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REVIEW ARTICLE

A GEOSPATIAL- STATISTICAL APPROACH TO ALIENATE PRIORITY AREA OF UPPER WATERSHED OF RIVER SUBARNAREKHA USING MORPHOMETRIC ASSESSMENT FRAMEWORK

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ARTICLE DETAILS

ABSTRACT

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Micro-watershed planning and management play an important role in addressing the issues and challenges of water scarcity of a region. The assessment of hydrological framework using morphometric calculation and GIS technology is a recognized tool for carrying out planning activities for the watershed. The uncertainties associated with the earlier work of watershed prioritization can be easily addressed with new emerging geospatial-statistical correlation techniques. A sum weightages methodology is applied on the upper watershed of river Subarnarekha in the state of Jharkhand, India, for identification of critical subwatershed, a priority level ranking and zonation mapping of each individual subwatershed is developed using the morphometric calculation coupled with GIS tools. This approach helps in identification and bifurcation of subwatershed with three level of priority, i.e, Low, Medium, High. The result reveals that 5.8 % of subwatershed lies in high priority zone that signifies the area as critical and susceptible zones of soil erosion, which requires immediate attention from planners and policymakers. The high-level priority region should be considered for soil, water, and land conservation work. This approach of prioritization techniques can further be extended to another critical watershed of India for better decision support system and planning

KEYWORDS

Subarnarekha, Watershed, Jharkhand, Morphometric, Ranchi.

1. INTRODUCTION

Watershed rejuvenation and development is an integrated approach to maintain ecological balance. It helps in the recharge of the water table, enhancing agricultural productivity thus reducing hunger and poverty. The Indian peninsula of southern Asia is endowed with rich footprints of mighty Himalaya, which is the origin of three rivers, namely the Ganges, Yamuna, and the Brahmaputra, can be called as "Ecological Fabric of Hindustan". Based on a study, the last decade has witnessed climatic change scenarios that may affect the sustainability of an ecosystem [1]. According to a 2006 World Bank study, water stress and crisis situations exist in river basins of India that has affected the health of the aquifer. With the current rate of utilization, in 2050 water demands would exceed all available sources of supply. Solutions are needed that could address the on-going crisis and constraints on both ground and surface water. Implementing good watershed management practices and approaches can be potentially useful.

Watersheds are self-sustained, composite hydrological entity incorporating many components and mechanisms, which play a significant role in sustained growth and development. The implementation of watershed management programs at sub-watershed and the micro-watershed level is a challenging task. The other limiting factor that interferes the sustainability practices related to watershed management is the missing data or data gaps. The management of water resource can be done using watershed prioritization techniques, an approach that is helpful in soil conservation, barren land rejuvenation, and rural employment generation. A scientific approach to watershed planning and management involves capturing different forms of precipitation for

storage (e.g., ponds, tanks) in the wet season, thus increasing soil moisture content and water availability for future use. The deviation from watershed management practices may result in deterioration of rivers and landform around many catchments, especially, in those regions where precipitation is limited for specific months. Post monsoon water conservation practices are utmost necessary for maintaining the balance between water availability and demand for agricultural, drinking and industrial use.

In India, extensive research regarding the morphometric analysis of river basin has been carried at various levels for resource planning and watershed management. Earlier attempt has been made to characterize the hydrogeological behavior of the upper watershed of river Subarnarekha through morphometric analysis [2]. According to a research, the identification of groundwater recharge potential and surface-water augmentation is done at Kurzadi watershed in West-Central India [3]. Similarly, the Geo-Hydrological study is conducted on Vishav drainage basin to identify low, moderate and high groundwater potential zones [4]. A statistical technique, like, the correlation between morphometric variables is also used to understand the nature, erosional status and hydrologic response of Pinjaur in the West and Sub-Himalayan Mountains [5]. The morphometric calculation is also exercised in establishing the level of erosion susceptibility in Rembiara watershed [6]. Several other techniques like geomorphologic instantaneous unit hydrograph (GIUH) is used for the derivation of hydrographs, which helps in integrated watershed [7]. Similarly, Mapping of the vulnerability of flooded area in the arid region is done in Ghardaia-Algeria [8]. According to a research, Semi-quantitative method of the sediment yield index (SYI) model for watershed prioritization is also a good technique for watershed prioritization [9]. Morphometric parameters have been used to

obtain the terrain of Limbang river basin Borneo [10]. Classification techniques like K-means Cluster Analysis (KCA), Fuzzy Cluster Analysis prioritization using the weighted sum model and Snyder's synthetic unit hydrograph can be used for obtaining flash flood risk [12]. Groundwater recharge potential zones mapping in upper Manimuktha Sub-basin, Vellar river Tamil Nadu India is obtained using GIS and remote sensing techniques [13]. A micro level basin hydromorphological relationships with morphometric parameters have been presented by [14]. A scholar demonstrated the Application of weights-of-evidence (WoE) and evidential belief function (EBF) models for the delineation of soil erosion vulnerable zones on Pathro river basin, Jharkhand, India [15].

The compound parameter calculation and ranking method is a common method used in watershed prioritization. In this method, the entire morphometric variables are assigned equal weightages. It is evident that all the associated variables in the watershed have a different level of impact on the overall geohydrological characteristics of the watershed. Therefore, assigning equal weightages may create a significant level of variation on the results. To overcome this level of variation, a statistical approach, WSA (Weighted Sum Analysis) [16] a correlation technique is used for ranking and prioritization of each subwatershed. The impact of morphometric input variables is considered individually to determine which parameter should be considered in the final combination for rank allocation.

