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RESEARCH ARTICLE

Analysis of Drainage Morphometry and Watershed Prioritization of Romushi - Sasar Catchment, Kashmir Valley, India using Remote Sensing and GIS Technology.

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Abstract

The application of remote sensing and geographical information system for the analysis of morphometric parameters are found to be of immense utility in watershed prioritization for soil, water conservation and natural resources management at micro level. This study is an attempt to carry out detailed investigation of linear, shape and relief morphometric parameters like stream length, stream order, drainage density, stream frequency, bifurcation ratio, Length of overland flow, basin perimeter, form factor, compactness coefficient, elongation ratio, basin relief, ruggedness ratio, shape factor and texture ratio in five micro-watersheds of Romushi-Sasar Catchment and their prioritization. For the study area, stream network along with their order was extracted from survey of India toposheets 1961 (1: 50,000 scale) and ASTER DEM 30m in GIS (geospatial) environment and stream order up to 6 has been examined. Based on morphometric analysis and the ranking of each parameter, the sub-watersheds have been classified into three categories high, medium and low in terms of priority for conservation and management of resources. The results reveal that RSMW4 and RSMW5 watershed falls under very high priority and emphasized that prioritization of smaller hydrological unit's i.e. micro-watersheds is ideally recommended for initiating soil and water conservation measures in a watershed**.** These high priority sub-watersheds have highest bifurcation ratio, high altitudinal, high slope and deep valley topography which indicate strong structural control on the drainage and are accordingly more prone to natural disasters because presence of structures in hard rock acting as weak planes and openings for seepage of water that enhance chances of landsliding. The sub-watershed RSMW4 and RSMW5 has lowest compound parameter value of 2.22, 2.44 and are likely to be subjected to maximum soil erosion. Hence theses should be provided with immediate soil conservation measures.

Introduction

The quantitative analysis of morphometric parameters is of immense utility in river basin evaluation, watershed prioritization for soil and water conservation, and natural resources management at micro level. Watershed refers to the naturally occurring hydrological units defined by naturally occurring boundaries and characterized by similar topographic, physical, and climatic conditions. Watershed is that area of land which contributes runoff to a common point along a single waterway, and is classified on the basis of its geographical area. A watershed is an ideal unit for the management of natural resources like land and water and for mitigation of the impact of natural disasters for achieving sustainable development. The proper management of watershed needs utilization of various aspects like, land, water, soil, and forest resources of a particular watershed for better production and lesser hazard to natural resources (Biswas et. al., 1999).

Remote sensing and GIS plays an important role in the study of watershed development, its management, and also in the study of prioritization of sub watersheds. GIS techniques are currently used for assessing various terrain and morphometric parameters of the drainage basins or watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. Morphometric analysis of drainage is of incredible importance for proper planning of watershed as it gives information about the basin characteristics in terms of slope, topography, soil conditions, runoff characteristics and surface water potential etc. Researchers from different places have done research on prioritization using morphometric parameters through the application of remote sensing and GIS. Morphometric analysis is a significant tool for prioritization of subwatersheds even without considering the soil map (Biswas et. al., 1999). Thakkar et. al., (2007) studied morphometric characteristics and prioritization of eight mini-watersheds of Mohr watershed, located in Gujarat state by using remote sensing and GIS. The studies has revealed that the shape parameters show a negative relation with runoff as well as soil erosion, while the other parameters (bifurcation, circulatory, form factor, texture, compactness and elongation ratios; drainage density; stream frequency) shows the positive relation with soil erosion. Ali et. al., (2013) studied morphometric analysis of Banas river basin using remote sensing and GIS technology. The morphometric characteristics of drainage and its effect on hydrology of watershed by using SRTM data and GIS were studied and concluded that the study of these aspects were useful for rainwater harvesting and watershed management plans (Sreedevi et al. 2009). Rudraiah et. al., (2008) has carried out morphometric analysis using Remote Sensing and GIS techniques in the Sub-Basin of Kagna River Basin, Gulburga District, Karnataka, India. The study of landuse/ landcover change to determine the socio-environmental impact in Ethiopia highland with the help of remote sensing and GIS has been carried out (Ali et. al., 2010; Meshesha et. al., 2014). The morphometric study involves the evaluation of stream parameters through the measurements of various stream properties (Kumar et. al., 2000; Ali et. al., 2003, Ali et. al., 2005; Pirasteh et. al., 2007). Morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds (Strahler, 1964). The morphometric assessment helps to elaborate a primary hydrological diagnosis in order to predict approximate behavior of a watershed if correctly coupled with geomorphology and geology (Esper, 2008). The hydrological response of a river basin can be interrelated with the physiographic characteristics of the drainage basin, such as size, shape, slope, drainage density and size, and length of the streams etc. (Chorley, 1969; Gregory and Walling 1973). Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Obi Reddy et. al., 2002). According to Biswas et. al., (1999) morphometric analysis can be used for prioritization of sub-watersheds by computing linear and shape parameters. This analysis can be achieved through measurement of linear, aerial and relief aspects of the basin and slope contribution (Ali, 1988; Nag and Chakraborty, 2003). The interpretation of remote sensing data in conjunction with sufficient real ground information makes it possible to identify and outline various ground features such as geological structures, geomorphic features and their hydraulic characters (Ali et. al., 2004; Iqbaluddin and Ali, 1983, 1984). The development of landforms and drainage network depends on the bed rock lithology and associated geological structures, hence, information on geomorphology, hydrology, geology and land cover can be obtained by the reliable information from the study of drainage pattern and texture (Arun et. al., 2005). The role of lithology and geological structures in the development of stream networks can be better understood by studying nature and type of drainage pattern and by a quantitative morphometric analysis (Nag et. al., 2003). Watershed prioritization is the ranking of different sub-watersheds of a watershed according to the order in which they have to be taken for treatment and soil conservation measures. Morphometric analysis could be used for prioritization of micro-watersheds by studying different linear and aerial parameters of the watershed even without the availability of soil maps (Biswas et. al., 1999). However, while considering watershed conservation work, it is not feasible to take the whole area at once. Thus, the whole basin is divided into several smaller units, as sub watersheds or micro watersheds, by considering its drainage system.

In the present study, evaluation of morphometric parameters was done for Romushi - Sasar Catchment of Kashmir Valley, NW Himalaya. The prioritization of sub-watersheds based on morphometric parameters through (GIS) techniques could be the very important for the conservation and management strategies.

1. Study Area

The Romushi - Sasar catchment falls in Kashmir valley, northern India, NW Himalaya (Fig. 1), between coordinates of 33°44′30″ to 34°00′ N and 74°43′ to 74°58′30″ E. The headstreams of Romushi draw their water from the snows peaks of Kharmarg (4604m) in the Pir-Panjal range. Its major upper torrents unite near Pakharpur to give rise to a sizable river which passes through a wide sandy bed of karewas slopes. The Romushi merges with the Jhelum near Wadipur below Awantipur. A few kilometers below it merges with the Jehlum, it receives the Sasar river which rises in the north of Hirpur. The Sasar shares some headstreams with the Romushi in its upper reaches and in the lower reaches itself merges with the Romushi, so Sasar may well be considered as a branch of the Romushi. The Sasar has a course of about 35 kilometers and the Romushi flows in a southeast direction and has a maximum course of about 54 kilometers.

The integrated use of existing geological map (Raza et at. 1978), use of PCA images and intensive ground survey were carried out to distinguish various geological units of the area (Fig. 2). Rock formations in the study area are quite diverse ranging from Precambrian to Recent. The commonest of the rocks present in the area are Panjal traps, karewas and alluvium. Panjal traps are lying in the extreme west, karewas covers most of the low-lying areas in middle and the recent alluvium has covered areas near the Jhelum River.

2. Data Base And Methodology

The present work is basically based on morphometric analysis of Romushi – Sasar catchment to prioritize the watershed for development and soil conservation measures. To assess the morphometric conditions, ASTER data (30 m resolution) and SOI topographical maps (1: 50,000) are used. At first, Romushi - Sasar watershed was delineated with the help of ARC GIS 9.3 software. Inlet and outlet are defined to demarcate Romushi - Sasar watershed. Sub-basins are also delineated by using the same software to carry out the sub-basin wise morphometric analysis.

