Current Journal of Applied Science and Technology

25(2): 1-12, 2017; Article no.CJAST.38589
Previously known as British Journal of Applied Science & Technology
ISSN: 2231-0843, NLM ID: 101664541

Marphometric Analysis and Prioritization of Micro Watersheds of Chandanwari Watershed of lidder Catchment Using Geospatial Techniques

Mohd Ayoub Malik[1*], Bashir Ahmad Pandit[1], Sheikh Umar[1] and Saika Manzoor[1]

[1]Division of Agricultural Engineering, Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST), Kashmir, 190025, India.

Authors' contributions

This work was carried out in collaboration between all authors. Author MAM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BAP and SU managed the analyses of the study. Author SM managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2017/38589
Editor(s):
(1) Samir Kumar Bandyopadhyay, Professor, Department of Computer Science and Engineering, University of Calcutta, India.
Reviewers:
(1) Brempong Fosu, Ghana.
(2) José Martínez Reyes, University of the Ciénega, México.
Complete Peer review History: http://www.sciencedomain.org/review-history/22599

Original Research Article

Received 1st December 2017
Accepted 28th December 2017
Published 5th January 2018

ABSTRACT

Himalayas are highly susceptible to natural hazards that are caused by the action of water such as floods, soil erosion and siltation of the hydro-electric power dams because of their mountainous nature. Soil erosion is the most devastating hazard affecting the livelihood of the people living in these regions. Therefore strategies need to be developed to reduce the impacts of soil erosion in these regions. The present study demonstrates the use of satellite based remote sensing data coupled with the observational field data framework to estimate the soil erosion susceptibility of the micro watersheds of the Chandanwari watershed of Lidder catchment falling in the western Himalaya, using geographical information system (GIS). In this study, watershed morphometry was used as an input to prioritize the micro watersheds on the basis of their different susceptibilities to soil erosion. The prioritization process identifies the highest priority watersheds in which to conduct management. Morphometric analysis has been commonly applied to prioritization of watersheds as

**Corresponding author: E-mail: seemalik2010@rediffmail.com;*

Watershed characteristics of a basin represent its physical and morphological attributes that are employed in synthesizing its hydrological response. Various morphometric parameters, namely linear parameters and shape parameters have been determined using Survey of India (SOI) toposheets at 1:50,000 scale for each micro-watershed and assigned ranks on the basis of value/relationship so as to arrive at a computed value for a final ranking of the micro-watersheds. The analysis has revealed that the total number as well as total length of stream segments is maximum in first order streams and decreases as the stream order increases. Horton‘s laws of stream numbers and stream lengths also hold good. Results of prioritization of micro-watersheds based on morphometry analysis show that micro-watershed CMW11, CMW12, CMW13, CMW14 and CMW7 fall under the category of very Severe erosion class; CMW3, CMW4, CMW5 & CMW6 fall under severe erosion class and are more susceptible to soil erosion and are in dire need of management and planning so that the problem of environment degradation in them can be addressed.

Keywords: Chandanwari; watershed; morphometry; soil; erosion; susceptibility; prioritization; GIS and remote sensing.

1. INTRODUCTION

A watershed is an area from which runoff resulting from precipitation flows past a single point into large stream, river, lake or ocean. In agricultural areas, draining of fields causes water to run off the land and into streams and lakes more quickly, bringing sediment, nutrients, and other pollutants along with it. This can lead to flooding and water quality problems. To reduce soil erosion, planning, conservation and management of the watershed is vital. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms [1]. Using micro-watershed as a basic unit in morphometric analysis is the most logical choice because all hydrologic and geomorphic processes occur within the watershed. The various studies indicate that morphometric attributes like bifurcation ratio, stream length, drainage density, drainage frequency etc substantially contribute to evaluate the hydrological characteristics of a basin and help in identification of overall terrain character of basin [2]. Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds [3]. Morphometric analysis requires measurement of linear features, areal aspects, gradient of channel network and contributing ground slopes of the drainage basin [4]. The morphometric parameters i.e., bifurcation ratio (Rb), shape factor(Bs), compactness coefficient (Cc), drainage density (D), stream frequency (Fs), drainage texture (Rt), length of overland flow (Lo), form factor (Rf), circularity ratio (Rc), and elongation ratio (Re) are also termed as erosion risk assessment parameters and have been used for prioritizing watersheds [5]. Remote sensing data provides accurate timely and real time information on various aspects such as size and shape of the watershed, land use/land cover, physiography, soil distribution, drainage characteristics etc. [6].

1.1 Objective of the Study

1. To study the morphometric parameters of Chandanwari watershed of Lidder Catchment
2. To prioritize micro-watersheds of Chandanwari Watershed to identify erosion susceptibility zones based on morphometric parameters.

1.2 Study Area Location

Chandanwari watershed of Lidder Catchment is situated in Southern part of Kashmir Valley. The total area of the watershed is 170 sq km. and the watershed is located between 34° 2' - 34° 10' N Latitude and 75° 20'-75° 33' E longitude (Fig. 1).

2. METHODOLOGY

2.1 Generation of Drainage Map

All the steams were digitized from Survey of India Toposheets, 1962 on a scale of 1:50,000. The digitization was done in GIS system (Arc Map 10.2). Strahler’s [3] system of stream analysis is probably the simplest, most used system and same has been adopted for this study (Fig. 2). 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.

