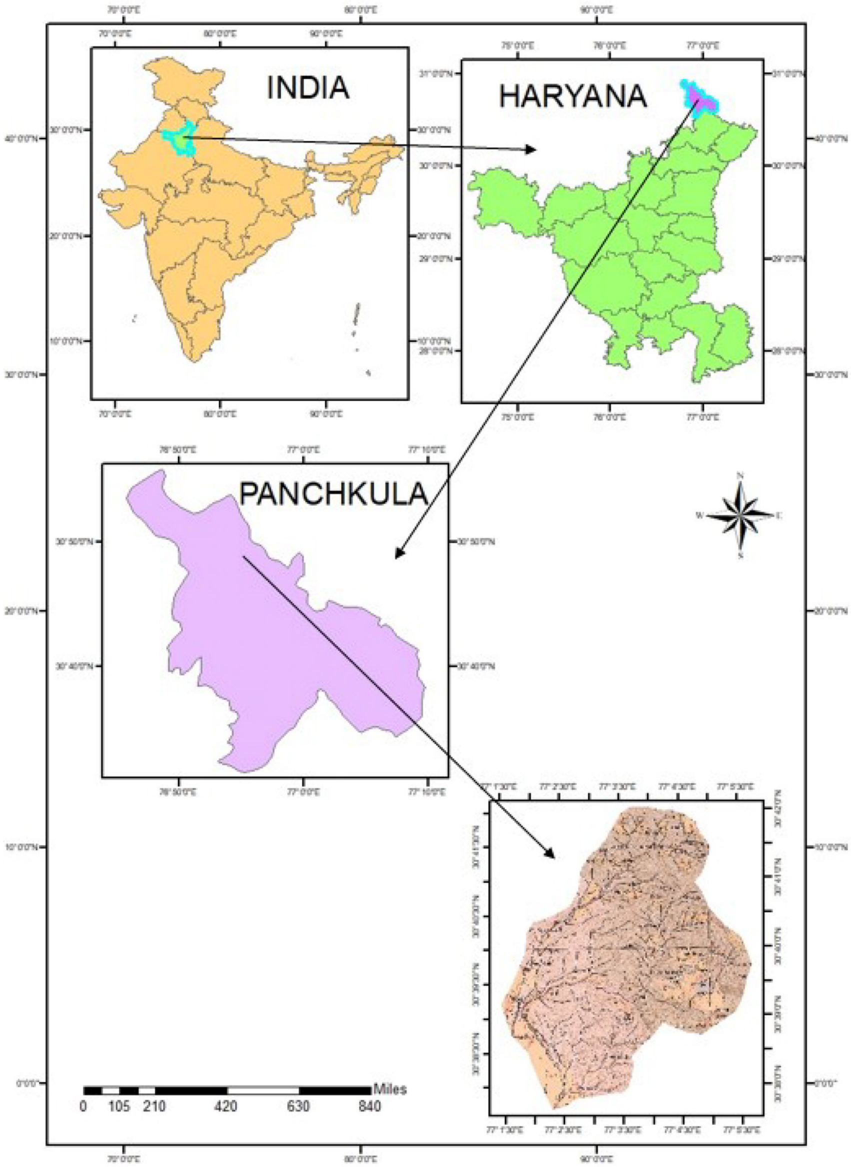

Fig. 1. Location map of study area.

was acquired from Survey of India, scanned for the purpose of geo-referencing and delineation. Digitization work was carried out for the entire watershed using GIS software (Arc GIS 10.4). The Dangri watershed was further subdivided into four sub watersheds on the basis of drainage flow direction, slope, relief and elevation. The sub-watersheds are designated as SW1–SW4, the smallest being SW3 covering 5.16 km^2 area, whereas the largest SW4 covers 10.04 km^2 area. Here, Fig. 2 indicates the flow chart of methodology in which all morphometric parameters are derived from GIS for prioritization of watershed.

