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ORIGINAL ARTICLE

Prioritization of sub-watersheds based on morphometric analysis using geospatial technique in Piperiya watershed, India

Surendra Kumar Chandniha · Mitthan Lal Kansal

Abstract Hydrological investigation and behavior of watershed depend upon geo-morphometric characteristics of catchment. Morphometric analysis is commonly used for development of regional hydrological model of ungauged watershed. A critical valuation and assessment of geo-morphometric constraints has been carried out. Prioritization of watersheds based on water plot capacity of Piperiya watershed has been evaluated by linear, aerial and relief aspects. Morphometric analysis has been attempted for prioritization for nine sub-watersheds of Piperiya watershed in Hasdeo river basin, which is a tributary of the Mahanadi. Sub-watersheds are delineated by ArcMap 9.3 software as per digital elevation model (DEM). Assessment of drainages and their relative parameters such as stream order, stream length, stream frequency, drainage density, texture ratio, form factor, circulatory ratio, elongation ratio, bifurcation ratio and compactness ratio has been calculated separately for each sub-watershed using the Remote Sensing (RS) and Geospatial techniques. Finally, the prioritized score on the basis of morphometric behavior of each sub-watershed is assigned and thereafter consolidated scores have been estimated to identify the most sensitive parameters. The analysis reveals that stream order varies from 1 to 5; however, the first-order stream covers maximum area of about 87.7 %. Total number of stream segment of all order is 1,264 in the watershed. The study emphasizes the prioritization of the sub-watersheds on the basis of morphometric analysis. The final score of entire nine sub-watersheds is assigned as per erosion threat. The sub-watershed with the least compound parameter value was assigned as highest priority. However, the sub-watersheds has been categorized into three classes as high (4.1–4.7), medium (4.8–5.3) and low (>5.4) priority on the basis of their maximum (6.0) and minimum (4.1) prioritized score.

Keywords Geo-morphometric analysis · Prioritization · Watershed · RS and GIS

Introduction

Fresh water is the finite entity and is directly related to population of living being. A watershed is a hydrological unit which generates runoff by itself as a result of precipitation. However, the runoff water depends upon morphology of the watershed. Quantitative analysis of the water in any catchment is very difficult rather than qualitative analysis. Morphometric analysis of streams is an important aspect for characterization of watershed. Proper planning and management of watershed is very necessary for sustainable development of living being. Geo-morphological analysis of a watershed is usually used for evolving the regional hydrological models for resolving different hydrological difficulties of the ungauged watersheds in the absence of data accessibility conditions (Gajbhiye et al. 2014). Morphometric analysis of a drainage basin and its stream channel arrangement can be well understood through the drainage network, aerial and relief aspects, and contributing ground slopes (Nag and Chakraborty 2003). For quantitative analysis of the watershed involving various components such as stream segments, basin perimeter, basin area, elevation difference, slope and profile of land has been responsible for the natural

S. K. Chandniha (✉) · M. L. Kansal
Department of Water Resources Development and Management,
Indian Institute of Technology, Roorkee 247667, Uttarakhand,
India
e-mail: chandniha.surendra@gmail.com

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development of basin (Horton 1945). Quantitative analysis of hydrological unit and channel networks has been developed from qualitative research work and valuable contributions. However, Horton's laws were subsequently modified and developed by several geo-morphologist, which is highly appreciable most notably by Strahler (1952), Leopold and Miller (1956), Schumm (1956), Melton (1957), Morisawa (1957), Strahler (1957, 1958), Scheidegger (1965), Shreve (1967), Gregory and Walling (1973). Morphometric parameters mainly depend upon lithology, bed rock and geological structures. Hence, the information of geomorphology, hydrology, geology and land use pattern is highly informative for reliable study of drainage pattern of the watershed (Astras and Soulankellis 1992). The major objectives of the study include morphometric analysis and prioritization of sub-watersheds is carried out for Piperiya watershed of Hasdeo river basin of Chhattisgarh state of India using remote Sensing and GIS techniques.