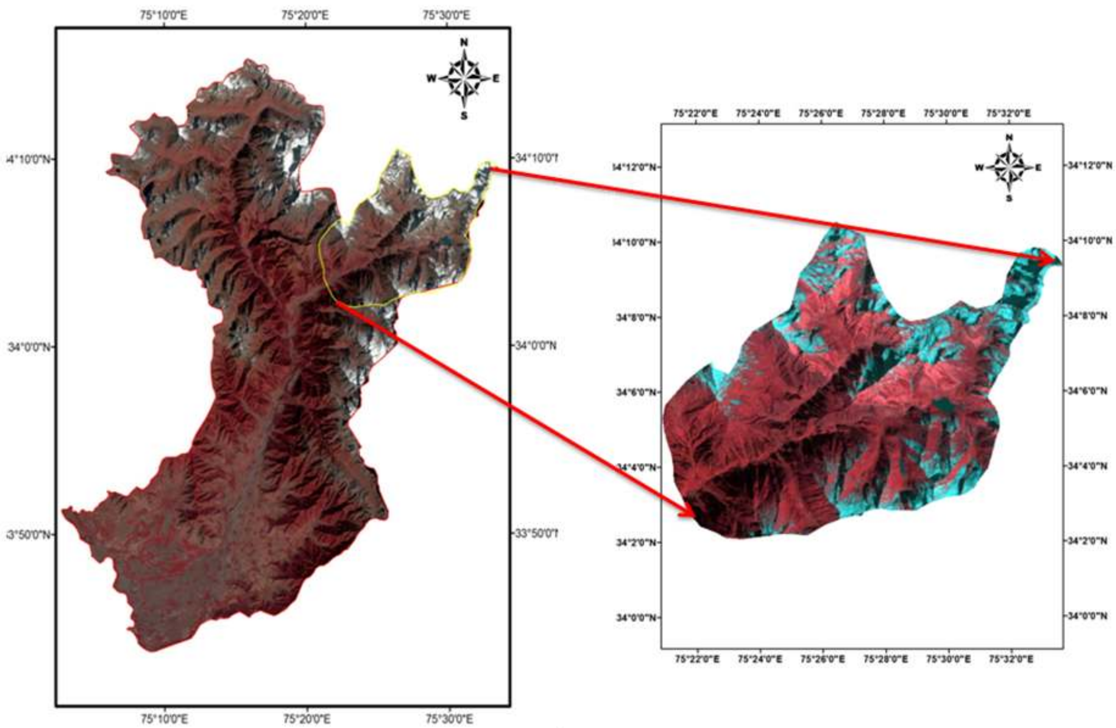

Fig. 1. Source: Generated from SOI toposheets 1961

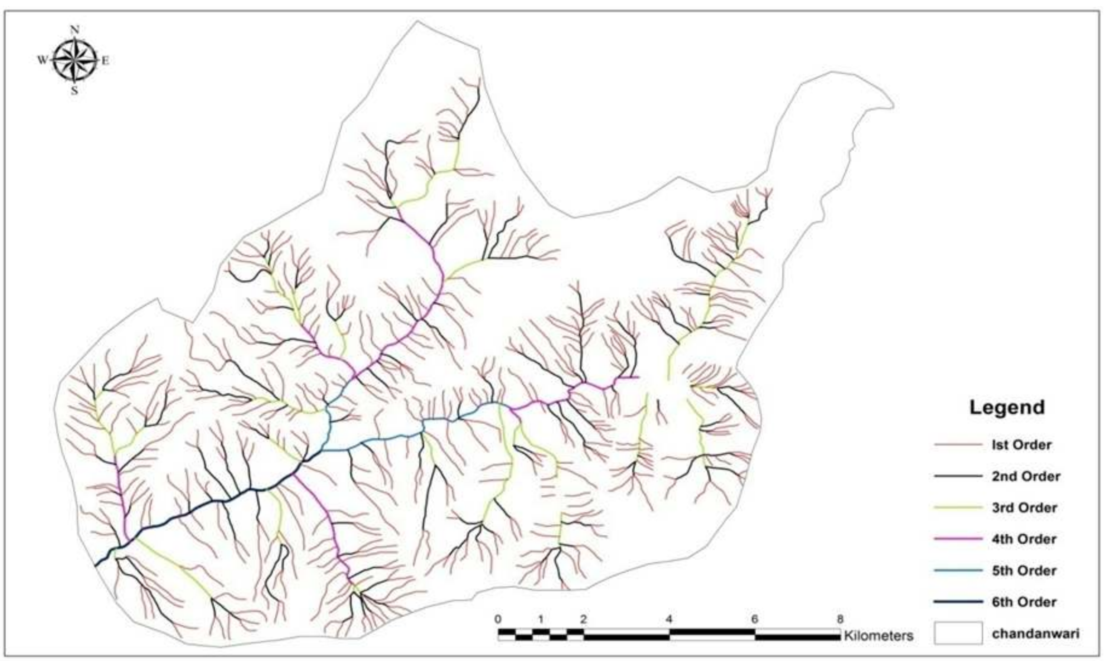

Fig. 2. Drainage map of Chandanwari watershed

2.2 Delineation of Micro Watersheds

For the demarcation of micro watersheds, hierarchical delineation system developed by AIS & LUS (AIS & LUS Technical Bulletin 9) was followed (Fig. 3).