2. STUDY AREA

Figure 1: Location of Subarnarekha River basin in state Jharkhand, India

The selected area for the present study is the upper watershed of river Subarnarekha, covering an area of 12831 Km², in the state of Jharkhand, India (figure 1). The origin of river Subarnarekha is a small rivulet in the village name *Piskanagri*, almost 15 km from the Ranchi city. The place of origin is surrounded by lush green small hillocks and agricultural land. The area surrounding the rivulet is also a holy place for the existing ethnic group of people (tribals), which they worship annually in the month of January every year. The origin point of the river is called as *rayen jhuma* in the nagpuri language of this region. This river flows through three districts of Jharkhand, Ranchi, East Singhbhum, and Saraikela Kharsawa, one district of West Bengal, i.e. West Medniapore and finally it joins the Bay of Bengal near Talsari, Odisha. Its main tributaries are Kanchi, Karkari, Kharkai, Raru, Garru, and Dulang. This river passes through one of the richest mineral belts of world chiefly consisting of ores of iron, copper, mica. This region also endowed with the thick cover of the mixed deciduous forest, primarily consisting of Sal (*Shorea robusta*). The latitudinal and longitudinal extension of the study area is 23° 18' N and 85° 11' E respectively. On the scale of 1: 2,50,000, this area is represented on Survey of India topographical map no. 73 E. Geomorphologically, this area is characterized by high spurs and water divide, gorges, deep valleys and waterfalls with deposits of red and laterite soil. The river course consists of rocks of granite, pegmatite [17]. The removal of the superincumbent load of overlying rocks from the earth's surface can be seen throughout the river channel due to continued erosion [18]. The climate of this region is characterized by hot summer from March to May and cold winter during the month of November to February. The mean monthly temperature varies from 40.5° C in the month of May to 9.00° C in December whereas annual average maximum and minimum temperatures vary from 32.4° C to 18.0° C respectively. This basin receives its rainfall from South-West monsoon, which starts from June and ends in October. The average annual rainfall for the basin is around 1800 mm. The cultivation is practiced for two seasons. In Kharif season, (June-October) rice is sown and in Rabi (November-March) wheat is the principal crop.

(FCA), and Kohonen Neural Networks (KNN) are used to prioritize 25 micro-watersheds of Kherthal watershed of Rajasthan [11]. Watershed

3. METHODOLOGY

Figure 2(a): Digital Elevation Model (DEM) of upper watershed of River Subarnarekha

Figure 2(b): Trunk stream network of upper watershed of River Subarnarekha

3.1 Morphometric analysis and watershed management

The management of watershed from a micro-catchment level to macro involves a complex integration of various physical processes and geomorphological units. The complexity of behavior of any watershed towards future scenario becomes a challenging task because it involves a balance between lithosphere and hydrosphere across spatial and temporal scales. The hydrogeological component like surface morphology, surface runoff, elevation, soil texture, landform, land use, etc., play significant role in devising a plan for integrated watershed management with advent of technology and application of analytical tools, these components can be studied with the help of a hydrological assessment framework called as morphometric analysis. Mathematical modeling has also emerged as a superb tool to address the challenges in watershed management. Extensive representation of watershed through the integration of its physical process and representing it in a digital format has given an edge for decision-makers and planners. Computer modeling of a watershed coupled with statistics, remote sensing and Geographic Information Systems (GIS) proved to be effective and efficient tools to address the issue of demand and supply. This integration of scientific and technological expertise has enhanced the efficiency and accuracy in the output of morphometric analysis. The Morphometric calculation process analyzes the extensive stream network to describe the geomorphological feature of the area. The output can further be extended to study and compare basins of different sizes, prioritization of subwatershed, and evaluation of groundwater recharge potential, suitable sites for rainwater harvesting.

3.2 Preparation of geospatial inputs

In the present study, to achieve the goals of morphometric analysis, GIS technique is used for the extraction of the drainage pattern of the river basin. The remotely sensed satellite data dated 20th April 2015 (path-140, row-44, and path-139, row-44) which represents the study area is downloaded from the freely available site, viz, <https://www Landsat.org>. These data are then processed in Erdas Imagine 9.0 of Leica Geosystems and Arc Gis 10.1 of Esri. The techniques and tools, like, image enhancement, radiometric correction, transformation, classification, and spatial analysis are used to derive various geo hydrological information of the study area. The elevation plays an important role in providing information about the river drainage pattern. The elevation data at a resolution of 90 m acquired through the shuttle radar topography mission (SRTM) available for the globe is downloaded from the <http://srtm.usgs.gov/data/obtaining.html> (dated 20th April 2015) and processed in Arc Gis 10.1, using hydrology tool [19]. Based on the data, the slope, aspects and other required information are extracted to prepare base maps. According to the digital elevation model (DEM), the study area shows the lowest elevation of 48 m and the highest elevation of 1043 m (figure 2a). The SRTM cover the entire globe with a 3 arc-second digital elevation model. The recent availability of data with 30-meter resolution gives finer details of topography. In this study, a comparison of data quality, comparing in detail of 30-meter resolution with 90-meter resolution does not give a significant difference.

The obtained topographic details of the DEM with 90-meter resolutions are sufficient to accomplish the present objective of this study. The trunk stream network (figure 2b) is extracted with the help of hydrology tools of Arc Gis 10.1. Apart from this, the comprehensive ground survey is also

conducted to incorporate ground truth inputs in preparation of base and drainage maps. The present study area is delineated into 10 subwatershed, i.e, SWD 1 to SWD 10.

4.RESULTS

4.1 Morphometric Characterization

The computation of morphometric parameters is done by calculating linear aspects, areal aspects and relief aspects. The calculated values are based on the mathematical formulae (Table 1-3).

Table 1: Method of calculating linear aspects of the drainage basin

S.no	Parameters	Symbol	Formula	Reference
1	Stream length	Lu	Length of the stream	[20]
2	Stream order	Nu	Hierarchical Rank	[21]
3	Bifurcation ratio	Rb	$Rb = Nu / Nu + 1$ Nu = No. of stream segments of a given order Nu+1= No. of stream segments of next higher order.	[22]
4	Stream length ratio	RL	$RL = Lu / Lu - 1$ Lu = total stream length of order 'u', Lu -1= the total stream length of its next lower order	[20]
5	Length of overland flow	Lg	$Lg = 1/D * 2$ where Lg = length of overland flow, D = drainage density	[20]
6	Length of the main channel	Lm	Length along longest water course from the outflow point of to the upper limit of catchment boundary	[20]
7	Mean stream length	Lsm	$Lsm = Lu / Nu$	[21]
8	Basin length	Lb	Distance between outlet and farthest point on the basin boundary	[21]
9	Basin perimeter	P	Length of the watershed divide which surrounds the basin	[21]