Salient features of study area

The Piperiya watershed originated from Hasdeo river catchment in Mahanadi basin at Chhattisgarh state in India. It lies between Northern latitude 22°37′46″ to 23°35′40″ and Eastern longitude 82°01′48″ to 82°37′29″ and area of the watershed is about 2,414 km^2 (Fig. 1). A watershed covers the three districts (Koriya, Korba and Bilaspur) of

Chhattisgarh and partially intersects the Anuppur district of Madhya Pradesh. However, the major part covers under Koriya district of Chhattisgarh. The topography is hilly in the northern part and becomes plain in south. Elevation of the watershed varies from 324 to 1,062 m, whereas Northern part of watershed has higher elevation. The Koriya district received about 1,411 mm rainfall in a year. Agriculture is the main source of livelihood for rural masses and the most of the living population is tribal community. There are four distinct seasons: per-monsoon (March–May), monsoon (June–September), post monsoon (October and November) and winter (December–February) the intervening rainy months of the south-west monsoon (June to September). In summer, temperatures reached up to 47 °C; however, the average temperature varies between 17 and 32 °C. The drainage outlet of the watershed is situated on Mahendragarh block of the Koriya district. Total population of the district is about 586,327 (Registrar General, India 2011), whereas the population lining in the watershed is about 362,823 as per population density. About 50 % area of the watershed is covered with forest and agricultural land.

Materials and methods

Drainage network was delineated by the Arcmap 9.3 using the ASTER Global Digital Elevation Model (GDEM) of National Aeronautics and Space Administration (NASA) of

Fig. 1 Location map of study area (Piperiya watershed)

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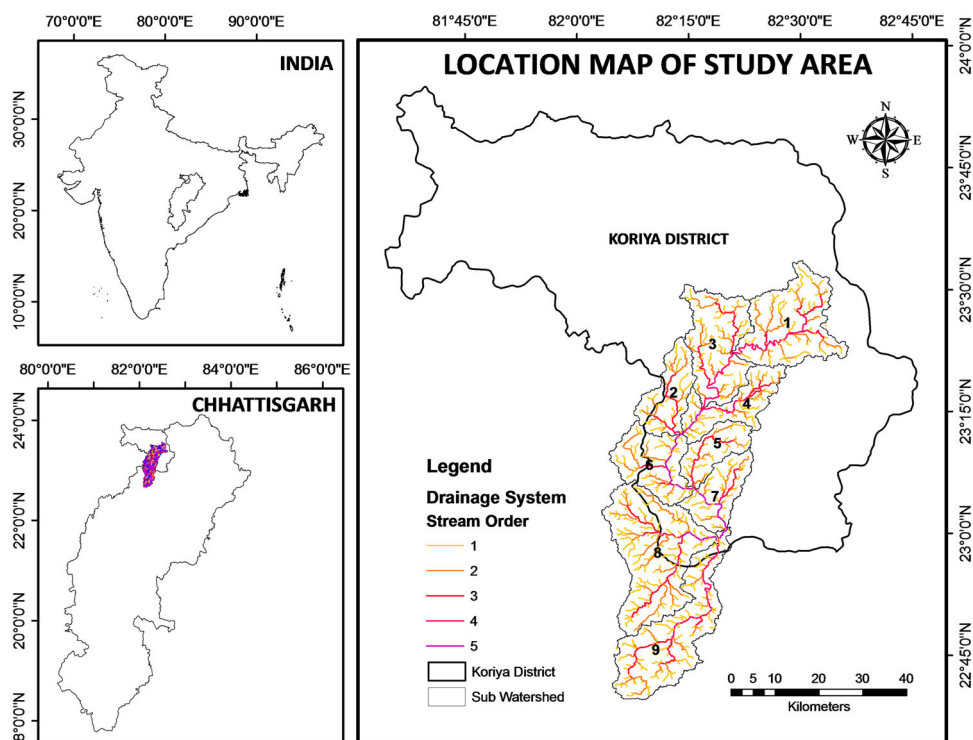
each sub-watershed. Computation of the basic parameters (i.e., area, perimeter, stream order, stream length, stream number and elevation) of each sub-watershed analyses was carried out separately using the RS & GIS approach. Finally, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circulatory ratio, elongation ratio and compactness ratio have been quantified with the help of standard formulae.

Morphometric analysis of watershed

The morphometric analysis refers to quantitative evaluation of hydrological unit. This is the most common approach which is used for basin analysis, morphometric associated with interpretation and analysis of fluvially originated landforms. Development of the basin directly refers to numerous components such as stream segments, basin length, basin area, altitude, volume, slope, profiles of the land, which show the development of the basin. The arrangement of the stream system of a drainage basin has been expressed quantitatively with stream order, drainage density, bifurcation ration and stream length ratio (Horton 1945). Horton's law of stream lengths projected the geometric association existing between the statistics of stream segments in consecutive stream orders. The law of basin areas shows the mean basin area of successive ordered streams forming a linear relationship.

Stream order

In any watershed study, the behavior of the flow finding is very difficult; therefore, it is necessary to subdivide the watershed into sub-watersheds. It will be done according to

stream order and area of the sub-watersheds. Stream order may also be defined as the number of order like first-order channels which are non-branching finger tip channel segments. Second-order channels are those channels which receive water from only first ordered channels. Third-order channels are those where two second ordered channels meet together (Strahler 1964) and so on shown in Fig. 2a. New higher order number is assigned if two streams of same order join. Order of stream always increases from upstream to downstream on the basis of watershed geomorphology.