2.3 Computation of Morphometric Parameters

The prioritization is based on the micro watershed's degree of erosion susceptibility using morphometric information, 1st rank was assigned in a way that the value of the parameter represents maximum contribution to the erosion and last rank represents minimum contribution. The average of the ranks of all the parameters for a particular watershed was designated by a compound value which represents the collective impact of all the parameters on erosion susceptibility of a micro watershed. It is denoted as Cp and is calculated from following formula. [7].

$$Cp = \sum_{i=1}^{n} R_i$$

Where,

Cp = Compound value of a particular watershed.
R_i = Rank of a particular watershed for a parameter.
n = Number of parameters

Table 1. Formulae for computation of Morphometric parameters

S. No.	Morphometric parameter	Formula	Reference
1	Stream order	Hierarchical rank	[3]
2	Stream length (Lu)	Length of the stream	[8]
3	Mean stream Length (Lsm)	Lsm = Lu/Nu Where, Lu = total stream length of order 'u' Nu = total no. of stream segments of order 'u'	[3]
4	Stream frequency (Fs)	Fs = Nu / A where, Nu = total no. of streams of all orders A = area of basin (km^2)	[9]
5	Bifurcation ratio (Rb)	Rb = Nu / Nu +1 Where, Nu = No. of stream segments of a given order Nu +1= No. of stream segments of next higher order.	[10]
6	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders	[11]
7	Drainage density (Dd)	Dd = Lu /A where, Lu = total stream length of all orders A = area of basin (km^2)	[9]
8	Drainage texture (Rt)	Rt = Nu / p where, Nu = total no. of streams of all orders P = perimeter (km)	[8]
9	Length of overland flow (Lg)	Lg = 1/Dd*2 where, Dd = drainage density	[8]
10	Elongation ratio (Re)	Re = 2 √(A / Pi)/ Lb where, A = area of basin (km^2) Lb = basin length Pi = Pi' value i.e. 3.14	[10]
11	Circulatory ratio (Rc)	Rc = 4*pi*A /P^2 where, pi = pi' value i.e. 3.14 A = area of basin (km^2) P = perimeter (km)	[12]
12	Form factor (Rf)	Rf=A/Lb^2 Where, A = area of basin (km^2) Lb^2 = square of basin length	[9]
13	compactness coefficient (Cc)	Cc= 0.2821 P/$A^{0.5}$ P = perimeter (km) A = area of basin (km^2)	[13]
14	Shape Factor (Bs)	Bs= Lb^2/A Lb^2 = square of basin length A = area of basin (km^2)	[13]

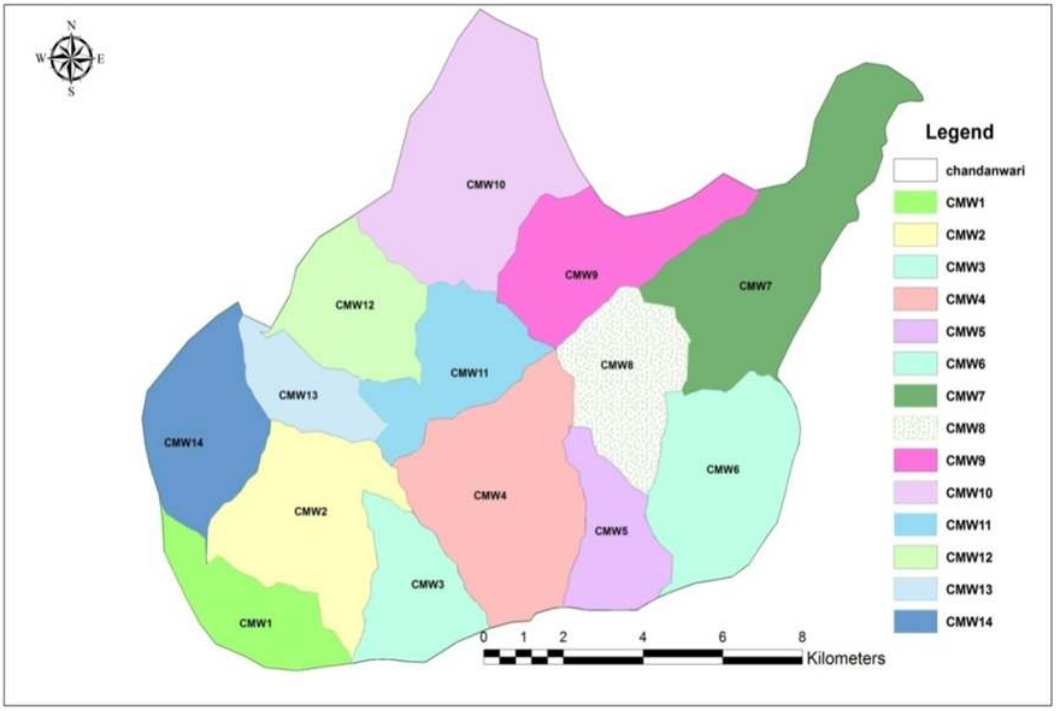

Fig. 3. Micro watershed map of Chandanwari watershed

3. RESULTS AND DISCUSSION

3.1 Quantification of Morphometric Parameters

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 characteristics and finally prioritization of micro watersheds was done on the basis of these linear and shape factors. The morphometric characteristics of the study area are given in Tables 2, 3, 4 and 5. These morphometric characteristics are elaborated as under.