Table 2: Method of calculating relief aspects of drainage basin

S.no	Parameters	Symbol	Formula	Reference
1	Basin Relief	R	$H = Z - z$ Where, Z = Maximum elevation of the basin (m) z = Minimum elevation of the basin (m)	[21]
2	Basin Relief Ratio	Rh	$Rh = H / Lbmax$ Where, H = Maximum basin relief (m) Lbmax = Maximum basin length (m)	[21]
3	Ruggedness number	Rn	$Rn = \text{Maximum basin relief (H)} * \text{drainage density (D)}$	[23]
4	Dissection index	DI	$DI = H / Ra$ Where, H = basin relief (m) Ra = Absolute relief (m)	[24]

Table 3: Method of calculating aerial aspects of drainage basin

S.no	Parameters	Symbol	Formula	Reference
1	Basin area	(A)	Area enclosed within the boundary of the watershed divide	-
2	Stream Density	Dd (Km/Km ²)	$Dd = L\mu / A$ Where, Dd = Stream density L μ = Total stream length of all orders and A = Area of the basin (Km ²).	[20]
3	Stream Frequency	Fs	$Fs = N\mu / A$ Where, Fs = Stream frequency. N μ = Total no. of streams of all orders and A = Area of the basin (Km ²).	[20]
4	Texture Ratio	Fs	$Fs = N\mu / P$ Where, N μ = No. of streams in a given order and P = Perimeter (Kms)	[20]

5	Form Factor	Rf	$Rf = A/Lb^2$ Where, A = Area of the basin and Lb = (Maximum) basin length	[20]
6	Constant maintenance Channel	(C)	$C = 1/D$ D= Stream density	[21]
7	Elongation ratio	(Re)	$Re = \sqrt{(4 \cdot A/p)}/Lb$	[21]
8	Circulatory ratio	(Rc)	$Rc = 4 \cdot \pi \cdot A/P^2$	[25]
9	Compactness constant	(Cc)	$Cc = 0.2821 P/A^{0.5}$	[20]

4.2 Linear aspects

Table 4: Linear aspect

Sub watershed identity codes	Area (Km ²)	Perimeter (Km)	Basin length (Km)
SWD-1	3347.18	325.91	89
SWD-2	1992.14	433	85
SWD-3	360.42	100.84	21
SWD-4	1144.64	167.11	39
SWD-5	560.36	128.8	37
SWD-6	904.37	181.31	44
SWD-7	747.47	256.42	34
SWD-8	1005.56	278.9	40
SWD-9	1376.06	353.28	48
SWD-10	1392.92	326.53	55

A linear aspect of a basin resembles the channel patterns of the drainage network. It includes stream order (U), stream length (L_μ), mean stream length (L_{sm}), bifurcation ratio (R_b), stream length ratio (R_L), length of overland flow (L_g) (Table 1).

4.3 Stream Order (U)

Table 5: Order wise total stream length (Km)

Sub watershed identity codes	1	2	3	4	5	6	7	8	Total stream (Km)
SWD-1	1370.7	623.17	376.22	89.14	171.64	1.23	0	0	2632.1
SWD-2	828.18	407.49	145.34	113.15	69.75	89.12	31.65	0	1684.68
SWD-3	296.12	181.07	77.9	21.83	26.52	5.7	12.06	0	621.2
SWD-4	480.25	227.85	112.05	52.43	69.43	67.96	0	0	1009.97
SWD-5	396.54	221.4	124.42	20.34	10.98	34.37	14.08	0	822.13
SWD-6	344.51	172.44	105.14	48.08	32.7	0	0	0	702.87
SWD-7	512.65	296.76	166.66	55.78	17.4	11.2	49.35	0	1109.8
SWD-8	409.9	200.5	91.91	63.68	26.69	0	0	0	792.68
SWD-9	555.56	256.03	124.15	40.27	35.63	1.63	0	40.31	1053.58
SWD-10	1032.2	575.77	262.17	147.41	30.88	0	0	58.68	2107.11

Figure 3: river network and stream order of upper watershed of River Subarnarekha

The Strahler's system (1952) of classification is a slight modification of Horton's system (1945) of classification. In this system of classification, the smallest, un-branched fingertip streams are designated as 1st order,

4.4 Stream Length (Lu)

Table 6: Order wise total stream length (Km)

Sub watershed identity codes	1	2	3	4	5	6	7	8	Total stream (Km)
SWD-1	1370.7	623.17	376.22	89.14	171.64	1.23	0	0	2632.1
SWD-2	828.18	407.49	145.34	113.15	69.75	89.12	31.65	0	1684.68
SWD-3	296.12	181.07	77.9	21.83	26.52	5.7	12.06	0	621.2
SWD-4	480.25	227.85	112.05	52.43	69.43	67.96	0	0	1009.97
SWD-5	396.54	221.4	124.42	20.34	10.98	34.37	14.08	0	822.13
SWD-6	344.51	172.44	105.14	48.08	32.7	0	0	0	702.87
SWD-7	512.65	296.76	166.66	55.78	17.4	11.2	49.35	0	1109.8
SWD-8	409.9	200.5	91.91	63.68	26.69	0	0	0	792.68
SWD-9	555.56	256.03	124.15	40.27	35.63	1.63	0	40.31	1053.58
SWD-10	1032.2	575.77	262.17	147.41	30.88	0	0	58.68	2107.11