Streams number (N_u)

Number of streams is also described as total counts of stream segments of different order separately and is inversely proportional to the stream order. Stream number is denoted by N_u.

Total stream length (L_u)

Total stream length is calculated as measuring the length of all ordered perennial streams within the catchment area of the watershed and is denoted by L_u. In general, the total stream length is measured by the 1: 100000 topographical maps.

Mean stream length ($L_{\bar{u}}$)

Mean stream length is the ratio of total stream length of particular order to the total number of same ordered stream and is denoted by $L_{\bar{u}}$ (Fig. 3).

Fig. 2 Watershed characteristics. **a** Stream order of sub-watersheds. **b** Digital elevation model of the watershed
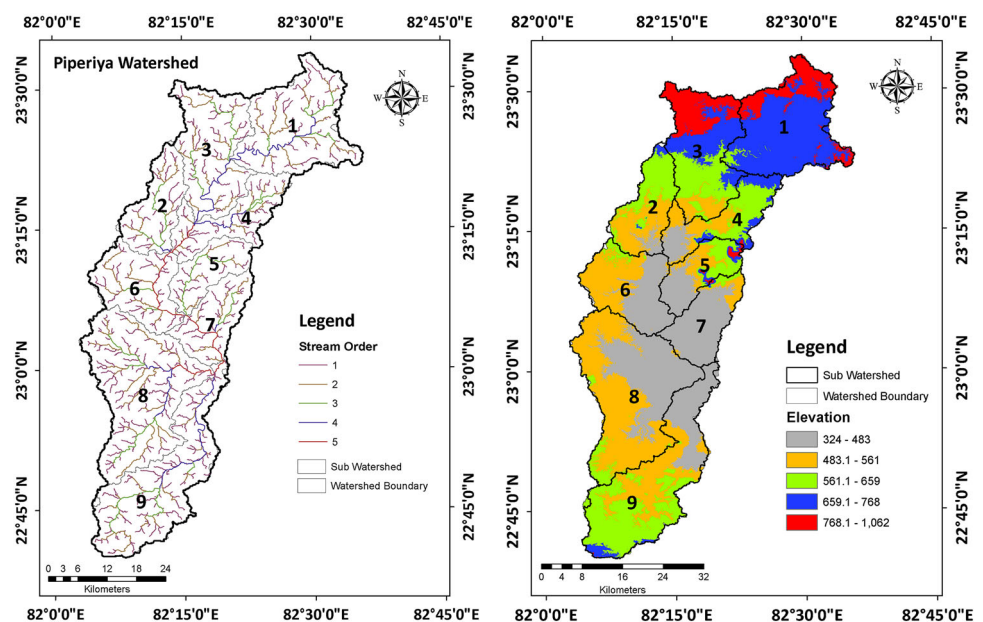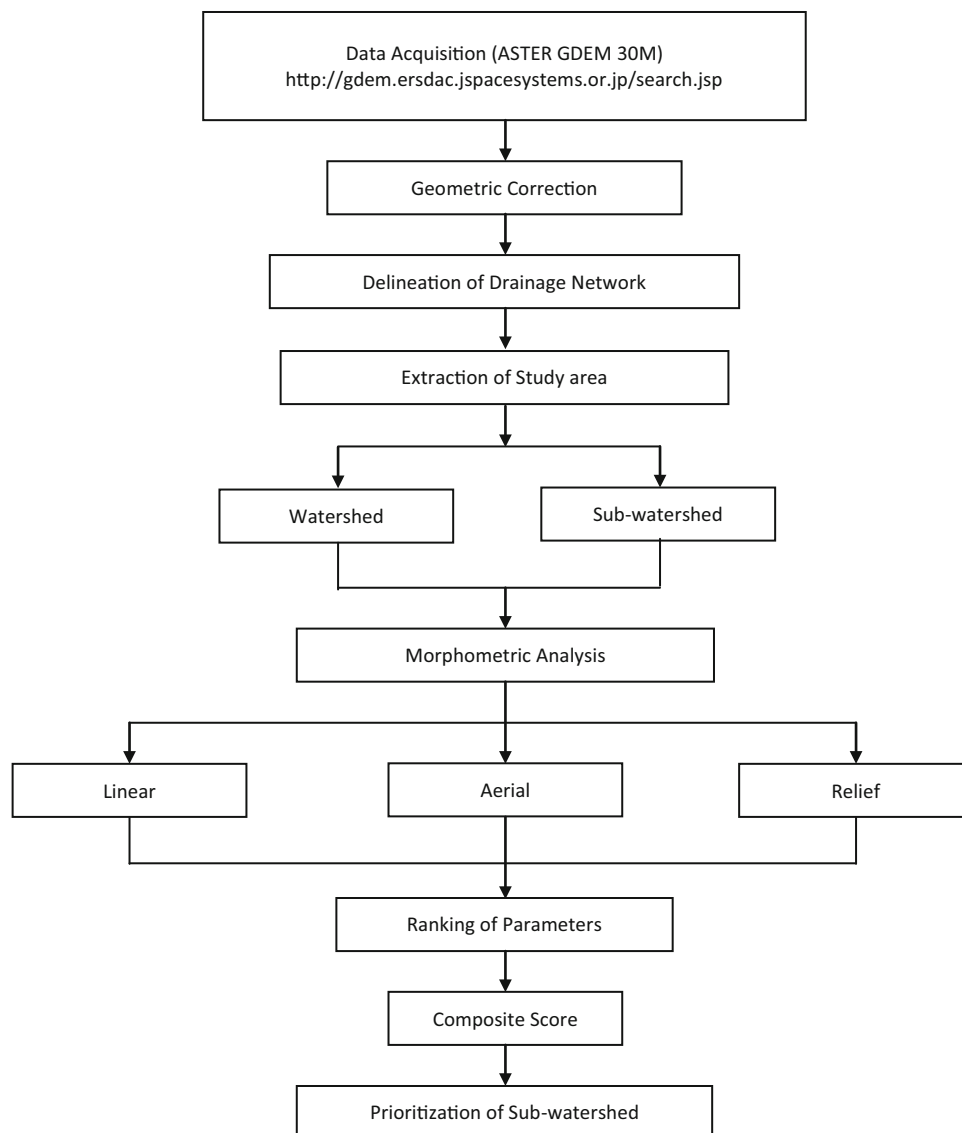
Fig. 3 Methodology used in this study