3.2 Linear Parameters

<u>3.2.1 Stream number and order</u>

The first and most important parameter in the drainage basin analysis is ordering; where by the hierarchal position of the streams are designated. Following Strahler's [3] scheme, it has been found that in Chandanwari watershed (Table 2), the total number of streams is 678, out of which 510 belong to 1st order, 122 are of 2nd order, 26 are of 3rd order, 14 are of 4^{th} order 2 are of 5^{th} order and 1 is of 6^{th} order. The micro watershed wise number and order is given in the Table 2. It reveal that the highest number of streams is found in CMW4 (80), followed by CMW6 (71) and CMW7 (66), where as the smallest number of streams is found in CMW9 (21) followed by CMW13 (28) and CMW1 (29). It is also revealed that the first order streams are highest in number in all micro watersheds which decreases as the order increases and the highest order has the lowest number of streams.

<u>3.2.2 Stream length (Lu)</u>

The micro watershed wise length of streams in different orders, mean length of the streams is given in (Table 2) where as their total length is given in (Table 3). It is revealed from these tables that the drainage network of the Chandanwari watershed is characterized by total length of 439 km. The micro watershed wise drainage length given in the table reveals that CMW4 constitutes the highest proportion of drainage length of 51.78 km, followed by CMW2 which is 46.37 km, while the lowest contributor is CMW9 followed by CMW13 contributing 14.69 km and 17.21 respectively.

Table 2. Order wise stream number, stream length and mean stream length

Micro watershed code	First order			Second order			Third order			Fourth order			Fifth order			Sixth order		
	No.	Length	Mean	No.	Length	Mean	No.	Length	Mean	No.	Length	Mean	No.	Length	Mean	No.	Length	Mean
CMW1	20	14.88	2.38	6	4.98	0.83	2	2.57	1.28	0	0	0	0	0	0	1	0.85	0.85
CMW2	45	27.50	0.61	13	10.04	0.77	3	2.59	0.86	2	0.86	0.43	0	0	0	1	5.38	5.38
CMW3	33	21.94	0.66	8	5.32	0.66	2	0.45	0.22	1	3.19	3.19	0	0	0	0	0	0
CMW4	62	34.67	0.55	13	8.75	0.67	2	3.00	1.50	2	0.40	0.20	1	4.96	4.96	0	0	0
CMW5	26	14.66	0.56	5	3.19	0.63	3	3.36	1.12	1	0.21	0.21	0	0	0	0	0	0
CMW6	55	24.49	0.44	13	6.27	0.48	3	4.27	1.42	0	0	0	0	0	0	0	0	0
CMW7	53	28.50	0.53	12	6.49	0.54	1	4.50	4.50	0	0	0	0	0	0	0	0	0
CMW8	26	14.66	0.56	9	9.32	1.03	0	0	0	2	3.09	1.54	0	0	0	0	0	0
CMW9	16	9.38	0.58	3	3.28	1.09	1	1.26	1.26	1	0.77	0.77	0	0	0	0	0	0
CMW10	30	20.10	0.67	8	6.10	0.76	2	2.89	1.44	1	1.87	1.87	0	0	0	0	0	0
CMW11	41	23.20	0.56	9	4.04	0.44	1	0.26	0.26	2	3.10	1.55	2	2.20	1.10	1	0.04	0.04
CMW12	43	22.30	0.51	11	5.56	0.50	3	3.88	1.29	1	1.83	1.83	0	0	0	0	0	0
CMW13	23	12.21	0.53	4	3.39	0.84	1	1.61	1.61	0	0	0	0	0	0	0	0	0
CMW14	37	24.80	0.67	8	4.52	0.56	2	2.84	1.42	1	2.23	2.23	0	0	0	0	0	0

Table 3. Total length of stream of all orders

Micro watershed code	Stream length of all orders (km)						Total stream length (km)
	1	2	3	4	5	6	
CMW1	14.88	4.98	2.57	0	0	0.85	23.28
CMW2	27.5	10.04	2.59	0.86	0	5.38	46.37
CMW3	21.94	5.32	0.45	3.19	0	0	30.9
CMW4	34.67	8.75	3	0.4	4.96	0	51.78
CMW5	14.66	3.19	3.36	0.21	0	0	21.42
CMW6	24.49	6.27	4.27	0	0	0	35.03
CMW7	28.5	6.49	4.5	0	0	0	39.49
CMW8	14.66	9.32	0	3.09	0	0	27.07
CMW9	9.38	3.28	1.26	0.77	0	0	14.69
CMW10	20.1	6.1	2.89	1.87	0	0	30.96
CMW11	23.2	4.04	0.26	3.1	2.2	0.04	32.84
CMW12	22.3	5.56	3.88	1.83	0	0	33.57
CMW13	12.21	3.39	1.61	0	0	0	17.21
CMW14	24.8	4.52	2.84	2.23	0	0	34.39
Chandanwari Watershed	293.29	81.25	33.48	17.55	7.16	6.27	439