The attribute table of the vector layer of the study area as obtained is used to compute and calculate the stream length. Horton's second law suggests that the total length of stream segments is maximum in first-order streams and decreases with the increase in stream order. The stream of relatively smaller length is characteristics of areas with larger slopes and finer texture, whereas the streams which are relatively longer, indicate a flatter

the confluence of two 1st order streams give stream of 2nd order; two 2nd order streams join to form a stream of 3rd order and so on. This way all successive streams join and forms stream of next order. The trunk stream is the stream segment of the highest order. Stream of order 1 to 3 are termed as headwater streams and constitute waterways in the upper reaches of the catchment. Nearly 80 % of world's waterways are of order 1 to 3. The largest stream order known is 12, for example, river Amazon has stream order of 12 [26]. Similarly, streams 4 to 6 are medium-size stream. As per the Strahler's (1964) ordering scheme, the upper watershed of river in Jharkhand is eighth-order stream (figure 3). The previous morphometric study conducted on river Subarnarekha also reveals that this basin is of eighth order [27]. The numerous 1st order stream are said to be formed by the continuous erosion of the river banks [28]. The main river stream joined by the major tributaries from its both banks resulting in increase of stream order. The increase in stream order directly affects the size of the river basin. The selected study area catchment has a size of 12831.12 Km². The area of the catchment represents the area of closed curve forming the horizontal projection of the catchment boundary. In this study, all sub-watersheds are subsequently subjected to hydrology tool of ARC GIS for extraction of detail stream network and other attributes (Table 5). The SWD-1 and SWD-4 is 6th order basins covering an area of 3347.18 Km², 1114.64 Km² respectively. Similarly, SWD-3, SWD-2, SWD-5, SWD-7 are 7th order basin having area 360.42 Km², 1992.14 Km², 560.36 Km², 747.47 Km² respectively. The 8th order basin is present in two subwatershed, i.e, SWD-9 ad SWD-10 which covers an area of 1376.06 Km² and 1392.92 Km² respectively.

gradient. There is an inverse relationship between the number of streams with stream order. As the stream order increases, the SWD-1, SWD- 2, SWD- 4, SWD- 7 show the slight variation in stream order length (table 6). This variation is caused due to the different elevation pattern, undulating landform, and flatter gradient.

4.5 Stream Number (N_μ)

Table 7: Stream number in different order of upper watershed of river Subarnarekha

Sub watershed identity codes	1	2	3	4	5	6	7	8	Total stream
SWD-1	1012	464	192	83	19	1	0	0	1771
SWD-2	967	425	201	55	15	11	1	0	1675
SWD-3	206	86	49	11	1	1	2	0	356

SWD-4	478	206	81	32	5	2	0	0	804
SWD-5	396	167	51	14	2	1	1	0	632
SWD-6	461	216	93	31	10	0	0	0	811
SWD-7	141	49	12	2	1	2	2	0	209
SWD-8	512	275	105	26	7	0	0	0	925
SWD-9	712	375	121	37	0	1	0	1	1247
SWD-10	701	364	111	39	10	0	0	1	1226

The total number of stream segments in a particular order is known as stream number (Horton 1945) Stream number is directly proportional to the size of the total drainage basin area. The total count of the stream segment (Table 7) is found to decrease as the stream order increase in the

basin. A higher stream number indicates a high rate of infiltration and less permeability to the soil. The 8th order stream is present in SWD-9 and SWD-10 only.

4.6 Stream length ratio (RL)

Table 8: Stream length ratio of upper watershed of river Subarnarekha

Sub watershed identity codes	2/1	3/2	4/3	5/4	6/5	7/6	8/7
SWD-1	0.45	0.60	0.24	1.93	0.01	0.00	0.00
SWD-2	0.49	0.36	0.78	0.62	1.28	0.36	0.00
SWD-3	0.61	0.43	0.28	1.21	0.21	2.12	0.00
SWD-4	0.47	0.49	0.47	1.32	0.98	0.00	0.00
SWD-5	0.56	0.56	0.16	0.54	3.13	0.41	0.00
SWD-6	0.50	0.61	0.46	0.68	0.00	0.00	0.00
SWD-7	0.58	0.56	0.33	0.31	0.64	4.41	0.00
SWD-8	0.49	0.46	0.69	0.42	0.00	0.00	0.00
SWD-9	0.46	0.48	0.32	0.88	0.05	0.00	0.00
SWD-10	0.56	0.46	0.56	0.21	0.00	0.00	0.00

Stream length ratio is calculated as the ratio of mean stream length of any given order (u) to the predecessor order of mean stream length (u-1). Stream length ratio signifies the relationship between the surface flow discharge and erosion stage of the basin. The erosion pattern over a long period of time also indicates the geomorphic development stages of the stream. The value obtained for different watershed shows a slight increase in stream length ratio from lower to higher stream order (Table 8). There

is a slight variation for stream length ratio for SWD-5 and SWD-7. The variation of stream length ratio between successive stream orders is due to the differences in slope and topographic conditions. The overall values of stream length of subwatershed suggest the developed geomorphic stage of a stream.

4.7 Mean Bifurcation Ratio (Rb)

Table 9: Bifurcation ratio of upper watershed of river Subarnarekha

Sub watershed identity codes	1/2	2/3	3/4	4/5	5/6	6/7	7/8	total	Mean
SWD-1	2.18	2.42	2.31	4.37	19.00	0.00	0.00	30.28	4.33
SWD-2	2.28	2.11	3.65	3.67	1.36	11.00	0.00	24.07	3.44
SWD-3	2.40	1.76	4.45	11.00	1.00	0.50	0.00	21.10	3.01
SWD-4	2.32	2.54	2.53	6.40	2.50	0.00	0.00	16.29	2.33
SWD-5	2.37	3.27	3.64	7.00	2.00	1.00	0.00	19.29	2.76
SWD-6	2.13	2.32	3.00	3.10	0.00	0.00	0.00	10.56	1.51
SWD-7	2.88	4.08	6.00	2.00	0.50	1.00	0.00	16.46	2.35
SWD-8	1.86	2.62	4.04	3.71	0.00	0.00	0.00	12.23	1.75

SWD-9	1.90	3.10	3.27	0.00	0.00	0.00	0.00	8.27	1.18
SWD-10	1.93	3.28	2.85	3.90	0.00	0.00	0.00	11.95	1.71

The bifurcation ratio is calculated by dividing the number of streams in the lower order by the number of streams in the higher of the two orders. In this study, the mean bifurcation ratio lies in between 1.18-4.33 (Table 9). The SWD-9 has lowest bifurcation ratio where as SWD-1 has the highest bifurcation ratio of 4.33. The higher the bifurcation ratio is an indicator of structural disorientation. In general, the Rb values lies between 3 to 5 for which geological structures of the watersheds do not disturb the drainage

pattern. So, as per the obtained result for the SWD-1, the value is within the range, which suggests there is no possible structural disorientation. The bifurcation ratio, having a value about 2 to 3 is of the flat region. Thus, considering the obtained value, SWD-4, SWD-5, SWD-7 have flatter gradient.

