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# Identification of Critical Sub-Watershed of Kotani Watershed in Chhattisgarh based on Morphometric Analysis using Geospatial Techniques

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**ABSTRACT: In this work, the suitable soil and water conservation measures and its development in the Kotani watershed have been achieved using the morphometric analysis-based recognition of critical sub-watershed, remote sensing and GIS techniques. In the delineation and identification of drainage lines, as well as in the management and planning that are water-based assets geospatial method has been found to be an effective tool. The work has shown that geospatial techniques can potentially use to evaluate morphometric aspects of the Seonath basin. The linear, areal and relief aspects, were used in the morphometric study. Various identification ranks were assigned after the compound factor has been assessed. In the ArcGIS 10.3 environment, DEM from the SRTM and additional thematic layers including drainage pattern and drainage density were created and analyzed. The results of identification of sub-watershed shows that critical sub-watershed SW1 falls under high priority rank because its compound parameters value was found to be lowest as 5.6. The Kotani watershed SW1 has low form factor, low elongation ratio, steep slopes, high drainage density, and high stream frequency.**

**Keywords:** GIS, morphometric parameter, drainage basin.

## INTRODUCTION

A watershed is a natural hydrological border that allows surface runoff to flow into a river at a single location. The drainage basin's channel network's morphometric study serves as key to understanding the drainage basin's geo-hydrological behavior and expresses the catchment's prevalent climate, geology, geomorphology, structural, etc. Remote sensing (RS) and geographical information system (GIS) were used to determine the morphometric aspects of thirteen sub-watersheds of Gagas watershed of Ramganga River basin placed in Almora district of Uttarakhand, India. In addition to shape parameters like form factor, circularity ratio, compactness coefficient, and elongation ratio, the morphometric aspects used for this purpose are based on the linear/aerial aspects of the watershed, including bifurcation ratio, drainage density, stream frequency, texture ratio, and mean length of overland flow (Kandpal *et al.*, 2017). Kandpal *et al.* (2018) were prioritized hilly sub-watersheds based on geomorphologic parameters obtained using remote sensing (RS) and geographical information system (GIS) in the Chaukhutia watershed of Ramganga River basin in state of Uttarakhand, India. The Chaukhutia watershed was delineated and further sub-divided into eighteen sub-watersheds using RS and GIS techniques. The watershed management process implies appropriate use of land and water resources for optimum production with minimum hazard to natural resources (Nag, 1998; Kanth *et al*., 2012). By measuring the watersheds' linear, areal, and relief parameters, the morphometric parameters of the watershed are analyzed. For morphometric study, remote sensing methods using imagery from satellites are useful tools. In order to analyze drainage morphometry, satellite remote sensing provides a synoptic perspective of an extensive area. Less time-consuming than ground surveys, image interpretation approaches provide useful results when combined with modest field testing. An essential component of taluk characteristics is the quantitative characterization of the drainage system (Strahler, 1964). Even without considering the soil map, morphometric analysis is an important tool for identifying micro-watersheds (Biswas *et al.*, 1999). Morphometry is the measurement and quantitative analysis of the earth's surface configuration, shape, and dimension of landforms (Agarwal, 1998; Obi Reddy *et al.*, 2002). Because all hydrologic and geomorphic processes occur inside the watershed, morphometric properties at the watershed scale may hold crucial information about its genesis and growth. Prioritization determines the highest priority watershed or erosion susceptibility zone for remediation. Watershed prioritization is the process of prioritizing the catchment's many micro-watersheds in order of priority for drainage line treatment and soil conservation measures. Once the micro-watersheds have been prioritized, a quantitative assessment of their morphometric properties provides the foundation for implementing appropriate soil and water conservation measures. The morphometric analysis has an advantage over the Weighted Sum Approach (WSA) and Principal Component Analysis (PCA) because it provides more precise relative information about the sub-watershed characteristics in relation to the watershed's hydrologic response.

The Kotani watershed has been situated in the moderate agro-climatic zone of the Chhattisgarh plains and it is reported to be semi-critical by CGWB, NCCR, Raipur, 2015. Rain and wind activities cause soil disintegration and degradation in the Kotani watershed, which leads to changes in waterway morphology, supply sedimentation and reduced reservoir storage capacity, because of these major difficulties Kotani watershed as been chosen for the current study. The primary goals of this study were to estimate geomorphologic characteristics and identify the most critical sub-watersheds of the Kotani watershed for soil and water conservation measures using geospatial technique.

**Study Area.** Kotani watershed is a sub-basin of the Seonath River situated between 20°17'56" to 21°22'57" N latitude and 80°22'57" E to 81°28'48" E longitude. The Kotani watershed has a drainage area of around 6951 km$^2$, and the watershed's average annual rainfall is 1124 mm. Fig. 1 depicts the location of the study watershed.