Five micro-watersheds are identified for further analysis. Direct measurements of geometric characteristics (e.g., area and perimeter of the basin, length and number of streams) were automatically obtained from GIS software. Toposheets (Survey of India) were mosaiced to subset the study region. The various morphometric parameters such as area, perimeter, stream order, stream length, stream number, bifurcation ratio, drainage density, stream frequency, drainage texture, length of basin, form factor, circulatory ratio, elongation ratio, length of overland flow, compactness coefficient, shape factor and texture ratio were computed based on the formula suggested by (Horton, 1945; Miller, 1953; Schumn, 1956; Strahler, 1964; Nookaratnam et. al., 2005) given in Table 1. Each morphometric characteristic is considered as a single parameter and knowledge based weightage has been assigned by considering its role in soil erosion. Each parameter has been given a rank as per morphometric result. For linear aspect, high weightage has been given for high values and aerial aspect are assigned low weightage for high values. This is because shape parameters such as elongation ratio, compactness coefficient, circularity ratio, basin shape and form factor have an inverse relationship with erodibility (Nookaratnam et. al., 2005), lower the value, more is the erodibility. The compound parameter values are calculated and the sub-watershed with lowest compound weight has been given highest priority. The final priority classification has been specified into three major classes i.e. High priority, Medium priority and Low priority. The high priority indicates need of reclamation process and action plan for soil conservation and Landslide mitigation.

3. Result and Discussion

The study carried out has been divided into three sections, the first section deals with delineation of stream numbers, stream order and stream lengths in the study area using SOI topographic maps on 1:50000 scale and ASTER DEM (30m) along with delineation of watershed area, perimeter and length in GIS environment shown in Table 2. The second section deals with the various linear and shape morphometric parameters and the third section deals with the prioritization of watersheds on the basis of these linear and shape morphometric parameters. Drainage pattern is characterized by irregular branching of tributaries in many directions with an angle less than 90^0. The watershed is divided into 5 sub-watersheds with codes RSMW1 to RSMW5.

3.1. Stream Number and Order (U):

For stream ordering Horton's Law was followed by designating an un-branched streams as first order stream, when two first order streams joint it was designated as second order, two second order join together to form third order and so on.

This is the most important parameter for drainage basin analysis, in the study area total number of streams found is 892 out of which 687 is of first order, 145 of second, 36 of third order, 20 of fourth, 3 of fifth and 1 of sixth order. The watershed wise number, order and length are given in Table 3. It reveals that maximum number of streams is found in RSMW5 (245) and minimum number for RSMW2 (125), it is also noted that first order streams are highest in number in all micro watersheds while highest order has the lowest number. The Romushi - Sasar is a 6th order stream (Fig. 3) covering an area about 615 km². The sub-watershed RSMW1, RSMW2, RSMW3, RSMW4, RSMW5 are 6^{th}, 6^{th}, 5^{th}, 5^{th} and 5^{th} order streams covering an area of 223.344, 133.753, 84.031, 77.607 and 95.770 km² respectively. The variation in order and size of the sub-watersheds is largely due to physiographic and structural conditions of the region.

3.2. Stream length (Lu):

The stream length was computed on the basis of the law proposed by (Horton, 1945), for all the 5 sub-watersheds and is shown in Table 3. It can be noted from the table that in each micro-watershed stream length decreases as the stream order increases (Horton, 1945) except RSMW2 and RSMW5 and this change may be due to flowing of streams from high altitude, lithological variations and moderately steep slopes (Singh and Singh, 1997).

3.3. Stream length ratio (RI):

The stream length ratio is the ratio of mean of segments of order (Lu) to mean of segments of next lower order (Lu-1) (Horton, 1945). Change in stream length ratio shown in Table 3 between different sub-watersheds showed an increasing and decreasing trend in the length ratio from lower order to higher order and in all sub-watersheds, there was a change from one order to another order indicating the late youth stage of geomorphic development of streams in the inter basin area. The sub-watershed showing increasing trend in length ratio noted from lower order to higher order indicates their mature geomorphic stage and in these sub-watersheds no one is in mature geomorphic stage.

3.4. Liner parameters

Linear parameters include stream frequency, drainage density, drainage texture, bifurcation ratio and length of overland flow.

3.4.1. Stream frequency (Fs):

The Stream frequency is defined as the total number of stream segments of all orders per unit area (Horton, 1932). Generally high stream frequency is related to impermeable sub surface material, sparse vegetation, high relief and low infiltration capacity of the region. The stream frequency of all micro-watersheds are mentioned in Table 2. The study revealed that the RSMW3, RSMW4 and RSMW5 watersheds have high stream frequency because of the fact that it falls in the zone of fluvial channels and the presence of ridges on both sides of the valley which results in highest stream frequency while as watersheds RSMW3 has medium stream frequency and watershed RSMW1 and RSMW2 has low stream frequency because of low relief (Fig. 4). Highest value of stream frequency noted for RSMW4 (2.69 km/km^2) and RSMW5 (2.55 km/km^2) produces more runoff in comparison to others.

3.4.2. Drainage density (Dd):

The drainage density is the stream length per unit area in a region (Horton, 1945 and Strahler, 1952). It is an essential element of drainage morphometry to study the landscape dissection, runoff potential, infiltration capacity of the land, climatic condition and vegetation cover of the basin. Drainage density in all the watersheds is given in Table 4 which varies from 0.99 to 3.00. It has been observed that low drainage density is found to be associated with regions having highly permeable subsoil material under dense vegetative cover, and where relief is low while as high values of drainage density are noted for the regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief (Nag 1998). Hence in this study high drainage density was found in RSMW3 and RSMM4 because of impermeable sub surface material and mountainous relief (Fig. 5). Low Dd value for RSMW1 and RSMW2 indicates that it has highly permeable sub surface material and low relief.

3.4.3. Drainage texture (Dt)

The Drainage texture is defined as the total number of stream segments of all orders per perimeter of the area (Horton, 1945). The drainage texture depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development (Smith, 1950) and classified drainage into five classes i.e., very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). The drainage texture (Table 4) found to be very coarse to coarse, value ranges from 3.91 for RSMW3 to 1.63 for RSMW1 for Romushi – Sasar catchment (Fig. 6).

3.4.4. Bifurcation ratios (Rb)

Horton (1945) considered bifurcation ratio as an index of reliefs and dissections. Strahler (1957) demonstrated that bifurcation ratio shows only a small variation for different regions with different environments except where powerful geological control dominates. Lower bifurcation ratio values are the characteristics of structurally less disturbed watersheds without any distortion in drainage pattern (Nag, 1998). Bifurcation ratio is related to the branching pattern of a drainage network and is defined as the ratio between the total number of stream segments of one order to that of the next higher order in a drainage basin (Schumn, 1956). The values of mean bifurcation ratio of different watersheds of Romushi - Sasar catchment shown in Table 4 varies from 2.78 to 3.08 indicating structural control in drainage development in some of the micro-watersheds (Fig. 7).

3.4.5. Length of overland flow (Lo)

It is one the most important independent variables affecting hydrological and physiographical development of a drainage basin. It is the length of water over the ground before it gets concentrated into definite stream channels and is equal to half of drainage density (Horton, 1945). Length of overland flow relates inversely to the average channel slope. Table 5 indicates the length of overland flow for various mini-watersheds which ranges from 0.17 for RSMW4 to 0.51 for RSMW1. The shorter length of over land flow for RSMW4 point out the quicker runoff process and higher length of over land flow for RSMW1 point out slower runoff process (Fig. 8).

3.5. Shape parameters of Drainage Basin

Shape parameters include form factor, shape factor, elongation ratio, compactness ratio and circulatory ratio.

3.5.1. Form factor (Ff)

Form factor is defined as the ratio of basin area to the square of the basin length (Horton, 1932). The values of form factor would always be less than 0.7854 (perfectly for a circular basin). High value of form factor stating the circular shape of the basin and Smaller the value of form factor more elongated will be the basin. Form factor value (Table 2) for all watersheds varies from 0.13-0.28. The observation shows that the RSMW4 and RSMW5 watersheds are highly elongated while as the watersheds RSMW1, RSMW2 and RSMW3 are less elongated. The values of form factor for Romushi - Sasar catchment indicates that the whole catchment is elongated. The elongated watershed with low value of form factor indicates that the basin will have a flatter peak flow for longer duration. Flood flows of such elongated basins are easier to manage than from the circular basin.