4.8 Relief aspects

Table 10: Relief aspect of upper watershed of river Subarnarekha

Sub watershed identity codes	Minimum relief (M)	Maximum relief (M)	Total Relief (M)	Ruggedness number	Relative relief	Dissection Index
SWD-1	209	1043	834	1.82	0.08	0.80
SWD-2	171	906	735	1.67	0.08	0.81
SWD-3	169	655	486	1.16	0.24	0.74
SWD-4	150	913	763	1.77	0.16	0.84
SWD-5	132	463	331	0.78	0.08	0.71
SWD-6	207	880	673	1.44	0.15	0.76
SWD-7	115	885	770	2.22	0.55	0.87
SWD-8	179	643	464	0.86	0.09	0.72
SWD-9	86	919	833	1.58	0.12	0.91
SWD-10	48	738	690	1.33	0.10	0.93

The relief aspects include total relief (H), relief ratio (Rh), relative relief and ruggedness number (Rn) (Table 10). Based on geophysical and topographic conditions of the terrain, relief aspects are used to evaluate the direction of stream flow and represent the denudation progression occurring within the catchment.

4.9 Basin relief (H)

Basin relief determines the geomorphic processes and landform characteristics. It is the elevation difference between the lowest and the highest point on the watershed. The lowest basin relief of 48 m is observed in the plains and highest of 1,043 m in the plateau region dominated by mountainous structures. The maximum basin relief is associated with SWD-1, whereas the lowest basin relief of 48 m is found in SWD-10. The maximum relief is a possible indication of available potential energy in the form of water channel moving down the slope, which can be harassed judiciously for energy production.

4.10 Basin relief ratio (Rh)

Relief ratio (Rh) measures the overall steepness of a drainage basin and is an indicator of the intensity of the erosional process operating on the slope of the basin. There is a direct relationship between the relief and the gradient of the channel. High relief ratio of the basin is an indicator of the

hilly region. The Rh depicts an inverse relationship with shape parameters and increases with decreasing drainage area and size of sub-watersheds of a given drainage basin. The overall steepness of the drainage basin can be ascertained using this parameter, which is useful as an indicator of the intensity of the erosion process in the watershed. A high value of relief ratio is the characteristics of the hilly region. The value of relief ratio of all subwatershed is between 8.65 to 23.14. The maximum value of relief ratio is obtained for the SWD-3 and minimum of for SWD-2. Since the obtained value is high, so, it can be inferred that the drainage basin has a steep slope. This may be the fact that region is predominantly dominated by a plateau with undulating landforms which make the surface steep.

4.11 Ruggedness number (Rn)

It is the product of maximum basin relief (H) and drainage density (D), where both parameters are in the same unit. Extreme values of ruggedness number occur when both variables are large, when a slope is not only steep but long, as well (Strahler, 1958). In the present study, the value of ruggedness number is 0.78 indicate a steep slope. The watershed areas having low relief, but high drainage density is rugged in comparison to the areas of higher relief having less dissection. In this study, the value of ruggedness number is found to be in the range of 0.78 to 2.22. (Table 10). The highest value of Rn is observed in SWD-7, where both total relief and drainage density values are high.

4.12 Areal aspect

Table 11: Areal aspects of upper watershed of river Subarnarekha

Sub watershed identity codes	Stream frequency	Drainage density	Drainage texture	Form factor	Elongation ratio	Circulatory ratio	Compactness constant	Constant of channel maintenance
SWD-1	0.53	0.79	5.43	0.42	0.73	0.40	5.00	1.27
SWD-2	0.84	0.85	3.87	0.28	0.59	0.13	2.68	1.18

SWD-3	0.99	1.72	3.53	0.82	1.01	0.45	1.50	0.58
SWD-4	0.70	0.88	4.81	0.75	0.97	0.51	1.39	1.13
SWD-5	1.13	1.47	4.91	0.41	0.72	0.42	1.53	0.68
SWD-6	0.90	0.78	4.47	0.47	0.77	0.35	1.70	1.29
SWD-7	0.28	1.48	0.82	0.65	0.9	0.14	2.65	0.67
SWD-8	0.92	0.79	3.32	0.63	0.89	0.16	2.48	1.27
SWD-9	0.91	0.77	3.53	0.60	0.87	0.14	2.69	1.31
SWD-10	0.88	1.51	3.75	0.46	0.76	0.16	2.47	0.66

The areal aspects (Table 11) determine various relationships between stream area, its length, basin shape, etc. It includes drainage density (Dd), drainage frequency (Fs), texture ratio (Rt), form factor (Rf), constant channel maintenance (Cm), circulatory ratio (Rc), compactness constant (Cc), Infiltration number (Ig), elongation ratio (Re).

4.13 Stream frequency

The number of stream segments per unit area is termed stream frequency (Fs). There is a direct relationship between surface runoff with stream frequency and drainage density. The stream frequency of all sub-watersheds is given in table 10. The value ranges from 0.28 to 1.13. It depends on the lithological characteristics of the basin and reflects the texture of the drainage network. The phenomenon that affects the variation of stream frequency is duration and type of precipitation. The precipitation in the form of thundershowers will immediately result in a large volume of surface runoff. This creates more surface drainages lines. The other parameters, which affect the stream frequency are vegetation cover, basin relief, subsurface material permeability. The stream frequency of all SWD shows that the basin has moderate vegetation, high infiltration capacity, forest cover, and barren land and later peak discharges owing to low surface runoff rate.

