Morphometric based prioritization of watershed for groundwater potential of Mula river basin, Maharashtra, India

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Abstract

Morphometric analysis gives a quantitative description of drainage basin. The main aim of the present study is to identify the morphometric parameters of a watershed of Mula River basin, Pune district of state Maharashtra, India, and to prioritize the sub-basin. The work outlines the significance of digital elevation model for assessment of drainage pattern and extraction of relative parameters. Basin has been divided into 5 sub-watershed namely SW1 to SW5. The stream order of watershed ranges from first to sixth order and have dendritic drainage pattern means homogeneity in texture and lack of structural control. Further, each parameter has been assigned their ranks according to their value. The basin with lowest parameter value is ranked as first. It was considered as high priority for adopting conservation measure as well. The suitable locations for conservation measure structures in highly prioritized sub-watersheds were also identified for the appropriate land and water management plane. The relevance of work shows the appropriate measure structure locations for preventing the soil from getting eroded from the highly prioritized sub-watershed.

1. Introduction

Land and water both are most vital natural resources of the earth as life and various developmental activities depend on it. These resources are limited and their uses are increasing day by day due to population rise. Therefore, a need for water resources planning, conservation and better management for its sustainable use is required for sustained growth of a country like India. Watershed management plays a significant role in conservation of water and soil resources and their sustainable development. Adoption of better watershed management practices overcomes issues of drought, flood, excessive runoff, poor infiltration, soil erosion, human health, and low productive yield.

Horton (1932, 1945) has explained the need of quantitative geomorphological analysis in management of water resource. Afterwards many geomorphologists have further developed the methods of watershed morphometry (Gregory, 1966; Schumm, 1956; Strahler, 1957, 1964). In India, many authors (Sreedevi, Subrahmanyam, & Ahmed, 2005; Yadav, Dubey, Szlard, & Singh, 2016; Yadav, Singh, Gupta, & Srivastava, 2014) used remote sensing and GIS tools in morphometric analysis and other (Balázs, Birá, Gareth, Singh, & Szabó, 2018; Narsimlu, Gosain, Chahar, Singh, & Srivastava, 2015; Paudel, Thakur, Singh, & Srivastava, 2014; Rawat & Singh, 2017; Singh, Basommi, Mustak, Srivastava, & Szabo, 2017; Singh, Mustak, Srivastava, Szabó, & Islam, 2015).

Morphometric analysis is a significant tool for prioritization of sub-watersheds even without considering the soil map (Biswas, Sudhakar, & Desai, 1999). Morphometry is the measurement of the configuration of earth’s surface shape and dimension of its landform (Clarke, 1996). It gives a quantitative description of drainage basin which is very much useful in studies such as hydrologic modelling, watershed prioritization, natural resources conservation and management, and rehabilitation.

Literature review suggests that previously drainage morphometric parameters were either extracted from topographical maps or field surveys. With advent of high resolution digital elevation model (DEM), the extraction of drainage parameters from DEM gets more popularity in last three decades due to rapid, precise, updated and cost effective way of performing watershed analysis (Maathuis & Wang, 2006; Moore, Grayson, & Ladson, 1991).
Majority of researchers have derived morphometric parameters from Shuttle Radar Topographic Mission (SRTM) DEM, it works on a C-band interferometric radar configuration (Elmahdy, Marghany, & Mohamed, 2016; Grohmann, Riccomini, & Alves, 2007; Kaliraj, Chandrasekar, & Magesh, 2015; Khalkho et al., 2017; Love Kumar, Khalkho, Pandey, & Nigam, 2017; Nigam, Tripathi, Ambast, Love Kumar, & Khalkho, 2017; Szabó, Singh, & Szabó, 2015) and CARTOSAT DEM (Yadav et al., 2014, 2016). These satellite products provide a better way to estimate precise morphometric parameters due to high spatial resolution and sophisticated computer program for any basin in rapid ways.