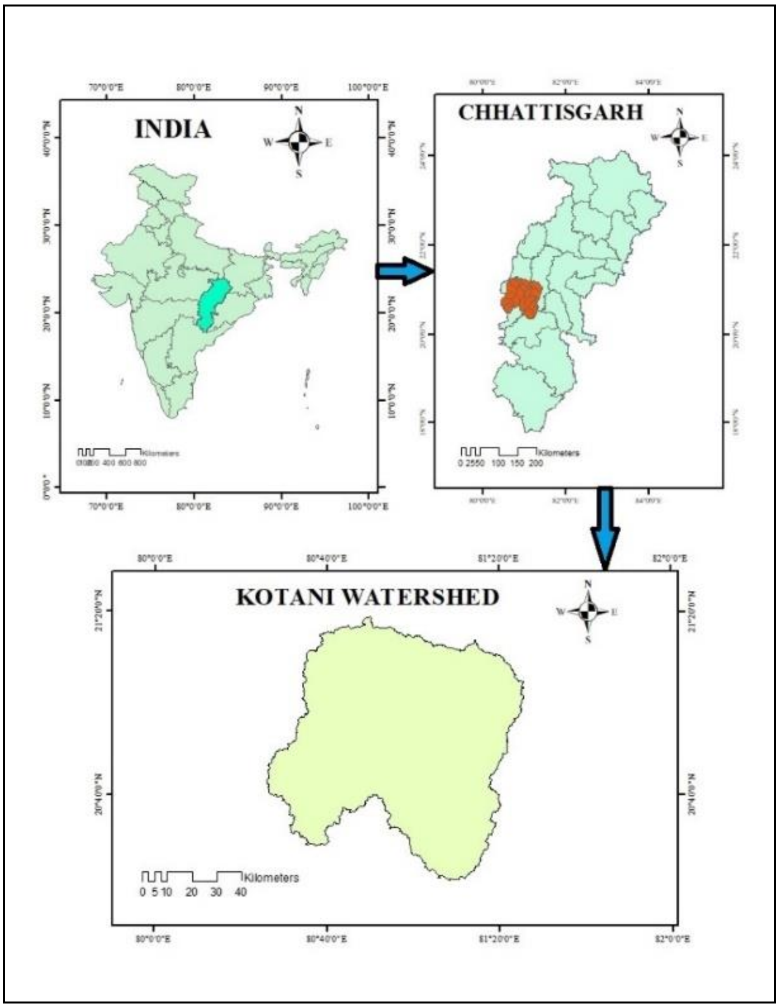


**Fig. 1.** Location map of the Kotani watershed.

## METHODOLOGY

With the use of ArcGIS 10.3 software and the World Geodetic System (WGS dating from 1984) the research area was delineated in the GIS environment at Richariya Lab, IGKV, Raipur. Toposheets no. 64C/15, 64C/16, 64D/13 64G/3, 64G/4, 64G/7, 64G/8, 64H/1 and 64H/5 of 1:50,000 scale were used in this study. SRTM (30m) data was used in this study to elicit drainage networks and investigation of Morphometric parameters. The various morphometric parameters were obtained using standard methodology according to Table 1.

**Table 1: Empirical relationships used for the analysis of morphometric parameters.**

| Morphometric parameters | Formulae | References |
|---|---|---|
| **Order of streams ($N_u$)** | Hierarchical rank | Strahler (1964) |
| **Stream length ($L_t$)** | Length of stream | Horton (1945) |
| Mean stream length ($L_{sm}$) | $L_{sm} = L_u/N_u$<br>In which,<br>$L_u$ = Total stream length of order 'u'<br>$N_u$ = Total no. of stream segments of order 'u' | Strahler, 1964) |
| Bifurcation ratio ($R_b$) | $R_b = N_u / N_{u+1}$<br>In which,<br>$N_u$ = Total no. of stream segments of order 'u'<br>$N_{u+1}$ = no. of stream segments of the next higher order | Schumn (1956) |
| Length of overland flow ($L_g$) | $Lg = 1/2D_d$<br>In which,<br>$D_d$ = Drainage density | Horton (1945) |
| Basin length ($L_b$) | $L_b = 1.321A^{0.568}$<br>In which,<br>A= Basin Area | Nookaratnam *et al.* (2005) |
| Basin Perimeter (P) | Outer boundary of drainage basin measured in kilometers. (GIS software analysis) | Schumn (1956) |
| Drainage density ($D_d$) | $D_d = L_u /A$<br>In which,<br>$L_u$ = Total stream length of all orders<br>A = Basin Area (km$^2$) | Horton (1945) |
| Stream frequency ($F_s$) | $F_s = N_u / A$<br>In which,<br>$N_u$ = Total no. of streams of all orders<br>A = Basin area (km$^2$) | Horton (1932) |
| Texture ratio (T) | $R_t = N_u / p$<br>In which,<br>$N_u$ = Total no. of streams of all orders<br>P = Perimeter (km) | Horton (1945) |
| Form factor ($R_f$) | $R_f = A/L_b^2$<br>In which, A = Basin area (km$^2$)<br>$L_b$ = Length of basin | Horton (1932) |
| Shape factor ($B_s$) | $B_s = L_b^2/A$ | Nookaratnam *et al.* (2005) |
| Circulatory ratio ($R_c$) | $R_c = 4 \times \pi \times A /P^2$<br>In which,<br>P = Perimeter (km) | Miller (1953) |
| Elongation ratio ($R_e$) | $R_e = (4 \times A / \pi)^{0.5} / L_b$ | Schumn (1956) |
| Compactness constant ($C_c$) | $C_c = 0.2821P/A^{0.5}$ | Horton (1945) |