Watershed perimeter (P_r)

Watershed perimeter is the total length of outer boundary of the watershed. It is manually calculated by the planimeter.

Maximum length of the watershed (L_b)

It is the distance between the remotest point of the watershed to the outlet.

Stream length ratio (RL)

The stream length ratio (RL) is the ratio of the mean length of the stream of a given order $(L_{\bar{u}1})$ to the mean length of the streams of the next smaller order $(L_{\bar{u}-1})$.

$$RL = \frac{L_{\bar{u}1}}{L_{\bar{u}1-1}}$$

Bifurcation ratio (R_b)

The bifurcation ratio is the ratio of the number of streams in lower order (N_u) to the next order (N_{u+1}). It is seen that the bifurcation ratio is lower in alluvial region as compared to the Himalayan zone.

$$R_b = \frac{N_u}{N_{u+1}}$$

Form factor (R_f)

Form factor is defined as the ratio of basin area (A) to square of the maximum length of the basin (L_b). The smaller the value of form factor, the more elongated will be

the watershed. The watershed with high form factors has high peak flows of shorter duration (Horton 1932).

$$R_f = \frac{A}{L_b^2}$$

Elongation ratio (R_e)

It is calculated as the ratio of equal diameter of the circle which has same area as that of the watershed to the maximum length of the basin. Elongation ratio is denoted by (R_e).

$$R_e = \frac{2}{L_b}\sqrt{\frac{A}{\pi}}$$

Circulatory ratio (R_c)

The circulatory ratio is influenced by the length and frequency of stream. The circularity ratio is a similar measure as elongation ratio, originally defined by Miller (1953) as the ratio of the area of the basin to the area of the circle having equivalent circumference as the basin perimeter and it is denoted by the (R_c).

$$R_c = \frac{12.57\,A}{P_r^2}$$

Drainage density (D_d)

Drainage density is the linear parameter of the morphometric analysis and is a sensitive indicator for erosion calculation by the stream and effect of topographic characteristics to the outlet. It is defined as the ratio of the total length of the streams in all ordered to the area of watershed or basin. It provides the link between the form attributes of the basin and the processes operating along stream course (Gregory and Walling 1973). The unit of the drainage density is km/km^2, which indicates the proximity of channel spacing, thus providing an idea about quantity measures of the watershed (Strahler 1964). Drainage density is denoted by (D_d).

$$D_d = \frac{L_u}{A}$$

Drainage frequency (F_s)

Drainage frequency is calculated as the number of streams per unit area of the watershed. It mainly depends upon the lithology of the catchment and indicates the texture of the drainage network.

$$F_s = \frac{N_u}{A}$$

Texture ratio (T)

It is the ratio of the total number of first-order stream segment to the perimeter of the watershed.

$$T = \frac{N_1}{P_r}$$

Maximum watershed relief (H)

Basin relief is the maximum elevation difference between highest and lowest point of the watershed.