3.5.2. Elongation ratio (Re)

The elongation ratio is defined as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin (Schumn, 1956). Analysis of elongation ratio indicates that the areas with higher elongation ratio values have high infiltration capacity and low runoff. A circular basin is more efficient in the discharge of runoff than an elongated basin (Singh et. al., 1997). The values of elongation ratio generally vary from 0.6 to 1.0 over a wide variety of climate and geologic types. Values close to 1.0 are typical of regions of very low relief, whereas values in the range 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964). Values of the elongation ratio (Table 2) are in the range of 0.40 to 0.60 indicating high relief and ground slope for maximum portion of sub-watersheds (Fig. 13). Shape of the micro watersheds found to be elongated have low elongation ratio and less elongated have high elongation ratio. In the watershed, these values are less than 0.7 and hence all the mini-watersheds are generally elongated in shape.

3.5.3. Circulatory ratio (Rc)

Circularity ratio is defined as the ratio of the area of the basin to the area of a circle having the same circumference as the perimeter of the basin (Miller 1953). Circulatory ratio in the study area (Table 2) found in the range of 0.24 to 0.53 which shows that the sub-watersheds are almost elongated. High value of circulatory ratio indicates the maturity stage of topography. The value 0.53 for RSMW3 indicates more circular in shape than the other sub-watersheds as can be observed from the Fig. 8 above.

3.5.4. Compactness Coefficient (Cc)

It is defined as the basin perimeter divided by the circumference of a circle to the same area of the basin. Compactness constant value for the whole study area is shown in Table 5. Highest value found for RSMW5 (2.02) while lowest value for RSMW3 (1.38). Compactness coefficient is directly proportional to the erosion risk assessment i.e. lower values signifies less vulnerability for risk factors, while higher values indicates great vulnerability and represents the need of implementation of conservation measures. So the study reveals that RSMW4 and RSMW5 are more prone to erosion risk in the whole catchment.

3.5.5. Shape Factor (Bs)

It is the ratio of the square of the basin length (Lb) to area (A) of the basin (Horton, 1945) and is in inverse proportion with form factor (Rf). Shape factor is highest for RSMW5 (7.90) and Lowest for RSMW2 (3.52) given in Table 5.

3.6. Relief Aspects of the Watershed

The relief aspects of sub-watershed are also important in water resources studies, direction of stream flow analysis and denudation conditions of the watershed. Relief aspects like basin relief (H), relative relief (Rp), relief ratio (Rh) and ground slope or ruggedness number (Rn) were measured and are given in Table 6.

3.6.1. Basin Relief (H)

Basin relief is described as the elevation difference between the reference points i.e. maximum vertical distance between highest (divide) and the lowest (outlet) located in the drainage basin (Fig. 9).

Schumm (1956) measured it along the longest dimension of the basin parallel to the principle drainage line. The relief for sub-watersheds varies from 259 to 2355 meters (Fig. 10). The watersheds have been divided into high, medium and low relief regions in which sub-water RSMW4 and SFMW5 are having highest basin relief. The high relief of these sub-watersheds indicates low gravity of water flow as well as infiltration and high runoff conditions as well as sediment down the slope.

3.6.2. Relief Ratio

Relief Ratio is the ratio of basin relief to the horizontal distance on which relief was measured (Schumm, 1956). According to Schumm (1956), there is a direct relationship between the relief and gradient of the channel. It measures overall steepness of the watershed and is also considered as an indicator for the intensity of erosion process occurring in the watershed. High value of relief ratio is the characteristics of the hilly region. The relief ratio for watersheds varies from 0.027 to 0.103 (Fig. 11). It was noticed that the higher values of relief ratio for RSMW4 and RSMW5 indicated steep slope and high relief, while the lower values for RSMW1 and RSMW2 indicated the presence of lower degree of slope shown in Fig. 13 below (Krishnaswamy, 1981).

3.6.3. Relative Relief (Rr)

Relative Relief (Rr) is the ratio of relief (H) to the perimeter of basin. It is an important morphometric variable used for the general estimation of morphological characteristics of terrain. The relative relief for watersheds varies from 0.009 to 0.041. The watersheds having higher relative relief have higher runoff potential than others. Therefore, the watershed RSMW2 and RSMW4 are having the lowest and highest runoff potential respectively.

3.6.4. Ruggedness number (Rn)

Ruggedness number (Rn) is the product of drainage density (Dd) and basin relief (H) (Strahler, 1957; Melton, 1958) in the same unit. In the present study ruggedness value ranges from 0.698 to 7.065. The highest value of ruggedness was observed in RSMW4 (7.065), RSMW5 (6.049) and RSMW3 (3.599) in which both total basin relief and drainage density values are high, i.e., in these sub-watersheds slope is very steep linked with its slope length (Fig. 12).

The sub-watersheds having low relief but high drainage density are ruggedly textured as areas of higher relief having less dissection. The higher ground slopes in case of above sub-watersheds lying in upper reach of the basin specify lower time of concentration of overland flow and the possibilities of soil erosion will be higher in these sub-watersheds (Fig. 13).

In relief aspect calculation, some of the linear (length, perimeter, etc.) and shape (drainage density) parameters are applied. Thus, the morphometric description has shown substantial role in differentiating the hydro-topographical behavior of the watershed through the analysis of linear, areal and relief aspects of the sub-watersheds.

3.7. Ranking and Prioritization of Sub-watersheds Based on Morphomatric Analysis:

The morphometric parameters i.e., drainage density, stream frequency, mean bifurcation ratio, drainage texture, length of overland flow, form factor, circularity ratio, elongation ratio, basin shape and compactness coefficient, are also termed as erosion risk assessment parameters and have been used for prioritization watersheds (Biswas et. al., 1999). The linear parameters such as drainage density, stream frequency, mean bifurcation ratio, drainage texture, length of overland flow have a direct relationship with erodibility while as shape parameters such as elongation ratio, circularity ratio, form factor, basin shape and compactness coefficient have an inverse relationship with erodibility (Nooka et. al., 2005). Hence, priority of the watersheds has been carried out for giving highest priority/rank based on highest value in case of linear parameters and lowest value in case of shape parameters.

The highest value of the linear parameter was ranked 1, the second highest value ranked 2, and so on. On the contrary, the shape parameters have converse relation with linear parameters, which means lower their value, more is the erodability. Thus the lowest value of the shape parameter was rated as rank 1 and the second lowest as rank 2, and so on.

Compound factor is computed by summing all the ranks of linear parameters as well as shape parameters and then dividing by number of parameters as shown in Table 7. From the group of these mini-watersheds, highest rank was assigned to the mini watershed having the lowest compound factor and so on. Depending upon the value of compound factor, ranking to each micro-watershed is assigned (Fig. 14).

In the Romushi - Sasar watershed, micro-watersheds RSMW4 and RSMW5 are given high rank with least compound factor value and RSMW1 and RSMW3 given medium rank and RSMW2 is assigned low rank Table 8. The Final prioritized map of the study area and prioritization ranks of sub-watersheds is shown in Fig. 15.

Figure Caption

Figure 1. Location map of Romushi - Sasar watershed of Kashmir Valley, India.
Figure 2. Geology of the study area as derived from PCA and existing geological map after (Raza, et. at., 1978).
Figure 3. Drainage map of Romushi - Sasar watershed with stream order.
Figure 4. Map shows high, medium and low stream frequency regions
Figure 5. Shows Drainage Density Variation in sub-Watersheds.
Figure 6. Texture map shows hard rock areas are fine textured.
Figure 7. High and medium bifurcation ratio sub-watersheds are highly structurally controlled.
Figure 8. Length of over land flow map illustrates that sub-watershed RSMW4 have quicker runoff process have quicker runoff process.
Figure 9. Shows elevation map of five sub-watersheds.
Figure 10. Shows comparison of basin relief which points out that maximum watershed have high relief.
Figure 11. Bar diagram illustrates Relief ratio comparison of sub-watersheds
Figure 12. Shows ruggedness variation in sub-watersheds.