Method of morphometric analysis

Morphometric analysis was carried out for the four

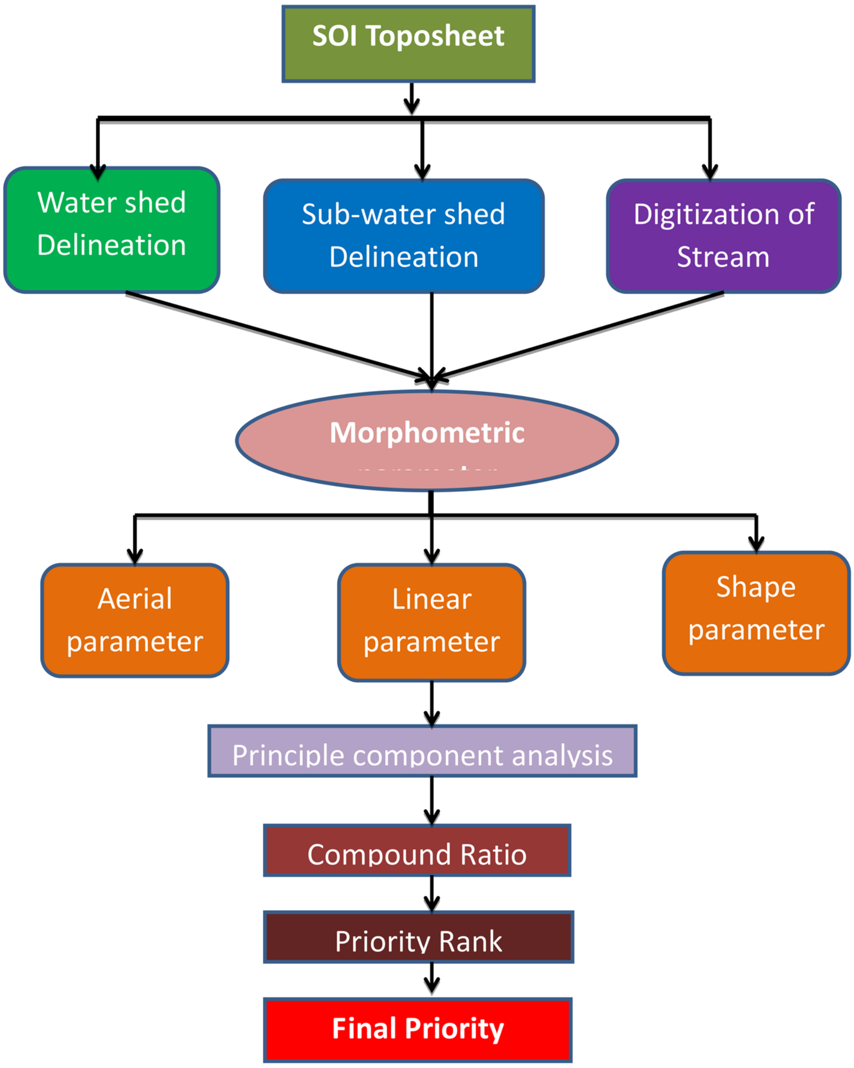

Fig. 2. Flow chart showing methodology for watershed prioritization using morphometric analysis.

sub watersheds. The parameters calculated in the present studies using GIS technique include the estimation of: (i) linear aspect, (ii) areal aspect, including stream order, stream length, bifurcation ratio, form factor, circulatory ratio, elongation ratio, drainage frequency, texture ratio. For the present study the input parameters for morphometric analysis are - area, perimeter, maximum elevation, minimum elevation stream length. that were obtained from digitized coverage of drainage network map in GIS environment. Table 1 shows the geomorphological parameters of stream network in a watershed that are required to understand the hydrogeological conduct of the watershed so that planning and management of its assets should be done sequentially.

Prioritization

For the current assessment, sub watershed prioritizing is carried out using morphometric analysis. Watershed prioritizing is the ranking of various sub watersheds according to the priority with which treatment and soil conservation measures must be implemented. Therefore, it was important to develop a proper system

Table 1. Formulae of morphometric parameters.