Compactness coefficient (C_c)

Compactness coefficient is the shape parameter of a watershed and is the ratio of perimeter of watershed to circumference of equivalent circular area of the watershed. The (C_c) is independent of size of watershed and dependent only on the slope (Horton 1945).

$$C_c = 0.2821\frac{P^{0.5}}{A}$$

Results and discussion

Morphometric parameters are important and useful to identify various hydraulic characteristics of drainage basin, i.e., patterns, shape, stage of stream, permeability of bed rock, health of streams, as well as help to correlate with lithological characteristics (Yadav et al. 2014). In the present study, morphometric analysis of the parameters, such as stream order, stream length, bifurcation ratio, drainage density, stream frequency, circulatory ratio, form factor, elongation ratio, texture ratio, compactness coefficient, length of over land flow and area, perimeter, elevation difference, basin length, total relief, number of stream and total stream length of the nine sub-watersheds has been carried out using the mathematical equation and their results are summarized in Tables 2 and 3.

Stream order

The term "stream orders" is the primary step of morphometric analysis which is based on the delineated streams and their branching proposed by (Strahler 1964). A perusal of the Table 1 indicates that there is nine sub-watersheds, out of these four sub-watershed has fifth ordered (SWS-4, SWS-7, SWS-8, SWS-9) and remaining five, four has fourth ordered (SWS-1, SWS-2, SWS-3, SWS-6) and last one have third ordered (SWS-5) sub-watershed. Bifurcation ratio is depending on stream order as well as number of streams. Total number of streams and stream length of all order is 1,264 and 1,589, respectively.

Stream length

The values of length (L_u) and total stream length are shown in Tables 1 and 2, respectively. According to Horton's

Table 1 Results of morphometric analysis for Piperiya watershed of Hasdeo river basin

S. no.	Sub basin name	Area km²	Number of streams					Stream length in km				
			I	II	III	IV	V	I	II	III	IV	V
1	SWS-1	355.25	153	16	5	1	–	93.9	68.9	25.8	32.1	–
2	SWS-2	170.77	76	8	2	1	–	57.2	28.4	23.3	3.0	–
3	SWS-3	302.72	133	15	2	1	–	87.0	62.4	31.5	23.0	–
4	SWS-4	180.12	93	14	2	2	1	71.2	32.9	14.1	15.3	8.2
5	SWS-5	132.63	55	7	1	–	–	39.0	20.7	22.8	–	–
6	SWS-6	216.27	100	10	2	1	–	66.8	43.3	9.6	19.7	–
7	SWS-7	161.1	72	9	2	2	1	54.0	27.2	10.6	2.1	15.1
8	SWS-8	489.79	218	19	4	2	1	183.2	100.9	33.4	18.8	10.8
9	SWS-9	405.96	208	19	3	2	1	146.5	53.0	32.2	35.2	4.0
Total area WS1		2,414.61	1,108	117	23	12	4	798.7	437.8	203.3	149.1	38.2

Table 2 Morphometric parameter of sub-watersheds of Piperiya watershed of Hasdeo river basin

Sub basin name	Area (km²)	Perimeter (km)	Elevation (m)		Basin length (km)	Total relief (m)	Number of stream	Total stream length (km)
			MAX	MIN				
SWS-1	355.25	168.76	1,062	592	27.59	470	175	221
SWS-2	170.77	107.46	726	413	21.82	313	87	112
SWS-3	302.72	158.63	964	469	28.46	495	151	204
SWS-4	180.12	147.17	882	402	26.66	480	112	134
SWS-5	132.63	87.08	893	365	19.37	528	63	82
SWS-6	216.27	112.52	651	350	20.36	301	113	139
SWS-7	161.10	98.26	897	324	20.66	573	86	94
SWS-8	489.79	190.82	651	354	32.32	297	244	336
SWS-9	405.96	221.51	811	333	41.84	478	233	267

second law (1945), the stream length characteristics of the sub-basins validate the "laws of stream length", which states that the average length of streams of each of the different orders in a drainage basin tends closely to approximate a direct geometric ratio (Horton 1945). In general, logarithms of the number of streams of a given order, when plotted against the order, the points lie on a straight line (Horton 1945). Most drainage networks show a linear relationship with a small deviation from a straight line (Chow 1964). Generally, the total length of stream segments decreases with stream order. Deviation from its general behavior indicates that the terrain is characterized by high relief and/or moderately steep slopes, underlain by

varying lithology and probable uplift across the basin (Singh and Singh 1997).