4.14 Stream density

The stream density determines the time travel by water. The measurement of Dd is a useful numerical measure of landscape dissection and runoff potential¹⁵. It reflects the land use and affects infiltration and the basin response time between precipitation and discharge. Drainage basin with high Dd indicates that a large proportion of the run-off activity due to precipitation. On the other hand, a low drainage density indicates the most rainfall infiltrates the soil surface and few streams are required to carry the run-off. Dd is the result of interacting factors controlling the surface runoff and in turn influences the output of water and sediment from the drainage basin. The Dd of the SWD-3, SWD-5, SWD-7, SWD-10 is high indicating low permeability of the subsurface material.

4.15 Stream texture

Horton (1945) defined the drainage texture as the total number of stream segments of all order in a basin per perimeter of the basin. Smith (1950) has classified drainage texture into five different textures, i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8). Some natural factor like climate, type of vegetation cover and its density, rock surface, soil type, infiltration capacity, relief and stage of development influences drainage texture coarse drainage texture is a result of low drainage density while fine drainage texture gives high drainage density. More value of texture ratio more will be a dissection, contributing more soil erosion. According to Smith classification, SWD-7 is of very coarse stream texture, while SWD-2, SWD-3, SWD-8, SWD-9, SWD-10 are of coarse stream texture and SWD-4, SWD-5, SWD-6 are of moderate stream texture.

4.16 Form factor

The form factor is the numerical index commonly used to identify different basin shapes. It is the ratio of basin area (A) to the square of basin length (Lb). Smaller the value of form factor, more elongated will be the basin

while the larger value is the representative of the circular basin. The form factor value of all sub watershed lies between 0.28 to 0.82, which is quite low, indicating an elongated shape basin.

4.17 Length of overland flow

It represents the total length of flow of water over the ground surface before it becomes concentrated in specific stream channels. The surface water moves over the land and leads to the stream tracing a particular stream channel whose characteristics depend on the steepness of the slope and land cover conditions. A scholar defined the length of overland flow as the length, projected to the horizontal, of non-channel flow from a point on the drainage divide to a point on the stream channel. The geo-hydrological development of the drainage basin is greatly affected by the length of overland flow. The length of overland flow value of sub-watershed ranges from 0.29 (SWD-3) to 0.64 (SWD-1, SWD-6). Shorter the length of overland flows quicker the surface run-off. The obtained value length of overland flow suggests that the SWD-3, SWD-5, SWD-7 have high surface runoff.

4.18 Constant channel maintenance

A scholar used the inverse of drainage density as a property termed as "constant of channel maintenance". Constant channel maintenance depends on the basin relative relief, lithology, climatic condition, etc. Higher values suggest more area is required to produce surface flow which implies that part of water may get lost by evaporation, percolation etc. lower value indicates fewer chances of percolation/infiltration and hence more surface runoff. The value of constant of channel maintenance for all the sub watershed of the study area lies within 0.58 to 1.27. The constant channel maintenance value of SWD-1, SWD-2, SWD-4, SWD-6, SWD-8, SWD-9 is high indicating that higher basin area is required for the maintenance of stream length of 1 km as compared to others.

4.19 Circulatory ratio

It is estimated as the ratio of the area of the basin (A) to the circular area (Ac) having a circumference equal to the perimeter of the river basin. When the value of circulatory ratio approaches unity, the basin shape tends to be circular. The value of the circulatory ratio of the study area lies within 0.13 to 0.51, which is less than unity. It signifies that the basin is elongated in shape. The various factors that predominantly affect the basin shape are relief and stream pattern that arises due to a continuous erosional activity of the land surface.

4.20 Compactness constant

It is the ratio between basin perimeters to the perimeter of a circle to the same area of the watershed. It derives the relationship between actual hydrologic basins to the exact circular basin having the same area as that of a hydrologic basin. The value of compactness constant is an indicator of erosion risk factors. Lower values signify less vulnerability while higher values indicate great vulnerability for erosion. It is one of the major aspects considered for evaluation and conservative measures to be implemented in a watershed for management and planning. The value of SWD-1 has the value of 5 indicating high erosion risk assessment factor. It reflects that this sub-watershed needs conservation measures as it is more vulnerable to erosion.

5. PRIORITIZATION OF SUB-WATERSHED

Table 12: Rank allocation to areal aspect of sub watershed of upper watershed of river Subarnarekha

Sub watershed identity codes	Stream frequency	Bifurcation ratio	Drainage density	Drainage texture	Form factor	Elongation ratio	Circulatory ratio	Compactness constant
SWD-1	9	1	2	2	2	3	8	9
SWD-2	7	2	5	5	7	10	6	10
SWD-3	2	3	1	1	9	7	1	2
SWD-4	8	5	10	10	8	5	5	5
SWD-5	1	4	6	6	10	4	4	4
SWD-6	5	9	9	9	6	2	9	7
SWD-7	10	6	8	8	1	8	3	8
SWD-8	3	7	7	7	5	1	7	1
SWD-9	4	10	4	4	3	6	10	6
SWD-10	6	8	3	3	4	9	2	3