Morphometric parameters of any watershed plays a crucial role in prioritization of sub-watershed, scientific literature have discussed role of morphometric parameters: watershed prioritization in the Guhiya basin, India (Khan, Gupta, & Moharana, 2001), check dam positioning by prioritization of micro-watershed using the Sediment Yield Index (SYI) model (Nookararatnam, Srivastava, Venkateswarao, Amminedu, & Murthy, 2005), computed morphometric characteristics of Lonar Nala, watershed in Akola district, Maharashtra prioritization of watershed (Moharir & Pande, 2014). Manju and George (2014) carried out critical evaluation and assessment through the calculation of morphometric parameter of Vagamon and Peermade sub-watershed of Kerala. Rais and Javed (2014) used morphometric parameters for the artificial recharge sites in Manchi Basin, Eastern Rajasthan. Yadav et al. (2016) have used the remote sensing and GIS for prioritization of the sub-watersheds of agricultural dominated northern river basin of India. Prioritization of sub-watersheds based on morphometric and land use analysis (Javed, Yousuf, & Rizwan, 2009).

In the present study, morphometric analysis and prioritization of sub-watershed are carried out for a watershed of Mula River basin in Pune district of Maharashtra, India. Watershed morphometric parameters namely bifurcation ratio, drainage density, stream frequency, stream length, circulatory ratio, elongation ratio etc. were extracted. The objectives of the current study are (i) to extract the morphometric parameters (bifurcation ratio, stream length, density of streams, number of streams, perimeter of study area, slope and elevation difference of drainage basin) from DEM using GIS technique and (ii) to prioritize sub-watersheds primarily for groundwater potential and conservation structures.

2. Materials and methods

2.1. Description of study area

The study is conducted on Mula River Basin of Pune district covering an area of 1294.70 km². It is east flowing river located on western ghat. The study area lies between 18°34’ and 18°33’ N latitude and 73°49’ E and 74°20’ E longitude. The river Mula is one of the sub tributary of Bhima on the Deccan Plateau. The drainage pattern of Mula River is dendritic. Pune district has a hot semi arid climate (BSh) bordering with tropical wet and dry (Aw) with average temperature ranging between 19 and 33 °C. The annual precipitation of Pune district is 722 mm which occurs mainly in monsoon season (June to September) and July is the wettest month of the year. The major crops found in this area is Jowar, wheat, bajra, sugarcane, rice, soybean, onion, groundnut, vegetables, turmeric, grape, pomegranate etc. (Figure 1).

2.2. Data-sets used

The toposheets were collected from Survey of India of scale of 1:50000. The topographical maps were geo-referenced in ArcGIS software. The Shuttle Radar Topography Mission (SRTM 30 m) data were used to derive the DEM. The boundary of Mula river basin was delineated using both toposheets and DEM. The DEM data of study area were freely available and it was downloaded from (https://earthexplorer.usgs.gov/). Further, the pre-processed DEM was used for extraction and quantification of morphometric parameters.

2.3. Methodology

The SRTM DEM was used for estimation of morphometric parameter of Mula river basin such as: Bifurcation ratio ($R_b$), Drainage density ($D_d$), Stream frequency ($F_s$), Stream length ratio ($R_l$), Mean stream length ($L_m$), Form factor ($F_f$), Elongation ratio ($R_e$), Circulatory ratio ($R_c$), Length of overland flow ($L_o$), Basin relief ($R_b$), Gradient ratio ($G_r$) etc. The detailed adopted methodology is expressed through flowchart (Figure 2). Table 1 explains the formulae used for quantitative determination of morphometric parameters. All the analysis was performed in the Geographical Information System environment with the aid of ArcGIS software.

Prioritization rating of five sub-watershed of Mula River is carried out through ranking the computed morphological parameters. The sub-watershed with lowest ranking is given the highest priority in terms of soil erosion and less conservation measure. Groundwater condition which is assessed on the basis of groundwater map acquired from government of Maharashtra’s, India.

3. Results and discussions

The linear, shape and relief parameters have been measured and determined.
Figure 1. Location map of the study area. Source: Author.