Figure 13. Shows the slope difference in different parts of the area
Figure 14. Rank wise Prioritized sub-watershed map of Romushi - Sasar watershed
Figure 15. Prioritized sub-watershed map of Romushi - Sasar watershed

Tables

Table 1. Formulae adopted for computation of morphometric parameters
Table 2. Morphometric Parameters of Romushi - Sasar watershed
Table 3. Stream Analysis of seven sub-watersheds of the catchment.
Table 4. Values of drainage density, texture and bifurcation ratios for Sub-watershed
Table 5. Values of Shape Factor, Compactness Coefficient, Length of Over Land Flow and Mean Stream Length for Sub-watersheds
Table 6. Relief Aspects of the Sub-watersheds
Table 7. Prioritization results of Morphometric analysis
Table 8. Prioritization Classes and the area under different priority zones.

Figure1

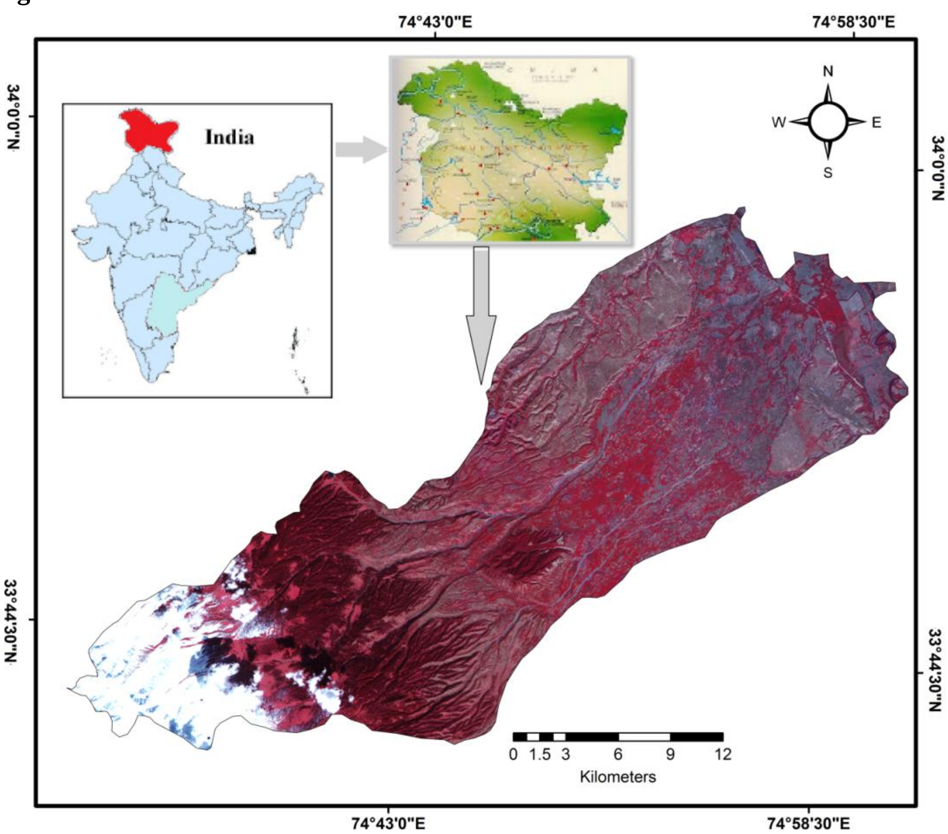


Figure2

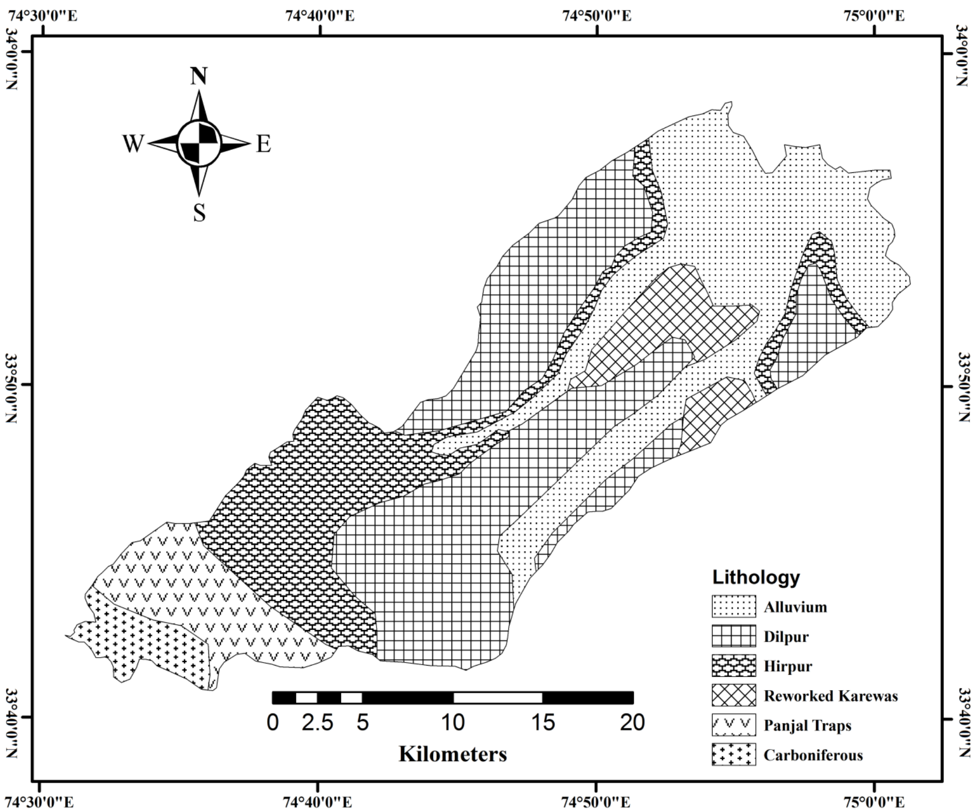


Figure3

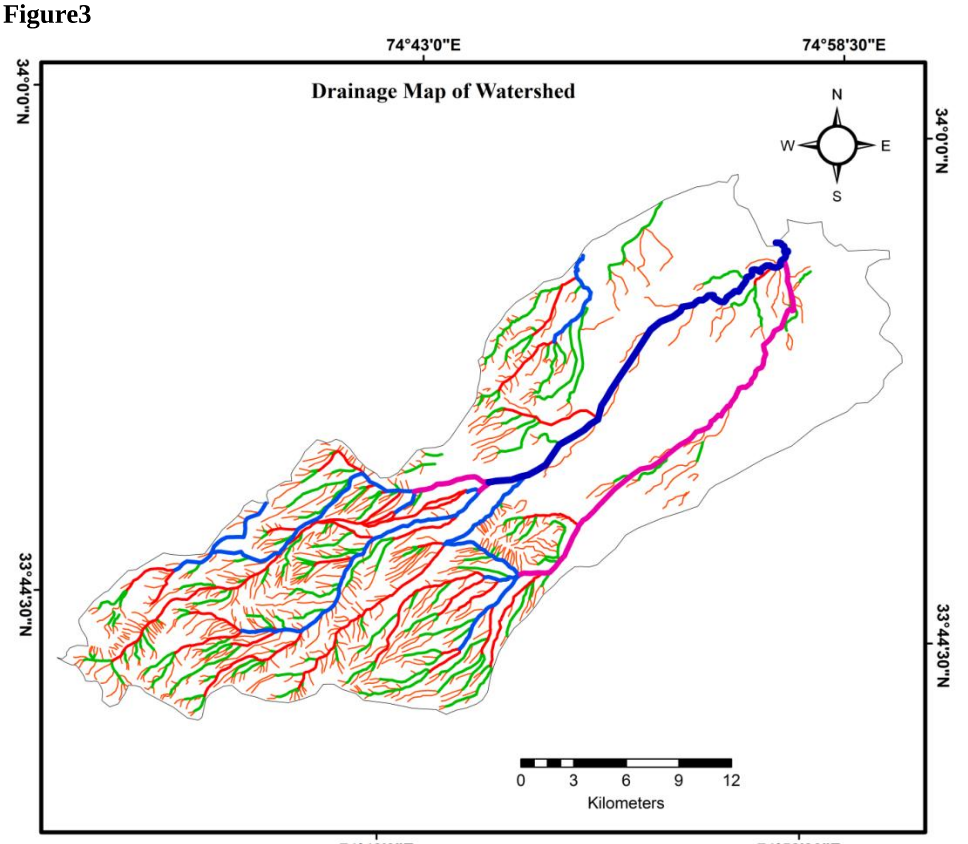
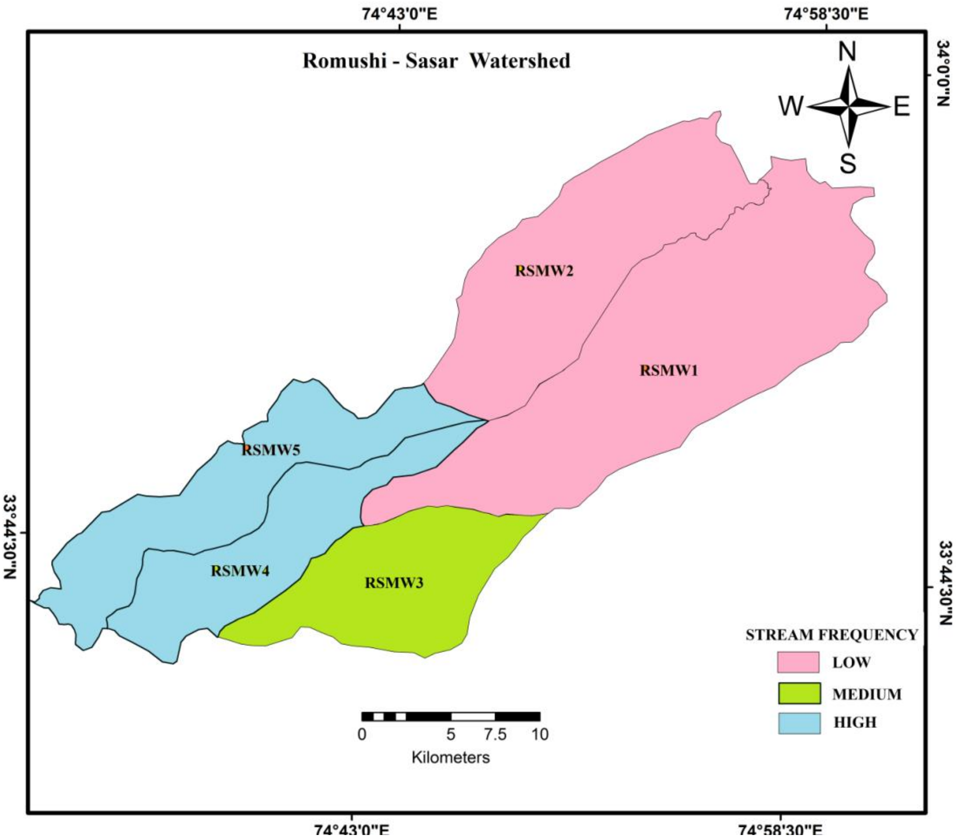


Figure4



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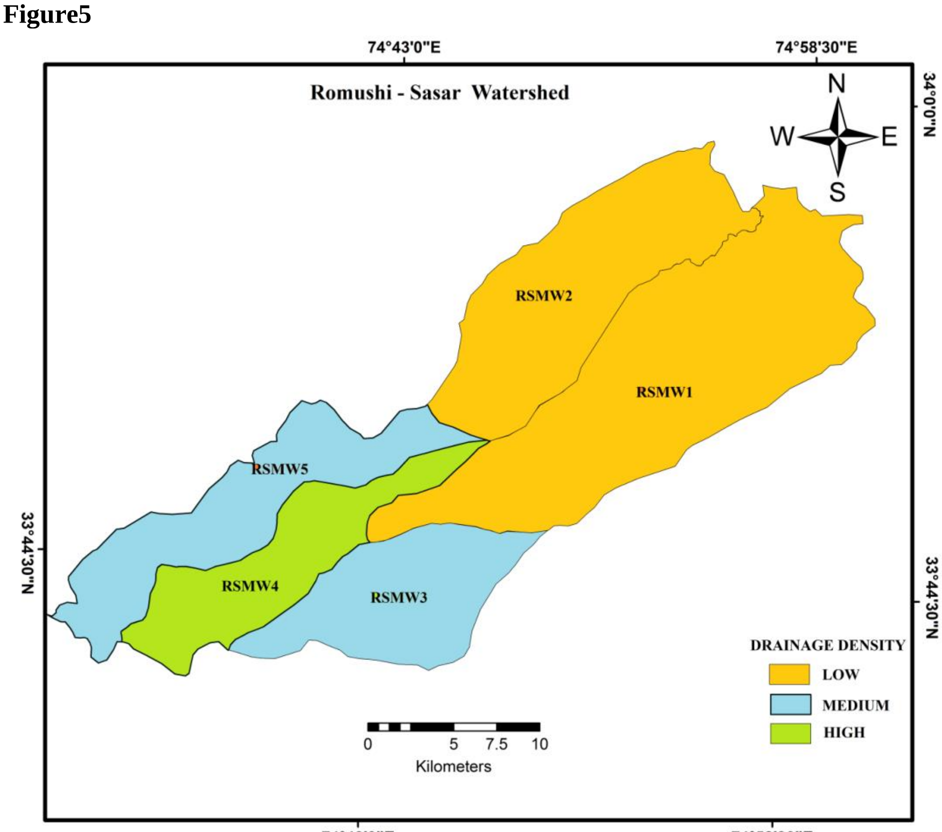

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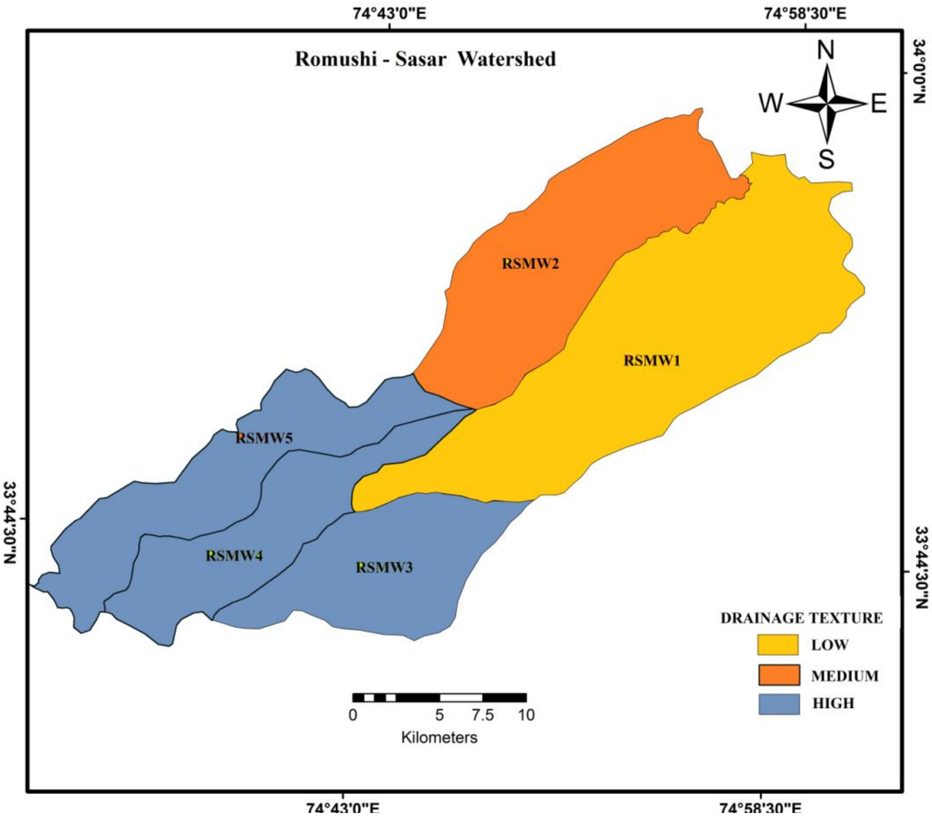