## RESULTS AND DISCUSSIONS

**Morphometric analysis of Kotani Watershed.** The watershed boundary was prepared on ArcGIS 10.3 on the basis putted outlet location which is taken by manually and verified by collected map from State Water Resource Department of the Government of Chhattisgarh. An automated approach of delineating streams, which is followed by a number of steps, including DEM, fill, flow accumulation, stream order, and drainage network. Kotani watershed was delineated into seventeen sub-watersheds with the help of ArcGIS 10.3 software which is given in Fig. 2. The basic morphometric parameters, including area (A), perimeter (P), length (L), and the number of streams (N), were determined from the sub-watershed delineated layer. Basin length (Lb), which was determined from stream length, was then calculated from the number of streams, and the bifurcation ratio (Rb), which was determined from the basin length. In accordance with Table 1, additional morphometric parameters were derived using the formulae. The greatest value of the linear parameters was evaluated as rank 1, the second-greatest value as rank 2, and so on, with the least value being placed last in rank for the identification of sub-watersheds. As a result, the lowest rank for a shape parameter was 1, the next lowest rank was 2, and so on, with the highest value being ranked last. After that, the compound parameter was calculated by adding together all the ranks of the linear and shape parameters, then dividing by the total number of parameters. The sub-watershed with the lowest compound parameter was given the highest prioritized rank out of the whole group of sub-watersheds.

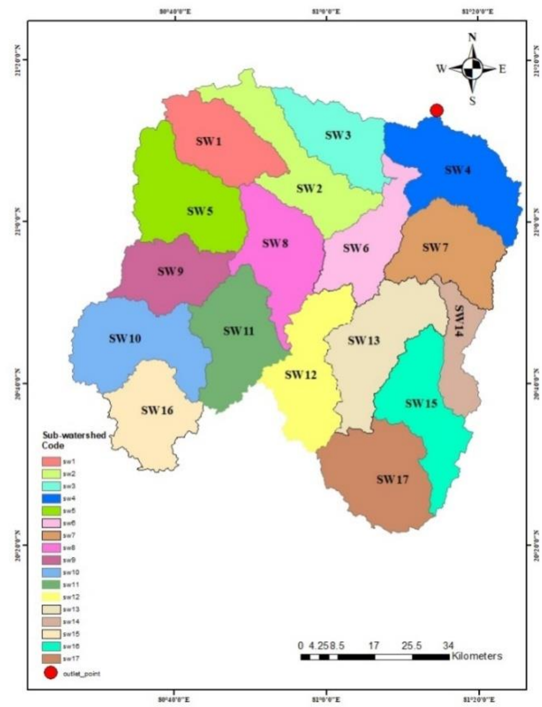


**Fig. 2.** Delineated boundary and sub-watersheds of Kotani watershed

**Area (A):** The area of the Kotani watershed is about 6951 $km^2$.Kotani watershed was divided into 17 sub-watersheds having the highest area 499.16 $km^2$ of SW4 and lowest area 199.78 $km^2$ of SW14. The calculated area of each sub-watershed is given in Table 2.

**Perimeter (P)**: The Kotani watershed has a total perimeter of 2062.15 km, with data on 17 sub-watersheds. The greatest sub-watershed, SW13, has a perimeter of 138.53 km and a basin area of 499.16 $km^2$. The smallest sub-watershed, SW14, has a perimeter of 95.46 km and a basin area of 199.78 $km^2$. All 17 sub-watersheds' perimeters were calculated using GIS software, which calculates the perimeter of each polygon automatically. The basin sub-watersheds perimeters are listed in Table 2.

**Stream length ($L_t$):** The most crucial element of a drainage basin is stream length. Based on the law purposed by Horton (1945), the stream length of each of the 17 sub-watersheds was estimated. Horton's second law stated that stream length increases as stream order decreases. This indicates that the first-order stream has a maximum length. Tables 2 and Fig. 2 express the total stream length and order-wise stream length of 17 sub-watersheds, respectively. It explains the permeability of the rock formations in a watershed. This alteration in the stream could be a result of lithological changes, streams flowing from high altitudes, or relatively steep slopes.

**Mean stream length ($L_{sm}$):** According to Strahler (1964), stream length is a distinctive parameter associated to drainage network components of drainage basins. In general, the higher the stream order, the longer the stream length and the lower the stream order, the shorter the stream length. The mean stream length for sub watersheds is given in Table 2.