Figure 2. Flowchart of used methodology.
**Table 1. Formulae used for computation morphometric parameters.**

| Sr.No. | Morphometric parameters | Formula/Definition | References |
|--------|-------------------------|--------------------|------------|
| 1      | Stream order (μ)        | Ranking hierarchically | Strahler (1964) |
| 2      | Stream length (Lμ)      | Total Length of the stream segments of that particular order | Horton (1945) |
| 3      | Mean stream length (L̄) | $L̄ = \sum L/μ$ | Strahler (1964) |
| 4      | Stream length ratio (R) | $R = L̄_n/L̄_{n+1}$ | Horton (1945) |
| 5      | Bifurcation ratio (Rb) | $Rb = N/N_{n+1}$ | Schumm (1956) |
| 6      | Drainage density (D)    | $D = \sum a/a^2$ | Horton (1932) |
| 7      | Texture ratio           | Number of stream segments of all order present in per diameter of that area | Horton (1945) |
| 8      | Length of overland flow (L) | $L = 1/2D$ | Where $D =$ Drainage density of basin |

**Estimation of areal parameters**

| Sr.No. | Formula/Definition | References |
|--------|--------------------|------------|
| 1      | Circularity ratio (Rc) | $Rc = 4\pi A/P^2$ | Miller (1953) |
| 2      | Elongation ratio (Rl) | $Rl = D/\sqrt{L}$ | Strahler (1945) |
| 3      | Form Factor (Fr) | $Fr = A/L^2$ | Horton (1932, 1945) |
| 4      | Compactness constant (Cc) | $Cc = (L/\pi)^2$ | Horton (1945) |
| 5      | Drainage texture (T) | $T = 1/\sqrt{Fr}$ | Horton (1945) |
| 6      | Shape factor (B) | $B = L^2/A$ | Horton (1932) |
| 7      | Constant of channel maintenance (C) | $C = 1/D$ | Schumm (1956) |
| 8      | Drainage Frequency (F) | $F = N/A$ | Horton (1945) |

**Estimation of relief aspects**

| Sr.No. | Formula/Definition | References |
|--------|--------------------|------------|
| 1      | Basin relief (R) | $R = H - h$ | Hadley and Schumm (1961) |
| 2      | Relief ratio (Rg) | $Rg = R/L$ | Schumm (1956) |
| 3      | Gradient ratio (G) | $G = (a-b)/L$ | Sreedevi et al. (2005) |

**3.1. Estimation of linear parameters**

**3.1.1. Stream order**

Stream ordering is the first step taken in any drainage basin analysis. In this work ranking of streams has been carried out based on the method proposed by Strahler (1964). The Mula River is VIth order. The stream ordering, area, numbers of streams, length of stream, and total segments of the five sub-watersheds are presented in Tables 2 and 3. It is observed that as stream order increases the stream number decreases. However, highest stream number was found in 1st order stream (Figure 3). Watershed encompasses a dendritic drainage pattern which indicates homogenous subsurface strata means lack of structural tectonic control. Change in stream order and stream number suggests that streams are flowing from high altitude and with less lithological variations.

**Table 2. Sub-watershed wise stream order with number of segments.**

| Sr no. | Sub watershed | Area (km) | Stream order (number of stream) | Total number of stream segment |
|--------|---------------|-----------|--------------------------------|-------------------------------|
| 1      | SW1           | 167.20    | I  282 II  60 III  12 IV  3 V  1 VI  0 | 358                           |
| 2      | SW2           | 330.80    | I  350 II  120 III  15 IV  2 V  1 VI  0 | 488                           |
| 3      | SW3           | 222.40    | I  312 II  80 III  13 IV  2 V  1 VI  1 | 409                           |
| 4      | SW4           | 325.80    | I  459 II  204 III  23 IV  4 V  1 VI  0 | 691                           |
| 5      | SW5           | 248.50    | I  314 II  76 III  15 IV  3 V  1 VI  0 | 409                           |
| 6      | Total         | 1294.70   | I  1717 II  540 III  78 IV  14 V  5 VI  1 | 2355                          |
| 7      | In (%)        | 72.10     | 22.84 3.24 0.57 0.21 0.05 100.00 |                               |

Note: Figure in parenthesis shows percentage stream segments contributed by different order.
components of drainage basins. Generally, it shows higher the stream order, longer the length of stream and lower the stream order shorter the length of stream. The mean stream length is presented in (Table 4).