Table 4. Results of morphometric analysis

Micro watershed code	Area (A) Km^2	Perimeter (P) Km	Length of basin (Lb) Km	Stream frequency (Fs) Km^{-2}	Form factor (R f)	Elongation ratio (Re)	Circulatory ratio (Rc)	Drainage density (Dd) Km^{-1}
CMW1	7.81	14.52	4.5	3.71	0.39	0.701	0.47	2.98
CMW2	14.76	21.97	5.09	4.34	0.57	0.85	0.38	3.14
CMW3	8.09	13.03	4.41	5.44	0.41	0.73	0.6	3.82
CMW4	19.21	18.9	5.07	4.16	0.75	0.97	0.68	2.71
CMW5	7.09	12.78	4.68	4.94	0.32	0.64	0.55	3.02
CMW6	14.15	15.9	4.66	5.02	0.65	0.91	0.70	2.48
CMW7	20.33	24.77	9.11	3.25	0.24	0.56	0.42	1.94
CMW8	9.96	13.81	3.64	3.71	0.75	0.98	0.66	2.72
CMW9	12.26	17.84	6.92	1.71	0.26	0.57	0.48	1.20
CMW10	21.06	20.48	6.70	1.95	0.47	0.77	0.63	1.47
CMW11	9.49	16.36	4.69	5.90	0.43	0.74	0.45	3.46
CMW12	9.8	13.68	4.22	5.92	0.55	0.84	0.66	3.43
CMW13	5.74	11.84	4.42	4.88	0.29	0.61	0.51	2.99
CMW14	10.93	15.23	6.26	4.39	0.28	0.60	0.59	3.15

Table 5. Results of morphometric analysis

Micro watershed code	Bifurcation ratio (Rb)					Mean (Rbm)	Drainage Texture (R_t)	Length of overland flow(l_g)	Compactness coefficient (C_c)	Shape Factor (B_s)
	(Rb12)	(Rb23)	(Rb34)	(Rb45)	(Rb45)					
CMW1	3.33	3	0	0	0	3.16	2	0.67	0.15	2.59
CMW2	3.46	4.33	1.5	2	0	2.82	2.91	0.64	0.16	1.76
CMW3	4.12	4.0	2	0	0	3.37	3.38	0.52	0.13	2.41
CMW4	4.76	6.50	1	2	0	3.56	4.23	0.74	0.12	1.34
CMW5	5.20	1.66	3	0	0	3.28	2.74	0.66	0.13	3.09
CMW6	4.23	4.33	0	0	0	4.28	4.47	0.81	0.12	1.54
CMW7	4.41	12.0	0	0	0	8.20	2.66	1.03	0.15	4.09
CMW8	2.88	0	0	0	0	2.88	2.68	0.74	0.12	1.33
CMW9	5.33	3.0	1	0	0	3.11	1.18	1.67	0.14	3.90
CMW10	3.75	4.0	2	0	0	3.25	2.0	1.36	0.13	2.13
CMW11	4.55	9.0	0.5	1	2	3.41	3.42	0.58	0.15	2.33
CMW12	3.90	3.66	3	0	0	3.52	4.24	0.58	0.12	1.82
CMW13	5.75	4.0	0	0	0	4.87	2.36	0.67	0.14	3.41
CMW14	4.62	4.0	2	0	0	3.54	3.15	0.64	0.13	3.59

3.2.3 Stream frequency (Fs)

Stream frequency is inversely related to permeability, infiltration capacity and directly related to the relief of watersheds [14,15]. High Fs thus indicates that the watershed has rocky terrain and very low infiltration capacity which contributes towards more erosion and vice versa. Among the micro watersheds of Chandanwari, highest stream frequency was observed in CMW12 (5.92/km^2) which indicated that it has the least infiltration capacity and thus highest erosion susceptibility in terms of Fs only. Fs was observed lowest in CMW9 (1.71/km^2) which indicated it possesses least erosion susceptibility. The other micro watersheds which followed in decreasing order of Fs were CMW11 (5.9/km^2), CMW3 (5.44/km^2), CMW6 (5.02/ km^2), CMW5 (4.94/km^2), CMW13 (4.88/km^2), CMW14 (4.39/km^2), CMW2 (4.34/km^2), CMW4 (4.16/km^2), CMW1 (3.71/km^2), CMW8 (3.71/km^2), CMW7 (3.25 km^2), CMW10 (1.95 km^2).

3.2.4 Mean bifurcation ratio (Rbm)

Mean bifurcation ratio is an indicator of structural complexity and permeability of the terrain and is thus negatively correlated with the permeability of a watershed. High Rbm indicates early hydrograph peak with a potential for flash flooding during the storm events which results in degradation of top soil [16,17]. The mean bifurcation ratio of all the micro watersheds is very high which indicates that all the micro watersheds are structurally complex and have low permeability. Among the micro watersheds of Chandanwari highest mean bifurcation ratio was observed in CMW7 (8.2) which indicated that it is structurally complex and have low permeability and thus highest erosion susceptibility in terms of Rbm only. Rbm was observed lowest in CMW2 (2.82) which indicated it possesses least erosion susceptibility. The other micro watersheds which followed in decreasing order of Rbm were CMW13 (4.87), CMW6 (4.28), CMW4 (3.56), CMW14 (3.54), CMW12 (3.52), CMW11 (3.41), CMW3 (3.37), CMW5 (3.28), CMW10 (3.25), CMW1 (3.16), CMW9 (3.11), CMW8 (2.88).