**Basin Length ($L_b$):** The *Kotani* watershed has a basin length of 680.07 km. The basin length of all the 17 sub-watersheds is given in Table 2. Sub-watershed SW14 has the shortest length as 26.77 km among all the 17 sub-watersheds. The distance between a basin's mouth and its output point is measured in straight lines and given Table 2 for each sub-watershed.

**Order of streams ($N_u$):** The first step in any drainage basin analysis is stream ordering. The approach given by Strahler 1957 was used to numbering the streams in this study. The *Kotani* watershed is of VI$^{th}$ order watershed. Table 2 shows sub-watershed wise order of streams. The watershed contained streams of 1$^{st}$, 2$^{nd}$, 3$^{rd}$, 4$^{th}$, 5$^{th}$ and 6$^{th}$ order of streams. The sub-watershed SW10 had the greatest number of 1$^{st}$ order streams, while sub-watershed SW14 had the lowest order of streams. The SW14 had the lowest number of second order streams, whereas SW11 had the largest number of second order streams. A dendritic drainage pattern in the watershed suggests homogeneous subsurface strata and a lack of structural tectonic control. Changes in stream order and number indicate that streams are flowing from a higher elevation and have fewer lithological variances. Fig. 3 represents the order of streams prevailing in the *Kotani* watershed.

**Table 2: Kotani watershed morphometric parameters by sub-watershed wise.**

| Sub-watershed code | Order of streams | | | | | | Area ($km^2$) | Perimeter (P) km | Basin length ($L_b$), km | Relief | Number of streams | Total Stream Length (km) | Mean Stream Length ($L_u$), km |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | | | | | | | |
| **SW1** | 38 | 9 | 2 | 1 | 0 | 0 | 360.63 | 99.38 | 37.44 | 268.56 | 50 | 171.93 | 3.44 |
| **SW2** | 43 | 8 | 2 | 2 | 2 | 1 | 448.22 | 170.22 | 42.36 | 248.64 | 58 | 206.15 | 3.55 |
| **SW3** | 30 | 7 | 2 | 1 | 1 | 1 | 333.64 | 107.65 | 35.82 | 254.18 | 41 | 140.22 | 3.42 |
| **SW4** | 41 | 9 | 1 | 1 | 1 | 1 | 494.66 | 136.83 | 44.8 | 229.2 | 53 | 205.7 | 3.88 |
| **SW5** | 40 | 11 | 4 | 1 | 0 | 0 | 490.05 | 118.96 | 44.56 | 261.44 | 56 | 215.05 | 3.84 |
| **SW6** | 30 | 8 | 1 | 1 | 1 | 1 | 345.29 | 126.6 | 36.53 | 250.48 | 41 | 151 | 3.68 |
| **SW7** | 33 | 7 | 0 | 1 | 0 | 0 | 409.64 | 107.38 | 40.25 | 244.75 | 41 | 167.34 | 4.08 |
| **SW8** | 38 | 7 | 1 | 1 | 1 | 0 | 420.24 | 129.09 | 40.84 | 255.16 | 48 | 181.19 | 3.77 |
| **SW9** | 25 | 6 | 1 | 0 | 0 | 0 | 327.38 | 98.4 | 35.44 | 279.56 | 32 | 141.86 | 4.43 |
| **SW10** | 49 | 9 | 3 | 1 | 0 | 0 | 494.57 | 135.15 | 44.79 | 281.21 | 62 | 215.6 | 3.48 |
| **SW11** | 42 | 12 | 2 | 2 | 1 | 0 | 438.74 | 117.78 | 41.85 | 265.15 | 59 | 196.07 | 3.32 |
| **SW12** | 43 | 11 | 2 | 1 | 0 | 0 | 438.53 | 135.08 | 41.84 | 270.16 | 57 | 182.67 | 3.2 |
| **SW13** | 47 | 10 | 2 | 1 | 0 | 0 | 499.16 | 138.53 | 45.03 | 256.97 | 60 | 217.82 | 3.63 |
| **SW14** | 18 | 3 | 1 | 1 | 0 | 0 | 199.78 | 95.46 | 26.77 | 272.23 | 23 | 84.21 | 3.66 |
| **SW15** | 30 | 7 | 2 | 1 | 0 | 0 | 357.64 | 106.3 | 37.26 | 304.74 | 40 | 152.29 | 3.81 |
| **SW16** | 38 | 7 | 2 | 1 | 0 | 0 | 414.57 | 131.95 | 40.52 | 265.48 | 48 | 187.06 | 3.9 |
| **SW17** | 45 | 9 | 3 | 1 | 0 | 0 | 478.62 | 107.39 | 43.97 | 294.03 | 58 | 211.91 | 3.65 |