3.1.4. Stream length ratio ($R_l$)
Stream length ratio is defined as the ratio between the mean stream lengths of one order with that of the next lower order of the stream segments. The stream length ratio between the streams of different orders of the study area does not follow any trend in different sub-watershed. This change might be attributed to the variation in slope and topography, indicating the late youth stage of geomorphic development in the streams of the study area (Vittala, Govindiah, & Honne Gowda, 2004). $R_l$ values of different orders and sub-watershed are presented in (Table 5). The length ratio gives a general idea

| Sr. no. | Sub watershed | Area (km) | I  | II  | III | IV  | V  | VI  | Total stream length |
|---------|----------------|------------|----|-----|-----|-----|----|-----|----------------------|
| 1       | SW1            | 167.20     | 171.10 | 69.90 | 30.80 | 24.40 | 8.40 | 0 | 304.60 |
| 2       | SW2            | 330.80     | 264.60 | 156.50 | 45.40 | 15.40 | 47.80 | 0 | 529.70 |
| 3       | SW3            | 222.40     | 204.80 | 107.80 | 44.50 | 5.70 | 22.10 | 11.46 | 396.36 |
| 4       | SW4            | 325.80     | 295.50 | 149.90 | 50.34 | 37.40 | 23.40 | 0 | 556.54 |
| 5       | SW5            | 248.50     | 219.50 | 90.70 | 55.14 | 21.69 | 16.36 | 0 | 403.39 |
| 6       | Total          | 1294.70    | 1155.50 | 574.80 | 226.18 | 104.59 | 118.06 | 11.46 | 2190.59 |
| 7       | In %           | 52.75      | 26.24 | 10.33 | 4.77 | 5.39 | 0.52 | 100.00 |
total numbers of stream segments of a given order to that of the next higher order in a basin (Schumm, 1956). Theoretically bifurcation ratio is 2.0 and natural drainage system has 3.0–5.0 in which geologic structures do not distort the drainage pattern (Strahler, 1964). The values of bifurcation ratio are presented in (Table 6).

If the bifurcation ratio is less it indicates plain terrain, permeable and soft bed rock where infiltrates more water makes better ground water potential zone. Lower bifurcation ratio is also due to the presence of large number of first and second order streams in the sub-basins (Kumar, Jayappa, & Deepika, 2011). The average bifurcation ratio for Mula river basin is 4.58 which indicates moderate to high hilly region, moderate ground slope, moderate to high run-off, and moderate permeability of bed rocks. This indicates that the drainage pattern of the basin has not been affected by the structural disturbances.

### 3.1.5. Bifurcation ratio ($R_b$)

Bifurcation ratio describes the branching pattern of a drainage network and is defined as ratio between the

![Figure 4. Sub watersheds of Mula River basin. Source: Author.](image)

Table 4. Sub-watershed wise stream order with mean stream length.

| Sub watershed | Mean stream length ($L_i$), km | Sr no. | I | II | III | IV | V | VI |
|---------------|--------------------------------|-------|---|----|----|----|---|----|
| SW1           |                                | 1     | 0.607 | 1.165 | 2.567 | 8.133 | 8.400 |
| SW2           |                                | 2     | 0.756 | 1.304 | 3.270 | 7.100 | 47.800 |
| SW3           |                                | 3     | 0.656 | 1.348 | 2.423 | 2.850 | 22.100 | 11.460 |
| SW4           |                                | 4     | 0.644 | 0.735 | 2.189 | 9.350 | 23.400 |
| SW5           |                                | 5     | 0.699 | 1.193 | 3.676 | 7.230 | 16.360 |
| Mean stream length |                        |       | 0.672 | 1.149 | 2.976 | 7.053 | 23.612 | 11.460 |

Table 5. Stream length ratio of sub-watershed.