The calculation of morphometric parameters helps in knowing various aspects of the geohydrological behavior of the upper watershed of river Subarnarekha. In the present study, the prioritization of watershed is done by considering the areal and linear aspects, whereas the role of relief aspects is not undertaken. There exists a correlation among various morphometric parameters, which is used for prioritization of subwatershed for management and planning. The earlier approaches of prioritization through the concept of only compound parameter ranking are not considered because this method gives equal importance to all morphometric parameters. In the case of risk evaluation and conservation practices, no input constraints can be treated equally because it gives rise to biases. Moreover, every sub-watershed has its own unique geo hydrological characters, which cannot be neglected in priority identification. Linear and areal parameters that are considered as erosion risk estimation factor are the length of overland flow, bifurcation ratio, drainage density, circularity ratio, compactness coefficient, drainage texture, stream frequency, form factor, and elongation ratio. The erosion factors are directly proportional to the linear aspect parameters. Thus, considering the relationship and to avoid the possibility of equal weightages assigning techniques, the methodology of WSA (Weightages Sum Analysis) is adopted. This method considers the statistical correlation techniques to decide which parameter should be considered for final analysis and subsequently for ranking purposes. The earlier studies related to the watershed prioritization reveals that the shape parameters show a negative correlation with surface runoff as well as soil erosion, whereas all the other linear parameters show a positive correlation with soil erosion¹⁷. So, considering, there is a direct relationship of land and water degradation factors with parameters, like, stream frequency, drainage density, drainage texture ratio and bifurcation ratio, the ranking is assigned to each of the values obtained from the morphometric calculation (Table 12). The assigning of highest priority, i.e., 1 for the SWD having the maximum calculated value of the parameter, and least priority ranking are given to the SWD having a minimum value. Remaining parameters (circulatory ratio, form factor, elongation ratio, compactness constant and basin shape) has an inverse relationship with the land and water degradation factors, so, rating is done by assigning highest priority, i.e., 1 for the SWD having minimum value of the parameter, and a similar procedure is followed until the last priority number is assigned. The ranks were assigned to all the parameters in consideration and a correlation matrix (Table 13) is developed. The analysis of the correlation matrix reveals that circulatory ratio shows a negative correlation with most of the morphometric parameters except stream frequency and compactness constant. Similarly, drainage density shows a positive correlation with all morphometric parameters except circulatory ratio. Consequently, weighted sum methodology is applied to calculate the sum of all correlation. The grand total obtained from the sum of all correlation variables is 11.030. Then, individual weightages are calculated for each parameter by dividing the sum of the correlation coefficient by grand total. Based on the individual parameter, a prioritization model with the following equation is formulated for actual and final ranking.

5.1 Prioritization model equation

$$= (0.151 * \text{stream frequency}) - (-0.045 * \text{form factor}) + (0.242 * \text{drainage density}) - (0.125 * \text{circulatory ratio}) + (0.242 * \text{drainage texture}) + (0.169 * \text{compactness constant}) - (0.018 * \text{elongation ratio}) + (0.099 * \text{mean bifurcation ratio})$$

Figure 5: Subwatershed priority rank of upper watershed of River Subarnarekha

This prioritization model equation is applied to subwatershed and the value obtained is called as a compound parameter value, which is used for priority assessment (Table 14). Subwatershed having the lowest value is assigned the highest priority level. Similarly, the lowest priority is given to the subwatershed whose compound parameter value is highest. A Sub watershed priority rank of all individual sub-watersheds is represented in figure 4. In this study, the SWD-7 (1.275) receives the highest priority and is allotted rank 1 followed by SWD-8 (1.718). The least priority is given to SWD-1 having a compound parameter value of 2.815 and this subwatershed is allotted rank 10. Based on compound parameter value of all 10 subwatershed, three class of priority level (Table 15) is constructed i.e, low, medium and high. The priority level "high" is assigned to the values from 1.275-1.718. The subwatershed falling under this range is SWD-7, covering 5.8% only. Consequently, the subwatershed SWD-1, SWD-2, and SWD-5 are given lowest priority that covers 46 % of the total area.

Based on the defined level of priority of all 10 subwatershed, prioritization zonation map is prepared. (figure 5). The high value of priority signifies the extent of vulnerability of soil and water loss from the surface of a watershed. Based on the map, it can be ascertained that 5.8 % of the upper

watershed of river Subarnarekha are in susceptible zone of risk. This area needs immediate attention from planners and policymakers for watershed planning and conservation.

Table 13: Correlation matrixes of morphometric parameters of upper watershed of river Subarnarekha

	Stream frequency	Bifurcation ratio	Drainage density	Drainage texture	Form factor	Elongation ratio	Circulatory ratio	Compactness constant
Stream frequency	1	-0.188	0.224	0.224	0.067	-0.636	0.285	0.685
Bifurcation ratio	-0.188	1.000	0.345	0.345	0.309	-0.273	-0.152	-0.297
Drainage density	0.224	0.345	1.000	1.000	0.224	0.079	-0.309	0.103
Drainage texture	0.224	0.345	1.000	1.000	0.224	0.079	-0.309	0.103
Form factor	0.067	0.309	0.224	0.224	1.000	-0.309	-0.527	0.394
Elongation ratio	-0.636	-0.273	0.079	0.079	-0.309	1.000	-0.055	-0.382
Circulatory ratio	0.285	-0.152	-0.309	-0.309	-0.527	-0.055	1.000	0.261
Compactness constant	0.685	-0.297	0.103	0.103	0.394	-0.382	0.261	1.000
Sum of correlation	1.661	1.091	2.667	2.667	1.382	-0.497	0.194	1.867
Grand total	11.030	11.030	11.030	11.030	11.030	11.030	11.030	11.030
Final weightages	0.151	0.099	0.242	0.242	0.125	-0.045	0.018	0.169

Table 14: Compound parameter constant and priority ranking of sub- watershed of upper watershed of river Subarnarekha

Sub watershed identity codes	Compound parameter constant	Priority ranking
SWD-1	2.815	tenth
SWD-2	2.048	eight
SWD-3	1.934	sixth
SWD-4	1.901	fifth
SWD-5	2.199	ninth
SWD-6	1.807	fourth
SWD-7	1.275	first
SWD-8	1.718	second
SWD-9	1.743	third
SWD-10	1.980	seventh

Figure 5: Zonation map of upper watershed of River Subarnarekha

Table 15: Priority level and type allocation of sub- watershed of upper watershed of river Subarnarekha

Priority type	Priority level	Sub watershed identity codes	Percentage of area (%)
High	1.718-1.275	7	5.8
Medium	1.980-1.718	3,4,6,9,8,10	48.2
Low	2.815-1.980	1,2,5	46

6.CONCLUSION

The advancement of GIS and remote sensing techniques has resulted in an efficient and effective study of geo-morphometric aspects of the drainage

basins. GIS-based tools facilitate the analysis of various geomorphological parameters of the drainage basin like the lithology, surface run off potential, infiltration capacity, etc. The morphometric parameters like drainage density, frequency is very significant classification of the drainage basin that controls and determines the pattern of various geomorphological parameters like runoff pattern, sediment yield, etc. The Dd of the basin reveals that the nature of subsurface strata is more or less permeable mainly due to the rocky structure presents on the river bed and adjoining river banks. The basin as a whole has low texture ratio, which reveals the high infiltration capacity and low runoff rate. Various morphometric parameters reveal the elongated shape of the basin and a delay in surface runoff. Based on final weightages analysis of the Subarnarekha, it is found that SWD-9 covering an area of 747.47 km² has received the highest priority. Accordingly, the priority classification map identifies the potential areas that should be considered for soil, water, and land conservation work. The division of priority into three different class help in preparation of susceptible zoning aspects. This zoning map is useful in classifying the area, which is under threat of high soil and water loss due to various hydro-geomorphologic conditions. The classification map reveals that the SWD-3, SWD-4, SWD-6 SWD-8, SWD-9, SWD-10 falls under the medium priority. These areas are quite satiable for implementation of conservation practices at this stage to avoid any anticipated land degradation phenomena. Thus, quantification and correlation among various individual morphometric parameters give a more logical approach to watershed prioritization.