Linear parameters of Kotani watershed

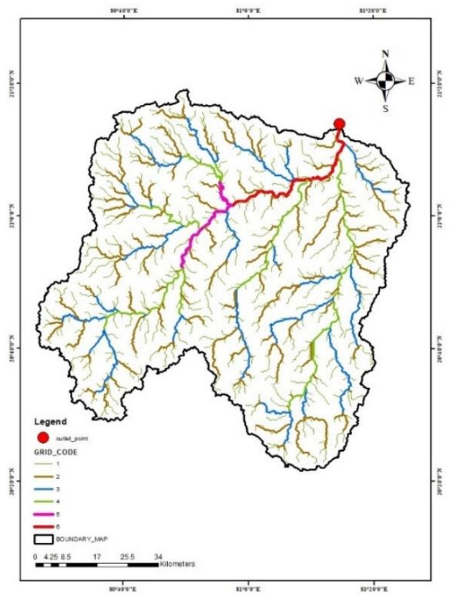


**Fig. 3.** Stream order mapof Kotani watershed.

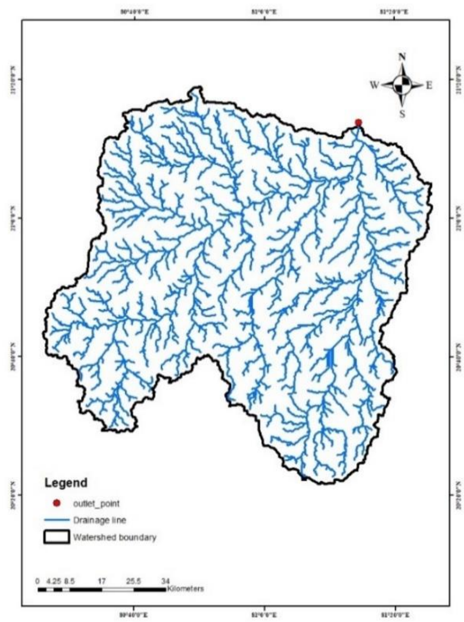


**Fig. 4.** Drainage map of Kotani watershed.

**Bifurcation Ratio ($R_b$):** The bifurcation ratio values are shown in (Table 3). If the bifurcation ratio is low, it reveals simple terrain, porous and soft bed rock, and a better ground water potential zone. The existence of a large number of first and second order streams in the sub-basins contributes to the lower bifurcation ratio. The average bifurcation ratio for the Kotani watershed is 3.65, indicating a moderate to moderately mountainous terrain, a moderate ground slope, moderate to high run-off, and moderate bed rock permeability. This signifies the structural disruptions had little effect on the basin's drainage pattern.

**Drainage Density ($D_d$):** The drainage density ($D_d$) measures the close nature of channel spacing. It is the total length of a stream segment of all orders per unit area. It is influenced by variables that regulate the typical length of the stream, such as weathering resistance, permeability of rock formation, climate, vegetation, and so on. $D_d$ values are generally low in places underlain by highly resistant permeable material with vegetative cover and low relief. High drainage density has been seen in areas with impermeable underlying material, scarce vegetation, and hilly relief. According to Table 3, the Drainage Density ($D_d$) of Sub-watersheds ranges from 0.41 to 0.48 for SW7 and SW1, respectively. Figs. 5 and 6 depict the Kotani watershed's drainage density and slope map.