Bifurcation ratio

The bifurcation ratio reflects the geological as well as tectonic characteristics of the watershed (Gajbhiye et al. 2014). Lower value of R_b indicates the partially disturbed watershed without any distortion in drainage pattern (Nag 1998). High value of R_b indicates the severe over land flow and low recharge for the sub-watershed. In this study, the value of mean bifurcation ratio varies between 3.10 and 7.43 which is shown in Table 3.

Table 3 Result of morphometric analysis for nine sub-watersheds of Piperiya watershed

Sub basin name	Bifurcation ratio	Drainage density	Stream frequency	Circulatory ratio	Form factor	Elongation ratio	Texture ratio	Compactness coefficient	Relief ratio	Length of overland flow
SWS-1	5.92	0.62	0.49	0.16	0.47	0.77	0.91	2.53	0.017	0.81
SWS-2	5.17	0.66	0.51	0.19	0.36	0.68	0.71	2.32	0.014	0.76
SWS-3	6.12	0.67	0.50	0.15	0.37	0.69	0.84	2.57	0.017	0.74
SWS-4	3.33	0.74	0.62	0.10	0.25	0.57	0.63	3.09	0.018	0.67
SWS-5	7.43	0.62	0.48	0.22	0.35	0.67	0.63	2.13	0.027	0.80
SWS-6	5.67	0.64	0.52	0.21	0.52	0.82	0.89	2.16	0.015	0.78
SWS-7	3.10	0.58	0.53	0.21	0.38	0.69	0.73	2.18	0.028	0.86
SWS-8	4.05	0.69	0.50	0.17	0.47	0.77	1.14	2.43	0.009	0.73
SWS-9	4.16	0.66	0.57	0.10	0.23	0.54	0.94	3.10	0.011	0.76

Drainage density

Drainage density depends upon both climate as well as physical characteristics of the drainage basins. It is a basic length scale in the landscape, which is recognized to be the transition point between scales where unstable channel-forming processes yield to stable diffusive processes (Tarboton et al. 1992). Drainage density is influenced by various factors, among which resistance to erosion of rocks, infiltration capacity of the land and climatic conditions rank high (Verstappen 1983). According to Langbein (1947), the significance of drainage density is a factor which determines the time of travel by water within the basin and suggested that it varies between 0.55 and 2.09 km/km^2 for humid region. In Piperiya watershed, drainage density of nine sub-watersheds varies from 0.58 to 0.74 and is shown in Table 3.

Stream frequency

Drainage frequency or channel frequency is directly related to stream population per unit area of the watershed (Horton 1932). It indicates the close correlation with drainage density value of the sub-watershed. Prioritization-wise ranking of the stream frequency of the all sub-watershed is summarized in Table 3. Higher value of drainage frequency shows the high runoff. In this study, SWS-4 produced more runoff as compared to other sub-watersheds; however, ranges vary from 0.48 (SWS-5) to 0.62 (SWS-4) as shown in Tables 3 and 4.

Circulatory ratio

Circulatory ratio (R_c) is influenced by the length and frequency of the stream, geological structures, land use land/cover (LULC), climatic variability, relief and slop of the sub-watersheds (Patel et al. 2013). In this present study, circulatory ratio varies from 0.10 (SWS-4) to 0.22 (SWS-5).

Form factor

Most of the researchers have suggested that the value of form factor is less than 0.7854 for perfectly circular basin (Rekha et al. 2011; Gajbhiye et al. 2014). In watershed, the smaller value of the form factor shows maximum elongation of the basin. The high value of form factor shows high peak in short duration and vice versa. In this study, it was found that the value of form factor varies 0.23 to 0.52, which indicates that the SWS-9 is more elongated as compared to SWS-6 (Fig. 2). However, the SWS-9 will be generating the high peak in short duration. Assigned priority of the form factor is summarized in Table 4.

Elongation ratio

Generally, the values of elongation ratio (R_e) generally lie between 0.6 and 1.0 which is associated with a wide variety of climate and geological properties. The values close to 1.0 are typical of regions of very low relief, whereas that of 0.6 to 0.8 are followed with high relief and steep ground slope (Strahler 1964). These values can be grouped into three categories, namely circular (>0.9), oval (0.9–0.8) and less elongated (<0.7). In this watershed, elongation ratio varies between 0.54 (SWS-9) and 0.82 (SWS-6), whereas the feature of watershed lies oval cum elongated in nature. However, sub-watersheds are elongated with steep slope with high relief (Chopra et al. 2005; Gajbhiye et al. 2014).