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REFERENCES

- [1] IPCC. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.). IPCC, Geneva, Switzerland, 151.
- [2] Kumar, P., Joshi, V. 2015. Characterization of hydro geological behavior of the upper watershed of river - Subarnarekha through morphometric analysis using remote sensing and GIS approach. *International Journal of Environmental Sciences*, 6(2), 429- 447
- [3] Pakhmode, V., Himanshu, K., Deolankar, S.B. 2003. Hydrological-drainage analysis in watershed-programme planning: A case from the Deccan basalt, India. *Hydrogeology Journa*1 595–604.
- [4] Hajam, R.A., Hamid, A., Bhat, S. 2013. Application of Morphometric analysis for Geo-hydrological studies using Geo-Spatial technology –A case study of Vishav drainage basin. *Hydrology Current Research* 4, 157
- [5] Pratik, D., Aggarwal, S.P., Verma, N. 2013. Correlation based morphometric analysis to understand drainage basin evolution: a case study of sirsa river basin, western Himalaya India. *Scientific annals of alexandru ioan cuza University of Iasi*.
- [6] Altaf, S., Meraj, G., Romshoo, S.A. 2014. Morphometry and land cover based multi-criteria analysis for assessing the soil erosion susceptibility of the western Himalayan watershed. *Environment Monitoring Assessment* 186, 8391–8412
- [7] Jain, M.K., Kothiyari, U.C. 2000. Estimation of soil erosion and sediment yield using GIS. *Hydrological Science Journal*, 45(5), 771–786
- [8] Yamani, K., Hazzab, A., Sekkoum, M. 2016. Modeling Earth Systems and Environment, (2), 147.
- [9] Jang, T., Vellidis, G., Hyman, J.B., Brooks, E., Kurkalova, L.A., Boll, J., Cho, J. 2013. Model for Prioritizing best management practice implementation: sediment load reduction. *Environment Management*, 51, 209–224

- [10] Krishnan, M.V.N., Prasanna, M.V., Vijith, H. 2017. Modeling Earth Systems and Environment, (3), 1477.
- [11] Srinivasa Raju, K., Nagesh Kumar, D. 2011. Classification of microwatersheds based on morphological characteristics, *Journal of Hydro-environment Research*, 101-109
- [12] Kadam, A.K., Jaweed, T.H., Umrikar, B.N. 2017. Modeling Earth Systems and Environment, (3), 1663.
- [13] Deepa, S., Venkateswaran, S., Ayyandurai, R. 2016. Modeling Earth Systems and Environment, (2), 137.
- [14] Prasad, R.N., Pani, P. 2017. Modeling Earth Systems and Environment, (3), 1491.
- [15] Gayen, A., Saha, S. 2017. Modeling Earth Systems and Environment, (3), 1123.
- [16] Aher, P.D., Adinarayana, J., Gorantiwar, S.D. 2014. Quantification of morphometric characterization and prioritization for management planning in semi-arid tropics of India: A remote sensing and GIS approach. *Journal of Hydrology*, 511, 850–860
- [17] Gupta, D.B., Mitra, S. 2013. Sustaining Subarnarekha river basin. *International Journal of Water Resources Development* 20, 431-444
- [18] Rasool, Q., Singh, V.K., Singh, U.C. 2011. The evaluation of Morphometric characteristics of Upper Subarnarekha Watershed drainage basin using Geoinformatics as a tool Ranchi Jharkhand. *International Journal of Environmental Sciences*, 1(7)
- [19] Tetford, P.E., Desloges, J.R., Nakassis, D. 2017. Modeling Earth Systems and Environment, (3), 1229.
- [20] Rabus, B., Eineder, M., Achim, R., Bamler, R. 2013. The shuttle radar topography mission—a new class of digital elevation models acquired by space borne radar. *ISPRS Journal of Photogrammetry & Remote Sensing*, 57, 241–262
- [21] Horton, R.E. 1945. Erosional development of streams and their drainage basins; hydrological approach to quantitative morphology. *Geological Society of America Bulletin*, 56, 275–370
- [22] Strahler, A.N. 1957. Quantitative analysis of watershed geomorphology *Trans Am Geophys Union* 38, 913–920
- [23] Schumm, S.A. 1956. Evolution of drainage systems and slopes in Badlands at Perth Amboy New Jersey. *Geological Society of America Bulletin*, 67, 597–64
- [24] Melton, M.A. 1958. Correlations structure of morphometric properties of drainage systems and their controlling agents. *Journal of Geology*, 66, 442–460
- [25] Magesh, N.S., Chandrasekar, N., Soundranayagam, J.P. 2012. Delineation of groundwater potential zones in Theni district Tamil Nadu using remote sensing GIS and MIF techniques. *Geoscience Frontiers*, (3), 189-196
- [26] Subramanyam, K. 2013. Engineering hydrology. Mc Graw Hill Education 4th Edition, 170
- [27] Satpathi, D.D.P. 1981. An outline of Indian Geomorphology a study in regional Geomorphology of Singhbhum, Classical publishing company, 1st Edition, 126
- [28] Chorley, R.J., Donald, E.G., Pogorzelski, H.A. 1957. New Standard for Estimating Drainage Basin Shape. *American Journal of Science*, 255, 138-141