3.2.5 Drainage density (Dd)

The lower drainage density of any watershed indicates that it has permeable subsurface material, good vegetation cover and low relief and vice versa [18,19]. In the Chandanwari watershed, lowest drainage density was observed in CMW9 (1.2/km) which indicated that it has the greatest permeability among the other micro watersheds or conversely it has the greatest tendency to withstand erosion if only Dd is taken as a criterion for erosion susceptibility. The next higher Dd was observed in CMW10 (1.47/km), and was followed by CMW7 (1.94/km), CMW6 (2.48/km), CMW4 (2.71/km), CMW8 (2.72/km), CMW1 (2.98/km), CMW13 (2.99/km), CMW5 (3.02/km), CMW2 (3.14/km), CMW14 (3.15/km), CMW12 (3.43/km), CMW11 (3.46/km). Since the highest drainage density was observed in CMW3 (3.82/km) which indicated that it has the lowest permeability and thus highest erosion susceptibility in terms of Dd.

3.2.6 Drainage texture (Rt)

Drainage texture is greatly influenced by infiltration capacity [8]. Regions of low infiltration capacity will give rise to higher Rt and thus will lead to more erosion. In the Chandanwari watershed, lowest drainage texture was observed in CMW9 (1.18/km) which indicated that it has the greatest infiltration capacity among the other micro watersheds or conversely it has the least susceptibility to erosion if only Rt is taken as a criterion for erosion susceptibility. The next higher Rt was observed in CMW1 and CMW10 (2/km), and was followed by CMW13 (2.36/km), CMW7 (2.66/km), CMW8 (2.68/km), CMW5 (2.74/km), CMW2 (2.91/km), CMW14 (3.15/km), CMW3 (3.38/km), CMW11 (3.42/km), CMW4 (4.23/km), CMW12 (4.24/km). Since the highest drainage texture was observed in CMW6 (4.47/km) which indicated that it has the lowest infiltration capacity and thus highest erosion susceptibility in terms of Rt.

3.2.7 Length of overland flow (Lg)

Length of the overland flow is one of the most important independent variable affecting both hydrologic and physiographic development of drainage basins [9]. Lg will be less for steeper slopes and longer for gentle slopes and is thus directly related to average slope of the channel. Among the micro watersheds of Chandanwari, highest Length of the overland flow was observed in CMW9 (1.67 km^2) which indicated that it has the highest potential to erode the land in a single stretch. The other micro watersheds which followed in decreasing order of Lg were CMW10 (1.36 km^2), CMW7 (1.03 km^2), CMW6 (0.81 km^2), CMW4 (0.74 km^2), CMW8 (0.74 km^2), CMW1 (0.67 km^2), CMW13 (0.67 km^2), CMW5

(0.66 km^2), CMW2 (0.64 km^2), CMW14 (0.64 km^2), CMW11 (0.58 km^2), CMW12 (0.58 km^2). Lg was observed lowest in CMW9 (0.52 km^2) making it least susceptible to erosion as for as Lg is concerned.

3.3 Shape Parameters

3.3.1 Elongation ratio (Re)

Elongation ratio generally varies from 0.6 to 1.0 and is associated with a wide variety of climate and geology. Values close to 1.0 are typical of regions with very low relief whereas that of 0.6 to 0.8 are associated with high relief and steep ground slope [20,21]. Among the micro watersheds of Chandanwari highest Elongation ratio was observed in CMW8 (0.8) indicating that it has least susceptibility to erosion in terms of Re only. Re was observed lowest in CMW7 (0.56) indicating highest susceptibility. The other micro watersheds which followed in decreasing order of Re were CMW4 (0.97), CMW6 (0.91), CMW2 (0.85), CMW12 (0.84), CMW10 (0.77), CMW11 (0.74), CMW3 (0.73), CMW1 (0.7), CMW5 (0.65), CMW13 (0.61), CMW14 (0.6), CMW9 (0.57).

3.3.2 Circularity ratio (Rc)

Circulatory ratio is influenced by many of the basin characteristics such as length and frequency of streams, geological structures, LULC, climate, relief and slope of the basin. Higher Rc is indicative of circular shape of the watershed and of the moderate to high relief and permeable surface. Low Rc indicates elongated, low relief and impermeable surface [21]. Among the micro watersheds of Chandanwari, highest Circulatory ratio was observed in CMW6 (0.7) indicating low infiltration capacity and resulting more erosion susceptibility in terms of Rc only. Rc was observed lowest in CMW2 (0.38) indicates it possesses low relief and higher infiltration capacity and resulting lower susceptibility. The other micro watersheds which followed in decreasing order of Rc were CMW4 (0.68), CMW8 (0.66), CMW12 (0.66), CMW10 (0.63), CMW3 (0.6), CMW14 (0.59), CMW5 (0.55), CMW13 (0.51), CMW9 (0.48), CMW1 (0.47), CMW11 (0.45), CMW7 (0.42).

3.3.3 Form factor (Rf)

The value of form factor would always be less than 0.7854 (for a perfectly circular basin) [22]. Smaller the value of form factor, more elongated will be the basin. The basins with high form factors have peak flows of shorter duration, whereas, elongated watershed with low form factors have peak flow of longer duration [23]. Among the micro watersheds of Chandanwari, highest form factor was observed in CMW4 and CMW8 (0.75) indicating that it has peak flows of shorter duration and are least susceptible to erosion in terms of Rf only. Rf was observed lowest in CMW7 (0.24) indicating highest susceptibility. The other micro watersheds which followed in decreasing order of Rf were CMW6 (0.65), CMW2 (0.57), CMW12 (0.55), CMW10 (0.47), CMW11 (0.43), CMW3 (0.41), CMW1 (0.39), CMW5 (0.32), CMW13 (0.29), CMW14 (0.28), CMW9 (0.26).