Texture ratio

Texture ratio depends upon properties of lithology of the basin, infiltration of the soil and relief aspect of the terrain (Vijith and Satheesh 2006). In the present study, the texture ratio of the sub-watersheds lies between 0.63 (SWS-5) and 1.14 (SWS-8), and categorized as medium in nature. The lower values of texture ratio indicate that the basin is plain with lower degree of slopes. The value of texture ratio and

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Table 4 Prioritized rank of sub-watersheds using the morphometric parameter

Sub basin name	Bifurcation ratio	Drainage density	Stream frequency	Circulatory ratio	Form factor	Elongation ratio	Texture ratio	Compactness coefficient	Relief ratio	Length of overland flow	Compound parameter	Final priority
SWS-1	3	7	8	4	7	7	3	6	4	2	5.1	V
SWS-2	5	4	5	6	4	4	7	4	7	6	5.2	VI
SWS-3	2	3	6	3	5	5	5	7	5	7	4.8	IV
SWS-4	8	1	1	1	2	2	8	8	3	9	4.3	II
SWS-5	1	7	9	9	3	3	9	1	2	3	4.7	III
SWS-6	4	6	4	7	9	9	4	2	6	4	5.5	VIII
SWS-7	9	9	3	8	6	6	6	3	1	1	5.2	VII
SWS-8	7	2	7	5	8	8	1	5	9	8	6	IX
SWS-9	6	5	2	2	1	1	2	9	8	5	4.1	I

assigned priority of each sub-watershed is shown in Tables 3 and 4, respectively.

Compactness coefficient

A circular basin is the most hazardous from a drainage stand point because it will yield the shortest time of concentration before peak flow occurs in the basin (Ratnam et al. 2005; Javed et al. 2009). The highest value was found in SWS-5 (2.13), while the lowest value was for SWS-9 (3.10). However, wide variations of compactness coefficient across the sub-watersheds are summarized in (Table 3).

Relief ratio

The values of relief ratio are given in Table 3 which ranges from 0.009 (SWS-8) to 0.028 (SWS-7). It is noticed that the high values of Rh indicate steepness of the basin (Vittala et al. 2004) and is an indicator of intensity of erosion process operating on the slopes of the watershed.

Length of overland flow

The length of overland flow (L_g) approximately equals half the reciprocal of the drainage density (Horton, 1945). This factor relates inversely to the average slope of the channel and is quite synonymous with the length of sheet flow. The values of length of overland flow in sub-watersheds vary from 0.67 (SWS-4) to 0.86 (SWS-7).

Prioritization of sub-watersheds

Drainage pattern of watershed refers to geospatial relationship among the streams or rivers and is associated with slope, soil type, rock resistance, structural and geological status of the basin. The study emphasizes the prioritization of the sub-watersheds on the basis of morphometric analysis. The final score of entire nine sub-watersheds and their ranking are shown in Table 4. The maximum and minimum prioritized score of sub-watersheds is 4.1 and 6.0, respectively. High priority indicates the greater degree of erosion at specific sub-watershed. However, it is necessary to improve the soil conservation measures as per priority in particular regions. In this study, *linear parameters* are bifurcation ratio, drainage density, texture ratio, length of overland flow, stream frequency, and the *shape parameters* are circularity ratio, form factor, elongation ratio and compactness coefficient. Hence, the *linear parameters* have a direct relationship with erodibility. Prioritization of sub-watersheds: the highest value of linear parameters was assigned as rank 1; second highest value was assigned as rank 2 and so on. The least value has been
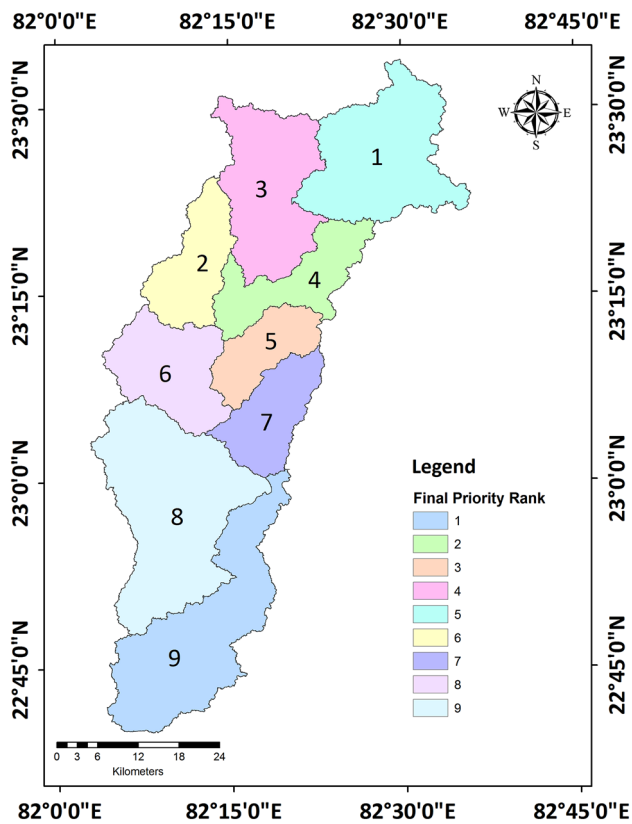
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Fig. 4 Final priority map of sub-watersheds