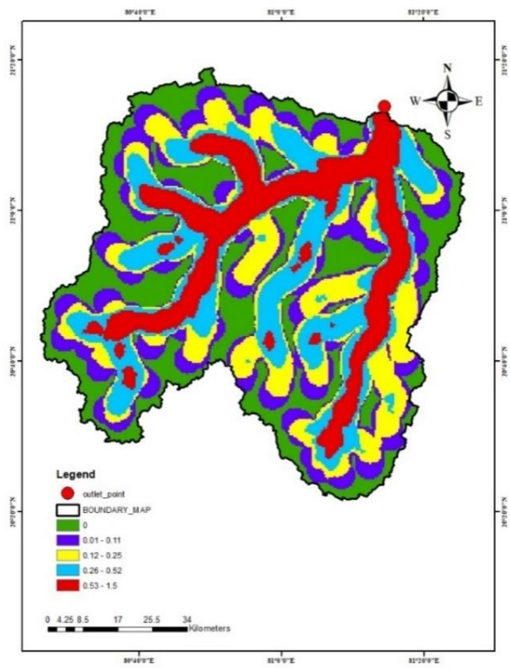


**Fig. 5.** Drainage density map of *Kotani* watershed.

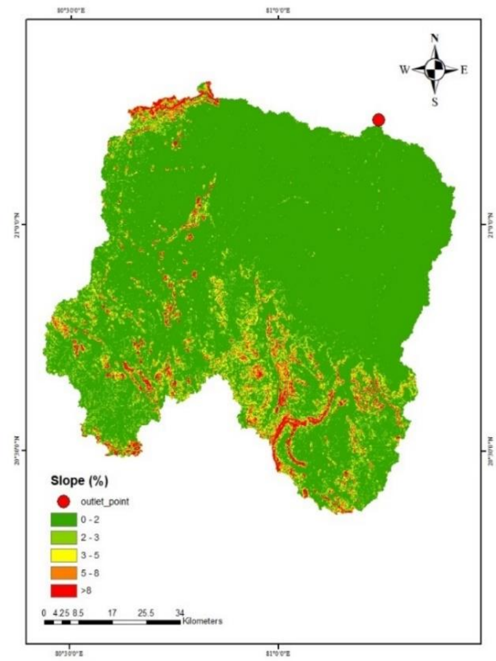


**Fig. 6.** Slope map of *Kotani* watershed.

**Drainage Frequency ($F_u$)**: The topographic feature is measured by the frequency of drainage. The total number of stream segments of all types per unit area is referred to as the stream drainage frequency (Horton, 1932). According to Table 3, the drainage frequency of sub-watersheds ranges from 0.10 for SW7 and SW9 to 0.14 for SW1.

**Length of Overland Flow ($L_g$)**: This element is inversely related to the average slope of the channel and is, to a considerable extent, synonymous with the length of sheet flow. It is about equal to half of the reciprocal of drainage density. According to Table 3, the length of overland flow (Lg) of sub-watersheds ranges from 0.21 (for SW3, SW4, SW12, SW14, and SW15) to 0.24 (for SW1).

**Texture ratio (T)**: It is the total number of stream segments of all sorts per perimeter of that area (Horton, 1945). Horton identified infiltration capacity as the single most important component influencing texture ratio, and defined drainage texture to comprise drainage density and drainage frequency. Table 3 illustrates that the texture ratio of sub-watersheds ranges from 1.21 to 1.97 for SW2 and SW17.

**Shape Parameters of Kotani Watershed**

**Circulatory Ratio ($R_c$):** It is influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief, and slope of the basin Table 3 shows that the circulatory ratio of Sub-watersheds value ranges from 0.27 to 0.52 for SW6 and SW17 respectively. The circular to oval shape of a sub-watershed provides for speedy runoff, resulting in a high peaked and narrow hydrograph, whereas the elongated shape allows for delayed water disposal, resulting in a broad and low peaked hydrograph. $R_c$ with a high value denotes mature and old topography.

**Form Factor ($R_f$):** For a perfectly circular basin, the form factor would always be smaller than 0.7854. The basin will be more elongated as the form factor value decreases. High form factor basins have high peak flows of shorter duration, whereas elongated sub-watersheds with low form factor have lower peak flows of longer duration. Flood flows in such elongated basins are less difficult to manage than in circular basins. Table 3 demonstrates that the Kotani watershed has a form factor of sub-watersheds value ranging from 0.25 to 0.28.

**Shape Factor ($B_S$):** It is defined as the ratio of the square length of the basin to its area (Horton, 1945), and it is inversely related to form factor ($R_f$). Kotani watershed form factor values range from 3.59 to 4.04. Table 3 shows the shape factor values for each of the 17 sub-watersheds.

**Elongation Ratio ($R_e$)**: It is the ratio of the drainage of a circle of the same area as the drainage basin to the basin's greatest length. A circular basin discharges runoff more efficiently than an elongated basin. The elongation ratio ranges from 0.6 to 1.0 and is affected by a wide range of climate and geology. Values close to 1.0 are indicative of very low relief places, whereas values ranging from 0.1 to 0.8 are associated with high relief and steep ground slope (Strahler, 1964). Table 3 reveals that the elongation ratio (Re) of sub-watersheds ranges between 0.56 and 0.60.

**Compactness Coefficient ($C_c$):** The compactness coefficient (Cc), also known as the Gravelius index (GI), is computed by dividing the basin perimeter by the diameter of a circle whose diameter is equal to the basin's area. Lower values indicate greater basin elongation and less erosion, whereas higher values indicate less elongation and greater erosion. The compactness coefficient (Cc) of sub-watersheds ranges from 1.39 (SW17) to 1.92 (SW6), as shown in Table 3.