Morphometric parameters	Formula	Reference
Stream order (U)	Hierarchical order	Strahler (1964)
Stream length (L_u)	Length of the stream	Horton (1945)
Bifurcation ratio (R_b)	$R_b = N_u/N_u+1$ Where, N_u = Total number of stream segment of order 'U'; N_u+1 = Number of segments of next higher order	Schumm (1956)
Drainage density (D_d)	$D_d = L/A$ Where, L = Total length of streams of all orders A = Area of the basin (km^2)	Horton (1945)
Drainage Frequency (D_f)	$D_f = N/A$ Where, N = Total number of streams A = Areas of the basin (km^2)	Horton (1945)
Drainage texture (R_t)	$R_t = Nu/P$ Where, Nu = Total number of streams of all orders P = Perimeter of the basin (km)	Horton (1945)
Form factor (R_f)	$R_f = Au/Lb^2$ Where, Au = Area of the basin (km^2), Lb = Maximum basin length (km)	Horton (1945)
Circulatory ratio (R_c)	$R_c = 4\pi A/P^2$ Where, A=Area of the basin P=Perimeter of the basin	Miller (1953)
Elongation ratio (R_e)	$R_e = (2 \times (A / \pi)0.5) / L_b$ Where, A=Area of watershed, π=3.14, L_b=Basin length	Schumm (1956)

for ranking the sub watersheds. Even without taking into account the soil map, morphometric analysis is an important tool for prioritizing sub watersheds (Biswass *et al*. 1999). Four sub-watershed sections of the Dangri river watershed are prioritized based on linear, shape and areal factors. The greatest value of the sub watershed's bifurcation ratio, drainage density, texture ratio and stream frequency were given a rating of 1, the next highest value was given a rating of 2 and so on. The lowest value for form factor, elongation ratio and circulation ratio were given a rating of 1, the next lowest value was given a rating of 2 and so on, as these factors have a negative link with soil erosion.

The ultimate priority rank was given to the sub-basins based on the composite value of these criteria. The lowest value in the final priority rank was therefore allocated as rank 1, the second-lowest value as rank 2 and the highest value was assigned as the last in the rank for the purpose of prioritizing the sub-basins. The lowest composite value was given the most priority, followed by the next lowest value, the second lowest value and so on, with the highest composite value being given the lowest priority.

RESULTS AND DISCUSSION

The study's findings are presented in this portion of the publication, along with any necessary comments.

Morphometric method

Morphological characteristics like stream order stream number, watershed area, channel slope and other aspects of watershed are important in understanding the hydrology of watershed. Runoff response of the watershed is different for various slopes. Study of morphometric parameters of all four sub watersheds were generated in GIS environment. The order was given to each stream by following Strahler (1964) stream order technique, i.e., two first-order streams join to make a second order. Two second-order streams join to make a third order and so on. The attributes were assigned to create the digital database for drainage layer of the river basin. The map showing the drainage pattern in the study area (Fig. 3) was prepared. The Dangri watershed

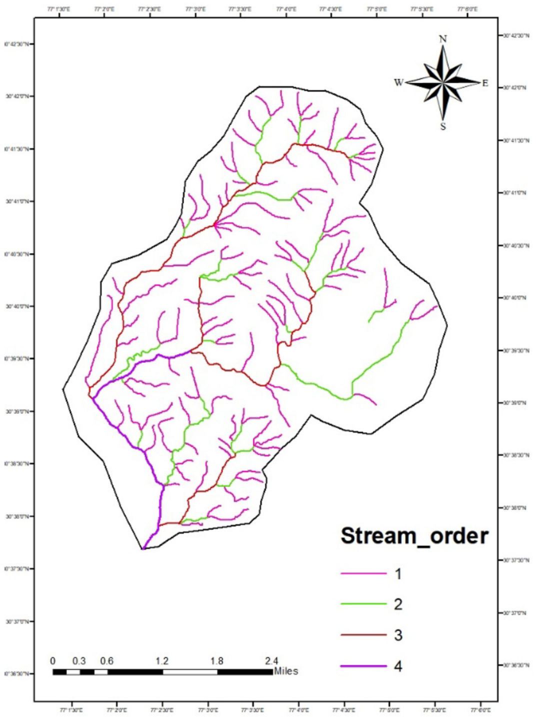

Fig. 3. Stream network of study area.