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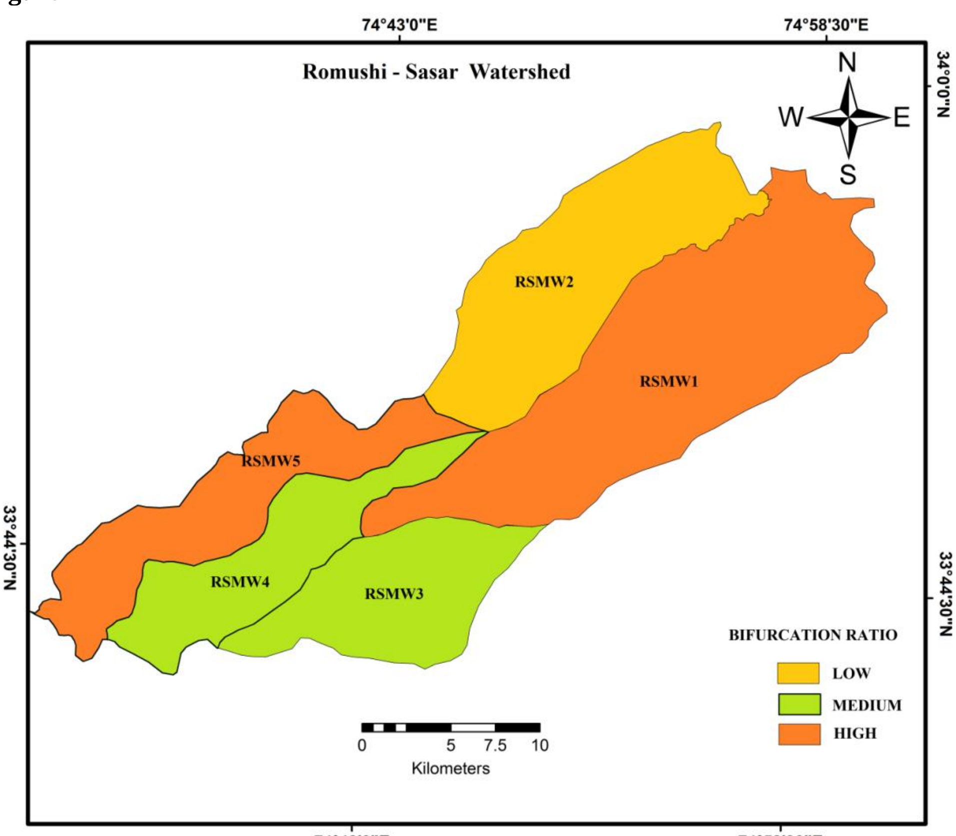