**Table 3: characteristics of the Kotani watershed's numerous sub-watersheds, both linear/aerial and shapes.**

| Sub-watershed code | Linear/aerial characteristic | | | | Shape characteristic | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $R_b$ | $D_d$ | $F_u$ | $L_g$ | T | $R_c$ | $R_f$ | $B_s$ | $R_e$ | $C_c$ |
| **SW1** | 3.57 | 0.48 | 0.14 | 0.24 | 1.73 | 0.46 | 0.26 | 3.89 | 0.57 | 1.48 |
| **SW2** | 2.68 | 0.46 | 0.13 | 0.23 | 1.21 | 0.19 | 0.25 | 4 | 0.56 | 2.27 |
| **SW3** | 2.7 | 0.42 | 0.12 | 0.21 | 1.3 | 0.36 | 0.26 | 3.85 | 0.58 | 1.66 |
| **SW4** | 3.89 | 0.42 | 0.11 | 0.21 | 1.5 | 0.33 | 0.25 | 4.06 | 0.56 | 1.74 |
| **SW5** | 3.46 | 0.44 | 0.11 | 0.22 | 1.81 | 0.44 | 0.25 | 4.05 | 0.56 | 1.52 |
| **SW6** | 3.44 | 0.44 | 0.12 | 0.22 | 1.19 | 0.27 | 0.26 | 3.86 | 0.57 | 1.92 |
| **SW7** | 5.86 | 0.41 | 0.1 | 0.2 | 1.56 | 0.45 | 0.25 | 3.96 | 0.57 | 1.5 |
| **SW8** | 2.89 | 0.43 | 0.11 | 0.22 | 1.4 | 0.32 | 0.25 | 3.97 | 0.57 | 1.78 |
| **SW9** | 5.08 | 0.43 | 0.1 | 0.22 | 1.44 | 0.43 | 0.26 | 3.84 | 0.58 | 1.53 |
| **SW10** | 3.82 | 0.44 | 0.13 | 0.22 | 1.6 | 0.34 | 0.25 | 4.06 | 0.56 | 1.71 |
| **SW11** | 3.13 | 0.45 | 0.13 | 0.22 | 1.67 | 0.4 | 0.25 | 3.99 | 0.57 | 1.59 |
| **SW12** | 3.8 | 0.42 | 0.13 | 0.21 | 1.35 | 0.3 | 0.25 | 3.99 | 0.57 | 1.82 |
| **SW13** | 3.9 | 0.44 | 0.12 | 0.22 | 1.57 | 0.33 | 0.25 | 4.06 | 0.56 | 1.75 |
| **SW14** | 3.33 | 0.42 | 0.12 | 0.21 | 0.88 | 0.28 | 0.28 | 3.59 | 0.6 | 1.91 |
| **SW15** | 3.26 | 0.43 | 0.11 | 0.21 | 1.43 | 0.4 | 0.26 | 3.88 | 0.57 | 1.59 |
| **SW16** | 3.64 | 0.45 | 0.12 | 0.23 | 1.42 | 0.3 | 0.25 | 3.96 | 0.57 | 1.83 |
| **SW17** | 3.67 | 0.44 | 0.12 | 0.22 | 1.97 | 0.52 | 0.25 | 4.04 | 0.56 | 1.39 |

**Identification of critical sub-watershed by themorphometric analysis.** During identification of critical sub-watershed, the compound parameter is calculated by adding all the ranks of linear and shape parameters and then dividing by the number of parameters. Because linear/aerial characteristics are directly related to soil erodibility, the higher the value, the greater the erodibility potential. The parameter with the greatest value assigns the highest priority ranking of 1, the parameter with the second highest value assign rank 2, and so on. The shape characteristics of a sub-watershed, on the other hand, have an inverse relationship with soil erodibility, i.e. the lower the value, the greater the erodibility potential. As a result, the shape parameters with the lowest value assign rank 1, the next lowest value assign rank 2, and so on. Ranking is awarded to each sub-watershed based on the value of the compound parameter.SW1 and SW11 are ranked first and second, respectively, with the lowest compound parameter values of 5.6 and 7.9. Table 4 shows the compound parameter values and relative rank of all sub-watersheds. Fig. 7 and 8 show the priority ranks and priority categories assigned to each sub-watershed.