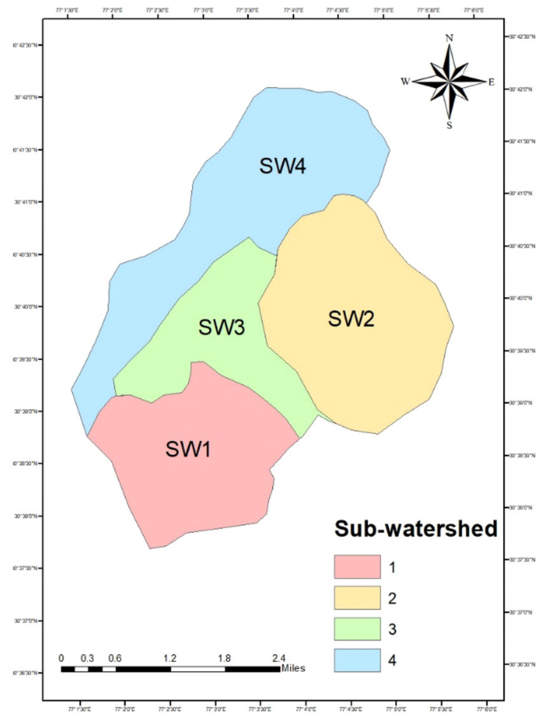

Fig. 4. Sub watershed boundary of study area.

has been divided into four sub-watersheds (Fig. 4) and details of each sub-watershed are given in Table 2. The study area shows dendritic to sub dendritic drainage pattern and parallel to subparallel pattern was also found in some areas.

Linear parameters

Linear parameters consist of bifurcation ratio, drainage density, stream frequency, drainage texture and length of overland flow.

The SW4 has maximum (R_b)=6.56, while SW3 has a minimum R_b (R_b=3.15). The value of R_b for sub-watersheds shows that influences of geological structure on the drainage network are negligible. The sub-watershed 4 has a maximum value (D_d= 3.35), while sub-watershed 2 has minimum D_d (D_d=2.41). Low value of drainage density (D_d) for the second watershed indicates that it has high resistance and impermeable subsoil material with dense vegetative cover and low relief. Sub-watershed 4 has a high value of D_d, indicating a well-developed network and torrential runoff resulting in intense flood. The sub-watershed 1 has maximum (D_f=5.10), while sub-watershed 2 has minimum D_f (D_f=3.24). The values of drainage frequency of sub-watershed area exhibit positive correlation with drainage density values of the area, indicating the increase in the drain population with respect to drainage density. Texture ratio (R_t) is an important factor in drainage morphometric analysis which depends on the underlying lithology, infiltration capacity and relief aspects of the terrain. The values of the texture ratio of all sub-watershed are presented in Table 3. The sub-watershed 1 has maximum (R_t = 3.36), while sub-watershed 3 has minimum R_t (R_t = 1.98) values. The values of the linear parameters for the four sub watersheds are presented in Table 3.

*Bifurcation ratio (R_b), drainage density (D_d), stream frequency (D_f), texture ratio (R_t).

Shape parameters

Shape parameters consist of form factor, circulatory

Table 2. Details of sub watersheds in the study area.

Sub water-shed No.	Area (sq. m)	Perimeter (m)	Elevation (m)		Total relief (m)	No. of streams	Max length of watershed (m)	Total stream length (m)
			Max	Min				
1	7441056.1	11295.1	517	453	64	38	3270	33737
2	9559551.1	11705.6	1024	789	235	31	3839	16657
3	5166875.8	13078.2	789	517	272	26	4975	23101
4	10043180.6	18825.4	1169	238	931	50	8078	24737

Table 3. Sub watershed wise computed morphometric parameters of study area.