3.3.4 Compactness coefficient (Cc)

Compactness coefficient expresses the relationship of a basin with that of a circular basin having the same area. A circular basin yields the shortest time of concentration before peak flow occurs in the basin [24]. The Compactness coefficient of a watershed directly corresponds to the infiltration capacity of the watershed [21]. Compactness coefficient has an inverse relation with erodibility [13]. Among the micro watersheds of Chandanwari, highest Compactness coefficient was observed in CMW2 (0.16) indicating it's least susceptible to erosion in terms of Cc only. Cc was observed lowest in CMW12, CMW8, CMW6 and CMW4 (0.12) indicating highest susceptibility to erosion.

3.3.5 Shape factor (Bs)

Rate of water and sediment yield along the length and relief of the drainage basin is largely affected by its shape. Therefore, in terms of response to erosion, basin shape behaves similar to form factor. Less is the shape factor higher is the susceptibility to erosion [21,24]. Among the micro watersheds of Chandanwari, highest shape factor was observed in CMW7 (4.09) indicating it's least susceptible to erosion in terms of Bs only. Bs was observed lowest in CMW8 (1.33) indicating highest susceptibility. The other micro watersheds which followed in decreasing order of Bs were CMW9 (3.9), CMW14 (3.59), CMW13 (3.41), CMW5 (3.09), CMW1 (2.59), CMW3 (2.41), CMW11 (2.33), CMW10 (2.13), CMW12 (1.82), CMW2 (1.76), CMW6 (1.54) and CMW4 (1.34).

Table 6. Compound values and erosion class depending upon the morphometric ranks

Micro watershed code	Morphometric ranks										C_p	Priority	Erosion class
	Linear parameters					Shape parameters							
	R_b	D_d	F_s	R_t	I_g	R_c	C_c	R_e	R_f	B_s			
CMW1	11	8	10	12	6	4	4	6	6	9	7.6	8	Moderate
CMW2	14	5	8	7	8	1	5	11	11	4	7.4	7	Moderate
CMW3	8	1	3	5	10	9	2	7	7	8	6	4	Severe
CMW4	4	10	9	3	5	12	1	13	13	2	7.2	6	Severe
CMW5	9	6	5	8	7	7	2	5	5	10	6.4	5	Severe
CMW6	3	11	4	1	4	13	1	12	12	3	6.4	5	Severe
CMW7	1	12	11	10	3	2	4	1	1	14	5.9	3	Very severe
CMW8	13	9	10	9	5	11	1	14	13	1	8.6	11	Slight
CMW9	12	14	13	13	1	5	3	2	2	13	7.8	9	Moderate
CMW10	10	13	12	12	2	10	2	9	9	6	8.5	10	Moderate
CMW11	7	2	2	4	9	3	4	8	8	7	5.4	1	Very severe
CMW12	6	3	1	2	9	11	1	10	10	5	5.8	2	Very severe
CMW13	2	7	6	11	6	6	3	3	4	11	5.9	3	Very severe
CMW14	5	4	7	6	8	8	2	4	3	12	5.9	3	Very severe

3.4 Prioritization of Micro Watersheds Based on Morphometric Analysis

Morphometric parameters directly serve as indicators of soil erosion intensity and have been termed as 'erosion risk assessment parameters'. These include the linear morphometric parameters such as drainage density, stream frequency, mean bifurcation ratio, drainage texture, and length of overland flow. These have a direct relationship with erodibility i.e. greater the values of these parameters more is the erosion severity in the region and vice-versa. Whereas some of the shape morphometric parameters such as elongation ratio, circulatory ratio, form factor, shape factor and compactness coefficient have an inverse relation with erodibility [5,13,21]. Based on these direct relationships for the linear parameters, the highest value of a morphometric parameter was given rank 1; the immediate higher value was ranked 2, and so on. Whereas for the shape parameters, the lowest value of a morphometric parameter was given rank 1; the value lower than this was ranked 2, and so on.

It is observed that no single parameter alone can be used to explain the erosion susceptibility of any micro watershed. Therefore after assigning ranks to every soil erosion risk morphometric parameter, Compound value (Cp) was derived by calculating the average of ranks assigned to the individual parameters. The average is used as an index denoting micro watersheds erosion susceptibility. The micro watershed with the lowest Cp value is most susceptible to erosion and needs highest priority for soil conservation measures. Based on Cp values of these parameters, the micro watersheds having the least rating value were assigned highest priority, next higher value were assigned second priority and so on. The final priority was given by classifying the highest and lowest range of Cp value into four classes as Very Severe erosion class (5.4-5.9), Severe erosion class (6 – 7.3), Moderate (7.4 – 8) and Slight erosion class (>8.5). Out of 14 micro watersheds, CMW11, CMW12, CMW13, CMW14 and CMW7 fall under the category of very Severe erosion class; CMW3, CMW4, CMW5 & CMW6 fall under severe erosion class; CMW1, CMW2 and CMW9 fall under moderate; whereas CMW8 and CMW10 fall under slight erosion class (above Table 6).