| Sub watershed | Stream Length Ratio ($R_i$) | Sr no. | II/II | III/III | IV/IV | V/V | VI/V | Average |
|---------------|-----------------------------|-------|------|--------|-------|-----|-----|---------|
| SW1           |                             | 1     | 0.409 | 0.441 | 0.792 | 0.344 | 0.496 |
| SW2           |                             | 2     | 0.591 | 0.290 | 0.339 | 3.104 | 1.081 |
| SW3           |                             | 3     | 0.526 | 0.413 | 0.128 | 3.877 | 0.519 | 1.236 |
| SW4           |                             | 4     | 0.507 | 0.336 | 0.743 | 0.626 | 0.553 |
| SW5           |                             | 5     | 0.413 | 0.608 | 0.393 | 0.754 | 0.542 |
| Average       |                             | 6     | 0.489 | 0.417 | 0.479 | 1.741 | 0.519 |

Table 6. Sub-watershed wise bifurcation ratio.

| Sr no. | Stream order | Number of streams | Bifurcation ratio |
|--------|--------------|-------------------|-------------------|
| 1      | 1            | 1                 | 1                 |
| 2      | 2            | 540               | 3.18              |
| 3      | 3            | 78                | 6.92              |
| 4      | 4            | 14                | 5.57              |
| 5      | 5            | 5                 | 2.8               |
| 6      | 6            | 1                 | 5                 |
| Average |              | 2355             | 4.69              |
permeable subsoil material under dense vegetation and low relief (Nautiyal, 1994). High value indicates impermeable rocks and sparse vegetation and hilly region. Average drainage density is 1.70 which indicates moderate permeability and better vegetation cover (Figure 5).

3.1.7. Texture ratio ($T$)

Texture ratio or drainage texture signifies the relative spacing of drainage lines. It is considered as the number of stream segments of all order present in perimeter of that area (Horton, 1945). Drainage texture of any drainage basin depends on climate, rainfall, and rock types, relief, and stage of development (Horton, 1945; Smith, 1950). Texture is classified into four categories: < 4 per km coarse, 4–10 per km intermediate, 10–15 per km fine and > 15 per km ultra fine. In the Mula river basin drainage texture ratio ranges from 0.55 to 4.50. In the sub watershed 1 and 2 have intermediate texture.
3.2.2. **Elongation ratio \((R_e)\)

The elongation ratio is the ratio of the diameter of a circle of the same area as the drainage basin to the maximum length of the basin (Schumm, 1956). The higher the elongation ratio of a basin indicates active denudational process with high infiltration capacity and low runoff in the basin and lower indicates higher elevation and high headward erosion along tectonic lineaments (Reddy et al., 2004; Yadav et al., 2014). The values of the elongation ratio generally vary from 0.6 to 1.0 over a large variety of climatic and geologic types (Rudraiah, Govindaiah, & Srinivas, 2008). Elongation ratio varies from 0.580 to 0.607 and for Mula basin average is 0.59 which indicates that lower peak flow of longer duration, an elongated shape of the basin (Table 7). Slope map shows the degree of slope (Figure 6).

3.2.3. **Form factor \((F_f)\)**

According to Horton (1932), form factor \((F_f)\) may be defined as the ratio of the basin area to square of the basin length. The form factor indicates the flow intensity of a basin for a defined area. The form factor value ranges zero to one. Smaller the value of the form factor, the more elongated shape of the basin. In this given study the form factor ranges from 0.264 to 0.290 (Table 7). It shows flatter peak flow for longer duration of drainage basin, also lesser value shows elongated shape.

**Figure 6.** Slope map of the study area. Source: Author.

which indicates less infiltration and higher soil erosion (Table 7).

3.1.8. **Length of overland flow \((L_o)\)**

According to Horton (1945), length of overland flow is the length of water over the ground before it gets concentrated into definite stream channels. The length of overland flow \((L_o)\) is defined as half of the reciprocal of drainage density (Horton, 1945). It is one of the most important independent variables, affecting both the hydrological and physiographical developments of the drainage basin (Horton, 1945). Table 7 has sub watershed wise information about the length of overland flow.