Sub water-shed No.	R_b	D_d	D_f	R_t	R_f	R_c	R_e
SW1	4.00	3.32	5.10	3.36	2.27	0.74	0.26
SW2	3.62	2.41	3.24	2.64	2.49	0.87	0.25
SW3	3.15	3.226	5.03	1.98	1.03	0.37	0.14
SW4	6.56	3.35	4.98	2.65	1.24	0.35	0.12

ratio and elongation ratio. The sub-watershed 2 has a maximum value (R_f = 2.49), while sub watershed 3 has minimum value (R_f = 1.03). A low value of form factor (R_f) indicates elongated shape of the sub-watershed. The elongated watershed with form factor indicates that the sub watershed will have flatter peaks for longer duration. The circulatory ratio (R_c) is influenced by the length and the frequency of the stream, geological structure, vegetation cover, climatic, relief and slope of the basin. The values of circulatory ratio of all sub-watersheds are presented in the Table 3. A circular basin is the most susceptible from a drainage point of view, because it will yield the shortest time of concentration before peak flow occurs in the basin (Nooka Ratnam *et al*. 2005). Values of elongation ratio of four sub watershed are presented in the Table 3. The sub-watershed 1 has a maximum value (R_e = 0.26), while sub-watershed 4 has a minimum value (R_e = 0.12). The values of shape parameters for four sub-watersheds are presented in Table 3.

Table 4. Prioritization of sub watersheds based on morphometric parameters of study area.

Sub water-shed No.	R_b	D_d	D_f	R_t	R_f	R_c	R_e	C_r	Priority
SW1	2	2	1	1	3	3	4	2.28	H
SW2	3	4	4	3	4	4	3	3.57	L
SW3	4	3	2	4	1	2	2	2.57	M
SW4	1	1	3	2	2	1	1	1.57	VH

*Form factor (R_f), circulatory ratio (R_c), elongation ratio (R_e).

Prioritization of sub watershed on the basis of morphometric analysis

The linear parameters such as drainage density, stream frequency, bifurcation ratio and texture ratio have direct proportional relationship with erodibility whereas shape parameters such as elongation ratio, circulatory ratio and form factor have inverse relationship with erodibility (Nooka Ratnam *et al*. 2005). The sub-watersheds were then categorized into four classes as very high (1.57), high (2.28), medium (2.57) and low (3.57) priority. Hence, on the basis of morphometric parameters, SW4 have very high priority, SW1 have high priority, SW3 have medium priority and SW2 have low priority. The prioritization of sub-watersheds based on morphometric analysis is presented in Table 4.

The composite rank of each sub-basin is used to compute the values of the composite parameters for each sub watershed, which are then divided by the number of parameters in each sub-basin. The ultimate priority rank was given to the sub-basins based on the composite value of these criteria. The lowest value in the final priority rank was therefore allocated as rank 1, the second-lowest value as rank 2 and the highest value was assigned as the last in the rank for the purpose of prioritizing the sub-basins. The Dangri River Basin's ultimate priority is depicted in Fig. 5. The final rating scale runs from 1.5 to 2.2 and

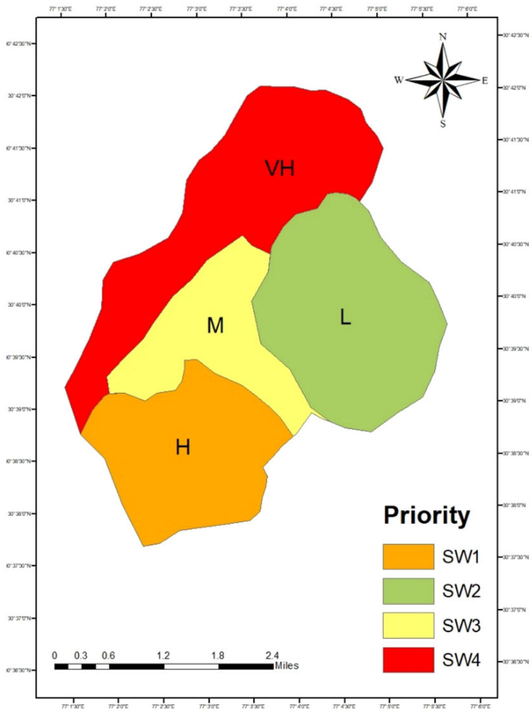

Fig. 5. Priority map showing priority rank category of watersheds of Dangri sub-catchment area.