4. CONCLUSION

The study has shown that the watershed is in conformity with the Hoton's law of stream numbers and law of stream lengths. It is observed that there is a decrease in the number of streams as the stream order increases. The total length of stream segments is maximum in first order streams and decreases as the stream order increases. The prioritization process identifies the highest priority watersheds in which to conduct management. Result of prioritization of micro-watersheds show that the micro-watersheds CMW11, CMW12, CMW13, CMW14 and CMW7 fall under the category of very Severe erosion class. The very Severe erosion class micro-watersheds have higher erosivity values due to their location in the hilly terrain with undulating topography. Therefore have better delivery ratio value considering the fluvial nature of hazards and need immediate attention. GIS and remote sensing approach in prioritization of micro-watersheds based on ranks obtained from morphometric parameters is found to be more appropriate and will certainly help planners and decision makers in judicious utilization of available resources for treatment of small hydrologic units and effective checking of soil erosion.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Obi Reddy GP, Maji AK, Gajbhiye KS. GIS for morphometric analysis of drainage basins. GIS lndia. 2002;4:9-14.
2. Singh OP. Geomorphology of drainage basins in palamau upland. In: Mandal. Recent Trends and Concepts in Geography. Concept Publishing Company, New Delhi. 1980;1:229-247.
3. Strahler AN. Quantitative geomorphology of drainage basins and channel networks, In: VT Chow (ed), Handbook of Applied Hydrology. McGraw Hill Book Company, New York, Section 4–11; 1964.
4. Nautiyal MD. Morphometric analysis of drainage basin, district Dehradun, Uttar Pradesh. Journal of Indian Society Remote Sensing. 1994;22(4):252-262.
5. Biswas S, Sudhakar S, Desai VR. Prioritization of sub-watersheds based on morphometric analysis of drainage basin, District Midnapore, West Bengal. Journal of Indian Society of Remote Sensing. 1999;27:155–166.
6. Umar S, Saika M, Ayoub Malik M. Morphometric analysis and prioritization of purinabal watershed of sindh Catchment for soil and water resource management using geo-spatial tool. International Journal of Recent Scientific Research. 2017;8(11):21634-21639.
7. Ahmad J, Khanday MY, Ahmed R. Prioritization of sub watersheds based on morphometric and land-use analysis using remote sensing and GIS techniques. Journal of the Indian Society of Remote Sensing. 2009;37:261–274.
8. Horton RE. Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. Geol. Soc. Am. Bull. 1945; 56:275–370.
9. Horton RE. Drainage basin characteristics. Trans. Am. Geophysc. Union. 1932; 13:350–361.
10. Schumm SA. The evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersy. Bulletin of Geological society of America. 1956;67:597-646.
11. Strahler AN. Quantitative analysis of watershed geomorphology. Trans. Am. Geophys. Union. 1957;38:913-92.
12. Miller VC. A quantitative geomorphic study of drainage basin characteristics in the Clinch mountain area, Virginia and Tennessee, Deptt. of Geology, Columbia University, Contract N6 ONR 271-30, Techinical Report 3. 1953;1-30.
13. Nooka Ratnam K, Srivastava YK, Venkateshwara Rao V, Amminedu E, Murthy KSR. Check dam positioning by prioritization of micro watersheds using SYI model and morphometric analysis-Remote Sensing and GIS perspective. J. Indian Soc. Remote Sensing. 2005;33:25–38.
14. Montgomery DR, Dietrich WE. Source areas, drainage density and channel initiation. Water Resources Research. 1989;25:1907–1918.
15. Montgomery DR, Dietrich WE. Channel initiation and the problem of landscape scale. Science. 1992;255:826–830.
16. Howard AD. Role of hypsometry and planform in basin hydrologic response. Hydrological Processes. 1990;4(4):373–385.
17. Rakesh K, Lohani AK, Sanjay CC, Nema RK. GIS based morphometric analysis of Ajay river basin upto Srarath gauging site of South Bihar. Journal of Applied Hydrology. 2000;14(4):45–54.
18. Luo W. Quantifying groundwater sapping landforms with a hypsometric technique. Journal of Geophysical Research. 1900; 105:1685–1694.
19. Harlin JM, Wijeyawickrema C. Irrigation and groundwater depletion in Caddo county, Oklahoma. JAWRA Journal of the American Water Resources Association. 1985;21(1):15–22.
20. Dar RA, Chandra R, Romshoo SA. Morphotectonic and Litho stratigraphic analysis of Intermontane Karewa basin of Kashmir Himalayas, India. Journal of Mountain Science. 2013;10(1):1–15.

21. Sadaff A, Mehraj G, Romshoo SA. Morphometry and land cover based multi-criteria analysis for assessing the soil erosion susceptibility of the western Himalayan watershed. Springer International Publishing Switzerland; 2014.
22. Rudraiah M, Govindaiah S, Srinivas V. Morphometry using remote sensing and GIS techniques in the subbasins of kagna river basin, Gulburga district, Karnataka, India. Photonirvachak. 2008;36:351–360.
23. Sangita MS, Nagarajan R. Morphometric analysis and prioritization of subwatersheds using GIS and remote sensing techniques: A case study of Odisha, India. International Journal of Geomatics and Geosciences. 2010;3:501.
24. Altaf F, Meraj G, Romshoo SA. Morphometric analysis to infer hydrological behaviour of Lidder Watershed, Western Himalaya, India. Geography Journal; 2013.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/22599