3.2. **Estimation of areal parameters**

3.2.1. **Circulatory ratio \((R_c)\)**

Circulatory ratio is the ratio of the basin area to the area of a circle with the same perimeter \((P)\) as the basin (Miller, 1953). In the given area circulatory ratio varies from 0 to 1. The circulatory ratio is influenced by geological structures, climate, relief, land cover and stream length and slope of the basin. The circulatory ratio for sub watershed 0.03–0.33 which indicates youth stage of the tributaries in the basin also basin is not circular in shape and low runoff indicates enough time for infiltration of water (Table 7).
3.2.4. Shape factor ($B_s$)
Shape factor means ratio of square of basin length ($L^2$) to the area of the basin. Shape factor of a basin helps to analyse shape irregularity of the drainage basin (Yadav et al., 2014). The average shape factor for Mula river basin is 3.65 (Table 7).

3.2.5. Compactness constant ($C_c$)
It is the ratio between basin perimeters to the perimeter of a circle to the same area of the watershed (Horton, 1945). It derives the relationship between actual hydrologic basins to the exact circular basin having the same area as that of hydrologic basin (Table 7).

3.2.6. Constant of channel maintenance ($C$)
The constant of channel maintenance is the inverse of drainage density (Schumm, 1956). Generally lower the C values of watershed indicate lower the permeability of rocks and vice versa. The average constant of channel maintenance for Mula river basin is 0.70 which indicates that moderate to high permeability, moderate slope and moderate surface runoff (Table 7).

3.2.7. Drainage texture
The meaning of drainage texture is relative spacing of drainage lines (Smith, 1950). The term drainage texture must be used to indicate relative spacing of streams in a unit area along linear direction. Drainage texture of any drainage basin depends on climate, rainfall, vegetation, soil and rock types, infiltration rate, relief and the stage of development (Horton, 1945; Smith, 1950).

Vegetation plays important role in defining the drainage texture and density (Kale & Gupta, 2001). According to Smith (1950) drainage basin is divided into four categories, that is coarse (< 4 per km), intermediate (4–10 per km), fine (10–15), and ultra fine (> 15 per km). Drainage texture helps to understand permeability and ground water recharge potentiality, higher the drainage texture which means higher permeability and better groundwater recharge potentiality. Mula river basin has different drainage texture in different sub watersheds (Table 7).

3.2.8. Drainage frequency ($F_s$)
The number of streams ($N_s$) in per unit area (A) is known as drainage density of the basin, if the stream frequency is high it indicates greater surface runoff and steep ground surface (Horton, 1932; Rao, 2009; Yadav et al., 2014). In this study area drainage frequencies are different for different sub watersheds. In the sub watershed number 1 and 4 have more than 2 per km$^2$. For entire basin it is more than 1.5 per km$^2$ it indicates moderate permeability and moderate soil erosion (Table 7).

3.3. Estimation of relief aspects
3.3.1. Basin relief ($R$)
Basin relief is the actual difference between highest and lowest points of the drainage basin. It is one of the morphometric parameters which helps to understand denudational characteristics of the basin also it controls the stream gradient and influence the surface runoff and sediment also. The lowest pint is 550 m, and highest point is 1241 m and moderate slope and moderate runoff.

3.3.2. Relief ratio ($R_e$)
Relief ratio is the ratio between the basin relief and basin length. It is actually influenced by rocks and slope of the basin. If the values of relief ratio are high it indicates hilly region and low ratio indicates pediplain and valley region (Kumar et al., 2011). Relief ratio for the Mula river basin is different for various for sub watershed 1 to 5 are 27.43, 17.79, 15.25, 19.40 and 19.34, respectively. Relief ratio helps to understand where to establish settlement and afforestation also for agricultural opportunities.

3.3.3. Gradient ratio ($G_r$)
It is the ratio of difference between source and mouth elevation of major stream of basin to maximum length of major stream of that basin. The gradient ratio of Mula river basin is 0.43 m/km, it indicates that height decrease 0.43 m per km along the valley. If the gradient ratio is high it indicates steep slope and high runoff and low value indicates gentle slope and less surface runoff and good possibility of infiltration.