just as the rankings were given to each sub-basin, the highest rank is given to the sub-basin with the greatest analysis value.

CONCLUSION

One of the most important elements for the quick creation and maintenance of watersheds is prioritisation. Techniques for GIS have shown to be effective instruments for updating and delineating drainage systems. The linear, areal, and relief aspects of basins were measured for the morphometric study. The change in slope and terrain may be the cause of the fluctuation in stream length ratio. From the analysis of sub watersheds parameter, it is found that drainage density of SW4 is high, which shows the area of this watershed is more prone to soil erosion and have sparse vegetation and the existence of low drainage density implies that the subsoil is very permeable and the drainage texture is coarse. Further studying the shape parameter of the watershed, the elongation ratio of SW1 is highest of all others, thus indicating that the area is less prone to erosion. According to the compound ranking of geomorphologic factors, sub watershed 4 should be given top priority and sub watershed 2 should receive the lowest ranking for undertaking soil and water conservation activities in the Dangri river watershed.

REFERENCES

Bhattacharya RK, Chatterjee ND, Das K (2019) Multi-criteria-based sub-basin prioritization and its risk assessment of erosion susceptibility in Kansai–Kumari catchment area, India. *Appl Water Sci* 9(4): 1-30.

Gajbhiye S, Mishra SK, Pandey A (2013) Prioritization of shakkar river catchment through morphometric analysis using remote sensing and GIS techniques. *J Emerg Technol Mech Sci Eng* 10(4): 129-142.

Gajbhiye S, Mishra SK, Pandey A (2013) Prioritizing erosion-prone area through morphometric analysis: An RS and GIS perspective. *Appl Water Sci* 4: 51-61.

Gupta P, Uniyal S (2013). Watershed Prioritization of Himalayan Terrain, Using SYI Model. *Int J Adv Remote Sens GIS Geogr* 1: 42-48.

Khadse GK, Vijay R, Labhasetwar PK (2015) Prioritization of catchments based on soil erosion using remote sensing and GIS. *Environ Monit Assess* 187: 333.

Khanday MY, Javed A (2017) Hydrological investigations in the semi-arid Makhawan watershed, using morphometry. *Appl Water Sci* 7(4): In press.

Singh A (2021) Prioritization of watershed using remote sensing and geographic information system. *Sustainability* 13: 9456.

Singh N, Singh KK (2017) Geomorphological analysis and prioritization of sub watershed using Snyder's synthetic unit hydrograph method. *Appl Water Sci* 7(1): 275-283.

Singh N, Tiwari P, Guru PK, Khalkho D (2014) Morphometric analysis for prioritization of watershed using GIS technique. *Int J Agric Engg* 7(1): 69-73.

Tamene L, Adimassu Z, Aynekulu E, Yaekob T (2017) Estimating landscape susceptibility to soil erosion using a GIS-based approach in Northern Ethiopia. *Int Soil Water Conserv Res* 5: 221-230.

Tirkey AS, Pandey AC, Nathawat MS (2013) Use of satellite data, GIS and RUSLE for estimation of average annual soil loss in Daltonganj watershed of Jharkhand (India). *J Remote Sens Technol* 1: 20-30.

Uddin K, Murthy MSR, Wahid SM, Matin MA (2016) Estimation of soil erosion dynamics in the Koshi basin using GIS and remote sensing to assess priority areas for conservation. *PLoS ONE* 11: e0150494.