assigned as last in rank. *Shape parameters* such as circularity ratio, form factor, elongation ratio and compactness coefficient have an inverse relationship with erodibility (Biswas et al. 1999; Ratnam et al. 2005; Javed et al. 2009). The least value of shape parameter has been shown more erodibility. Thus, the lowest value of shape parameters was assigned as rank 1, next lower value was assigned as rank 2 and so on and the highest value was rated last in rank. Hence, the ranking of the sub-watersheds has been determined by assigning the priority/rank (Table 4). At last, the compound parameter has been calculated as averaging all the parameters in particular sub-watersheds. However, the final priority has been assigned as the least rating value was assigned as highest priority; next higher value was assigned second priority and so on. Finally, the highest score of compound parameter was assigned last rank (Fig. 4). The sub-watersheds has been categorized into three classes as high (4.1–4.7), medium (4.8–5.3) and low (>5.4) priority on the basis of span of Cp value. To archive on the basis of morphometric analysis, SWS-9, SWS-4 and SWS-5 fall in the high priority, SWS-3, SWS-1, SWS-2 and SWS-7 fall in medium priority and SWS-6 and SWS-8 in the low priority category (Table 4). To archive for management point of view, the conservation practices or measures are recommended as per their final priority.

The morphometric study is one of the most appropriate techniques to quantify the present issue related to water distribution and erosion pattern over the catchment. Remote sensing and geospatial technique also provides valuable information about natural resources as well as physical terrain parameters of the area. In the present study, remote sensing and Geographical Information System (GIS) have been utilized for generating contours, slope, drainage pattern, drainage order, catchment delineations and other inventories for the study area. GIS with its capability of integration and analysis of spatial, and multi-layered information is obtained in a wide variety of formats both from remote sensing and other conventional sources, which are an essential prerequisites for sustainable planning of land and water resources and its management. Hydro geomorphology parameters as discussed in this study can play an important role in water and land use planning in a watershed.

Conclusions

The quantitative morphometric analysis was carried out for nine sub-watersheds of Piperiya watershed at Hasdeo river basin using the geospatial technique. Landscape morphology is a function of drainage, climate, and structure of a particular basin region. The present paper has illustrated morphometric analysis based on several drainage parameters, by which the watersheds have been classified as fifth order basins. The drainage density values of entire nine sub-watersheds are below 5 revealing that the subsurface strata are permeable, and characteristic feature is coarse. The linear aspects, i.e., stream order, bifurcation ratio, stream length and aerial aspects such as drainage density (D_d), stream frequency (F_s), form factor (R_f), circulatory ratio (R_c) and elongation ratio (R_e) have been carried out on the basis of soil erosion. The conventional methods of morphometric analysis are time consuming and error prone, so instead GIS technique has been used for more reliable and accurate estimation of similar parameters of watersheds. However, geological field verification also agrees with the present morphological-based prioritization.

The morphometric analysis of different sub-watersheds shows their relative characteristics with respect to hydrologic response of the catchment. The morphometric analysis of nine sub-watersheds exhibits the dendritic drainage pattern and the variation in stream ratio might be due to changes in slope as well as topographic features of the study region. It was found that the SWS-9, SWS-4 and SWS-5 are shown higher erosion and soil loss-prone areas. Hence, suitable soil erosion control measures are required in these sub-watersheds to preserve the land from further erosion. Higher runoff may also affect the sediment per

unit volume. The variation in bifurcation ratio among the sub-watersheds is described to the difference in topography and geometric development. The stream frequencies for all sub-watersheds of the study exhibit positive correlation with the drainage density values indicating the increase in stream population with respect to increase in drainage density. Drainage density is very coarse to coarse texture. Elongation ratio shows that specific sub-watershed possesses circular shape, while the remaining marks elongated pattern. The present study is valuable for erosion control, watershed management, land and water resources planning and future prospective related to runoff study.

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