Table 8. Estimated compound parameter with priority ranking.

| Linear Parameters | Shape Parameters | Compound Factor | Prioritized Ranks | Interpretation |
|-------------------|------------------|----------------|------------------|---------------|
| Sr. No. | Sub-Watershed | ($R_s$) | ($D_s$) | ($F_u$) | ($L_s$) | ($T_s$) | ($R_s$) | ($B_s$) | ($R_e$) | ($C_c$) | 2.10 | 1 | High |
| 1 | WS1 | 4 | 1 | 1 | 1 | 1 | 1 | 5 | 1 | 5 | 3 | 2.10 | 1 | High |
| 2 | WS2 | 2 | 5 | 5 | 5 | 3 | 4 | 1 | 5 | 1 | 3 | 3.40 | 4 | Very low |
| 3 | WS3 | 5 | 2 | 3 | 2 | 4 | 4 | 1 | 5 | 1 | 4 | 3.30 | 3 | Low |
| 4 | WS4 | 1 | 3 | 2 | 3 | 5 | 2 | 2 | 4 | 2 | 5 | 2.90 | 2 | Medium |
| 5 | WS5 | 3 | 4 | 4 | 4 | 2 | 5 | 3 | 3 | 3 | 2 | 3.30 | 3 | Low |

Note: The first priority shows most deficit area in ground water and last priority indicates surplus zone of groundwater.
Figure 7. Map showing prioritized sub-watershed with their ranks. Source: Author.

Figure 8. Identify location of different measures structures of SW1. Source: Author.
4. Prioritization of Sub-watershed for Groundwater Prospect

The analyses of morphometric parameters are significant in identifying and determining the zones of groundwater potentialities and areas of high erosion risk (Yadav et al., 2016). Prioritization of five sub-watersheds has been done to identify the zone having high soil erosion activity so that with the time proper conservation measures can be taken for checking the soil erosion in that particular area. The parameter of all five sub-watersheds is calculated and priority ranking is presented in Table 8. The Final prioritized map of the study area showing different sub-watershed with their priority ranking is explain in Figure 7.

5. Suitable Sites for Conservation Measure Structures

Remote sensing and GIS techniques proved to be highly beneficial while attempting prioritization of river basin and found to be suitable for identification of suitable locations for conservation measure structures in highly prioritized sub-watersheds. The drainage map and slope map were prepared. The most critical sub-watershed (SW1) was found through the morphological parameters analysis. Total 79 conservation measure structures sites was suggested in sub-watershed SW1, out of these 40 sites for nala plugging, 30 sites for percolation tank and 9 sites for the check dam was found to be suitable for the proper management practices (Figure 8). These studies are extremely essential for the implementation of soil erosion prevention practices as well as land and soil management practices.

6. Conclusion

In this study, it shows that morphometric parameters are good option to evaluate higher, lower soil erosion and deficit and surplus zones of groundwater for the Mula River basin. In this study area watershed prioritization showed that SW1 gets maximum priority for the higher soil erosion and most deficit zone of groundwater. Sub-watersheds (SW 4) have moderate soil erosion and groundwater condition. The sub-watershed SW2, SW3 and SW 5 has less soil erosion prone area and is good in groundwater condition means have good availability of groundwater. Drainage density of Mula river basin shows moderate permeability of rocks and in higher altitude areas have high drainage density. High stream frequency in the SW 1, SW 2 and SW 4 of > 2/km² shows steep slopes, less infiltration, and hilly regions and poor groundwater condition and high erosion. SW 3 and SW 5 have moderate groundwater condition and moderate erosion. SW 1 and SW 5 natural drainage is controlled by relief. On the basis of priority and weighted sum analysis the possible locations of 79 conservation measures structure was proposed in the prioritized sub-watershed (SW1). In future work the coupling of morphometric parameters with the multicriteria decision-making will be carried out.

Disclosure statement

No potential conflict of interest was reported by the authors.

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