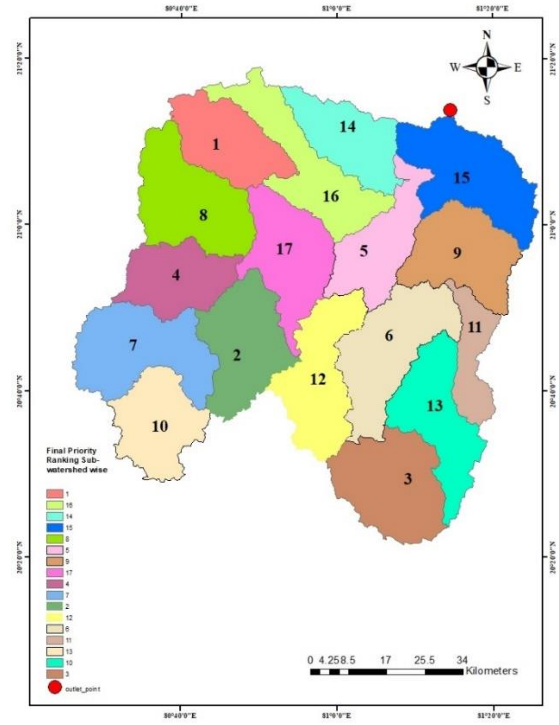


**Fig. 7.** Priority ranks of each sub-watershed.

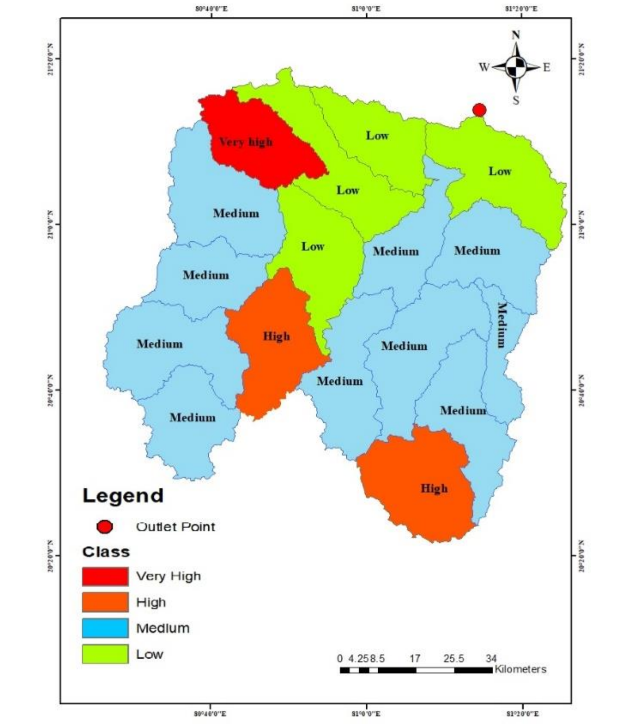


**Fig. 8.** Priority categories of each sub-watershed.

**Table 4: Ranking of sub-watersheds on the basis of linear/aerial and shape characteristics.**

| Sub-watershed code | Linear/aerial characteristics | | | | | Shape characteristics | | | | | Compound ranks | Final priority ranking | Final priority category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $R_b$ | $D_d$ | $F_u$ | $L_g$ | T | $R_c$ | $R_f$ | $B_s$ | $R_e$ | $C_c$ | | | |
| **SW1** | 9 | 1 | 1 | 1 | 3 | 2 | 6 | 12 | 5 | 16 | 5.6 | 1 | Very high |
| **SW2** | 17 | 17 | 4 | 2 | 15 | 17 | 12 | 6 | 12 | 1 | 10.3 | 16 | Low |
| **SW3** | 16 | 12 | 6 | 14 | 14 | 8 | 3 | 15 | 2 | 10 | 10 | 14 | Low |
| **SW4** | 4 | 9 | 15 | 15 | 8 | 10 | 15 | 2 | 15 | 8 | 10.1 | 15 | Low |
| **SW5** | 10 | 11 | 12 | 6 | 2 | 4 | 14 | 4 | 14 | 14 | 9.1 | 8 | Medium |
| **SW6** | 11 | 2 | 9 | 6 | 16 | 16 | 4 | 14 | 4 | 2 | 8.4 | 5 | Medium |
| **SW7** | 1 | 8 | 16 | 17 | 7 | 3 | 7 | 11 | 7 | 15 | 9.2 | 9 | Medium |
| **SW8** | 15 | 14 | 12 | 11 | 12 | 12 | 8 | 9 | 8 | 6 | 10.7 | 17 | Low |
| **SW9** | 2 | 6 | 17 | 10 | 9 | 5 | 2 | 16 | 3 | 13 | 8.3 | 4 | Medium |
| **SW10** | 5 | 15 | 5 | 8 | 5 | 9 | 15 | 3 | 16 | 9 | 9 | 7 | Medium |
| **SW11** | 14 | 5 | 2 | 4 | 4 | 7 | 10 | 7 | 10 | 11 | 7.4 | 2 | High |
| **SW12** | 6 | 13 | 3 | 15 | 12 | 13 | 11 | 8 | 11 | 5 | 9.7 | 12 | Medium |
| **SW13** | 3 | 15 | 8 | 8 | 6 | 11 | 15 | 1 | 16 | 7 | 9 | 6 | Medium |
| **SW14** | 12 | 4 | 11 | 13 | 17 | 15 | 1 | 17 | 1 | 3 | 9.4 | 11 | Medium |
| **SW15** | 13 | 7 | 14 | 12 | 10 | 6 | 5 | 13 | 6 | 12 | 9.8 | 13 | Medium |
| **SW16** | 8 | 16 | 10 | 3 | 11 | 14 | 8 | 10 | 9 | 4 | 9.3 | 10 | Medium |
| **SW17** | 7 | 10 | 7 | 5 | 1 | 1 | 13 | 5 | 13 | 17 | 7.9 | 3 | High |

## CONCLUSIONS

The current study highlights the utility of remote sensing and GIS approaches in identifying key sub-watersheds based on morphometric analysis. Results of identification of critical sub-watersheds shows that SW1 falls under very high priority category and greater risk to soil erosion SW1 has been identified by steep slope, high drainage density, high stream frequency, low form factor, and low elongation ratio. The greater the degree of soil erosion in the SW1, the more likely it is that soil conservation measures will be implemented. Immediate attention to soil conservation measures is essential in the SW1 to protect the land from future erosion and to mitigate natural dangers. One significant disadvantage of morphometric analysis is that it provides little information on the spatial distribution of shape changes across the organism. Morphometric analysis techniques must be adopted by all government and non-government organizations involved in the planning, implementation, and managing of watershed programs in the Chhattisgarh.

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