Figure8

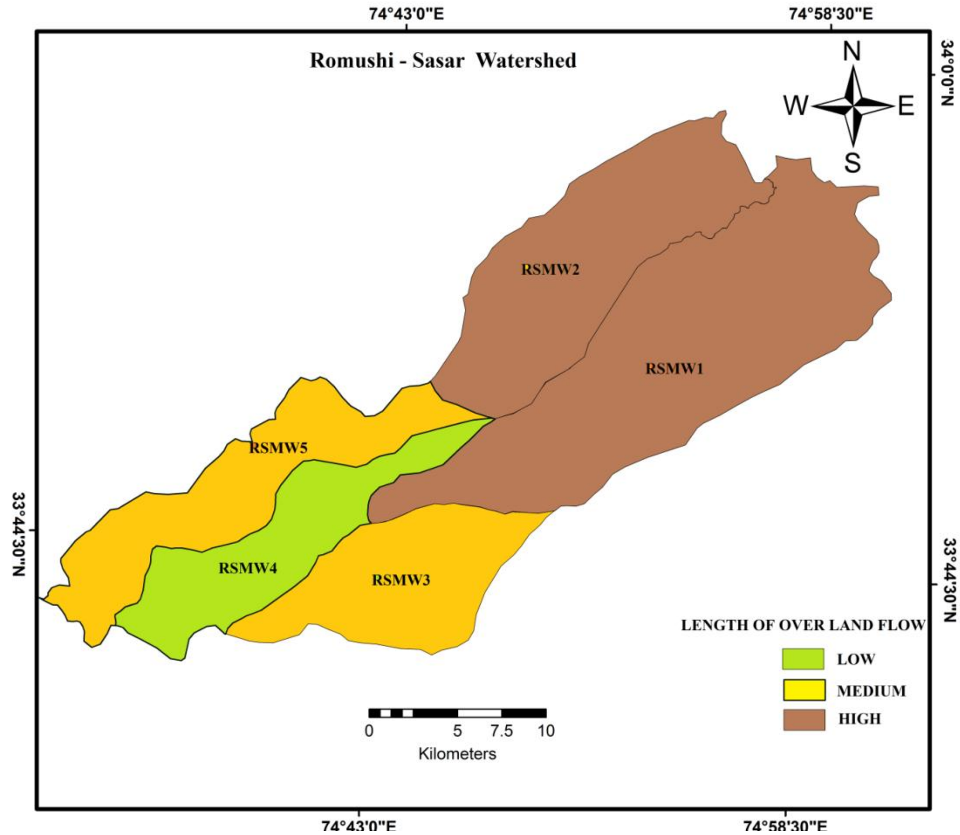


Figure9

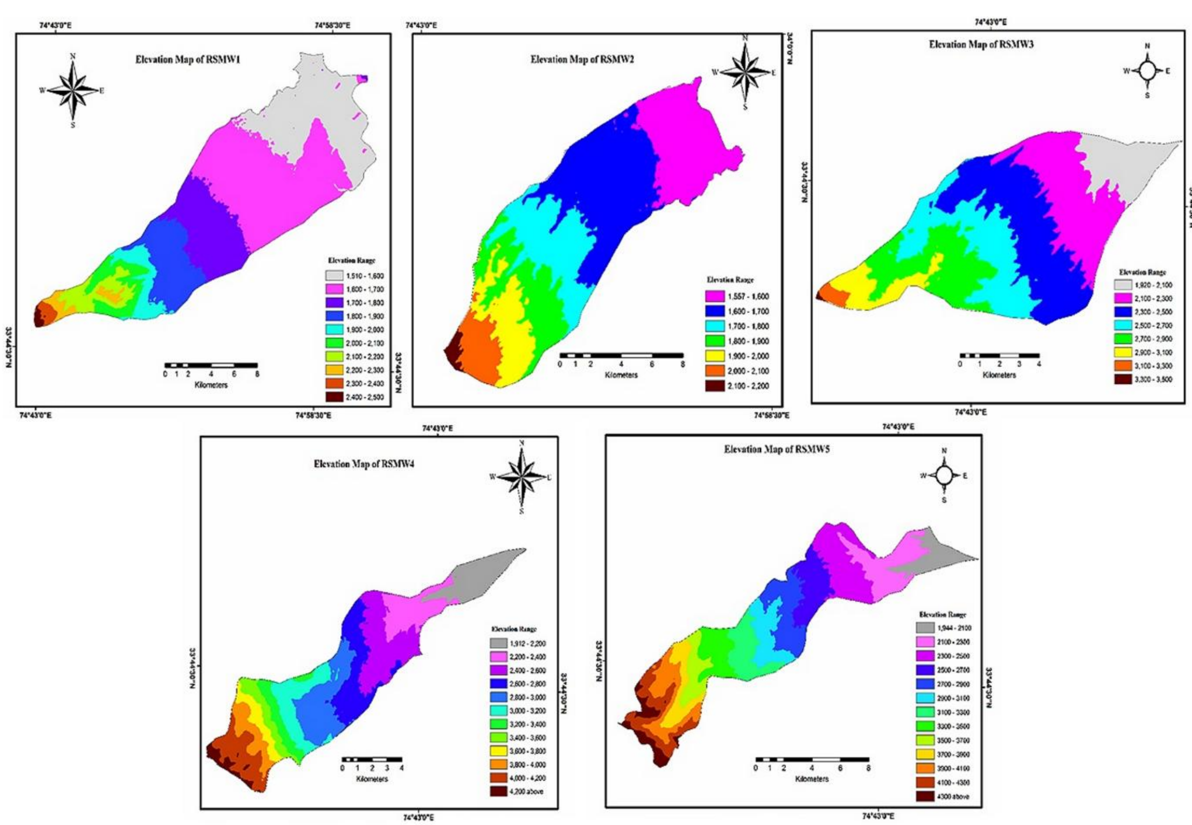


Figure10

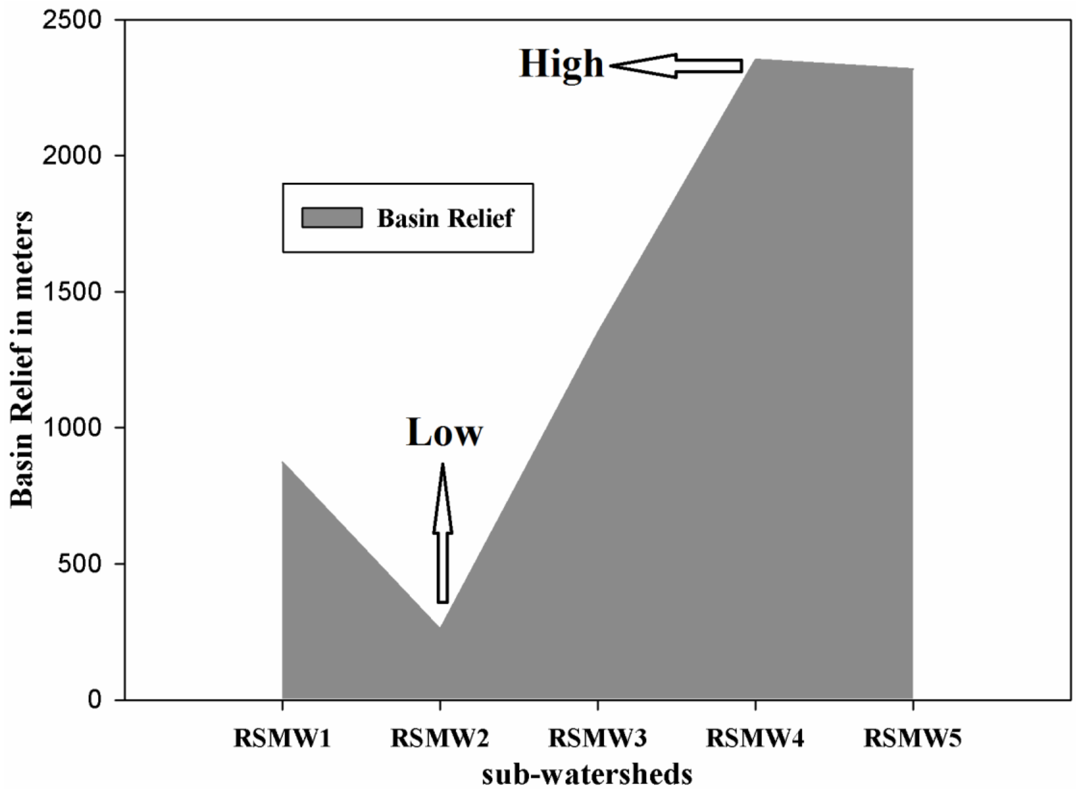


Figure11

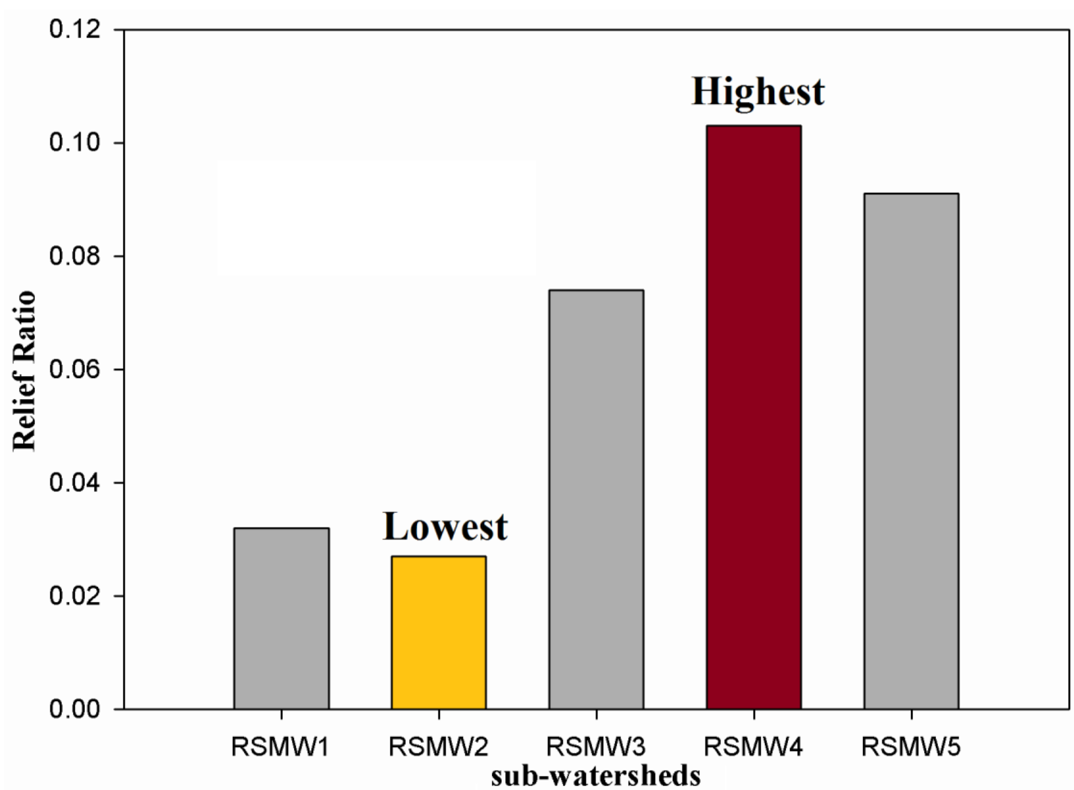


Figure12

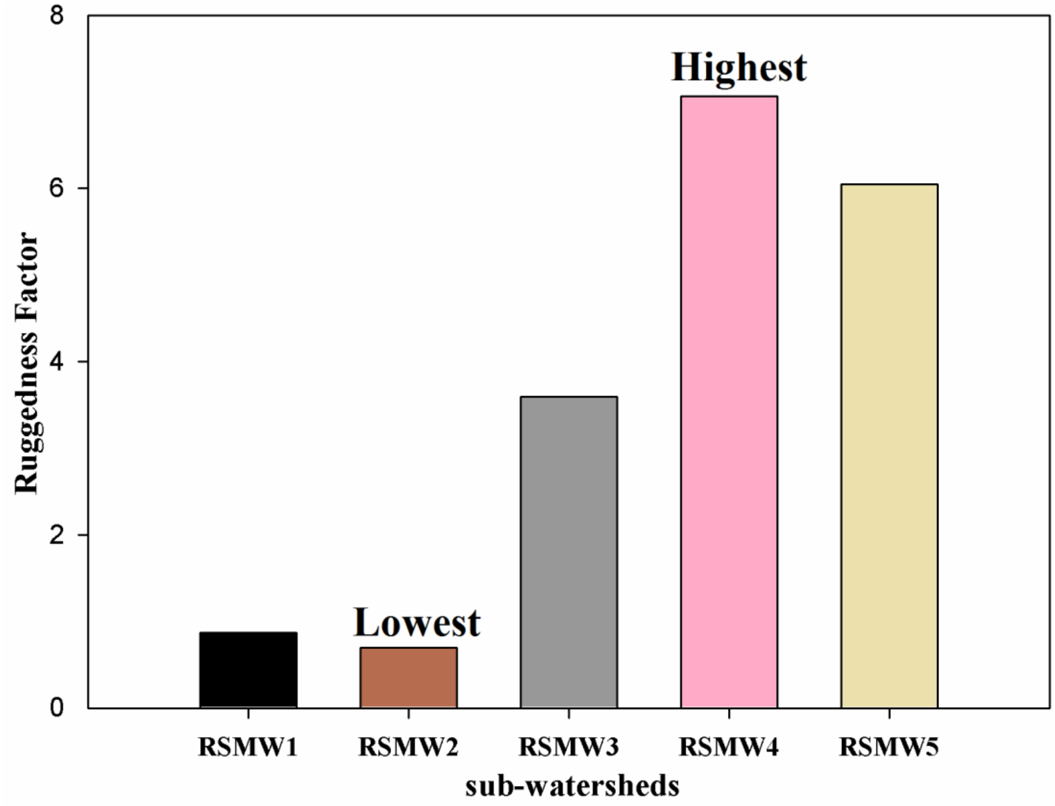


Figure13

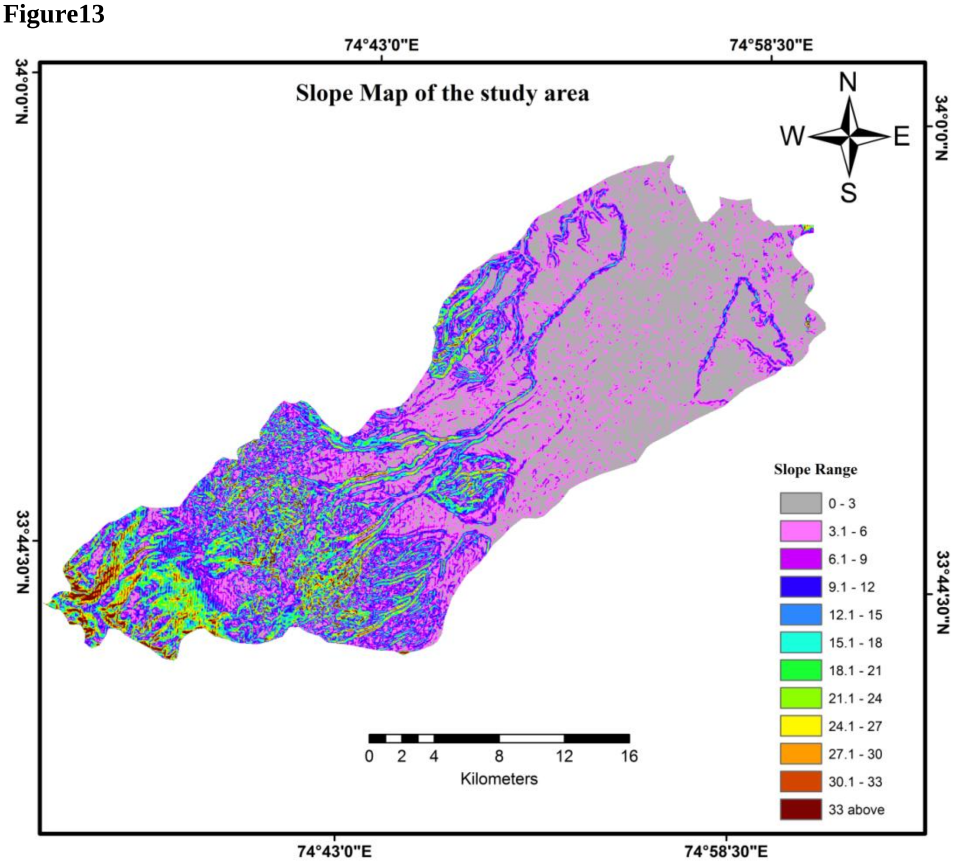


Figure14

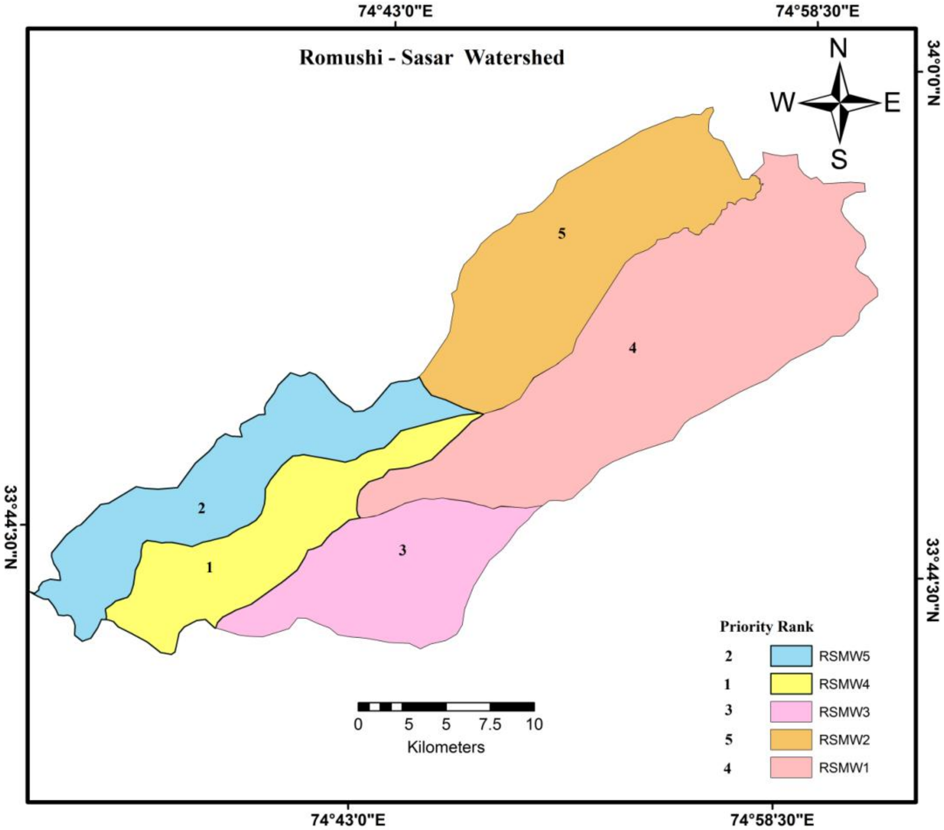
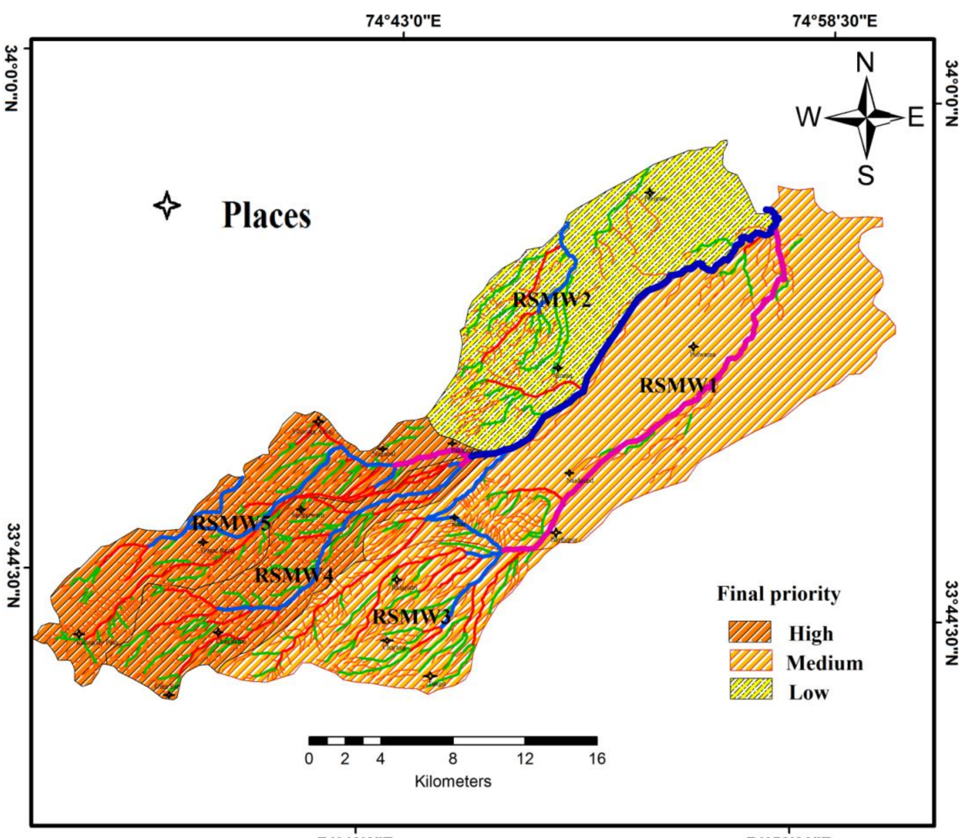


Figure15



Tables:

Table1. Formulae adopted for computation of morphometric parameters

S No	Morphometric parameters	Formula	Reference
1	Stream order (u)	Hierarchical rank	Strahler (1964)
2	Stream length (Lu)	Length of the stream	Horton (1945)
3	Mean stream length (Lsm)	Lsm = Lu / Nu Where, Lsm = Mean stream length Lu = Total stream length of order 'u' Nu = Total no. of stream segments of order 'u'	Strahler (1964)
4	Stream length ratio (RL)	RL = Lu / Lu – 1 Where, RL = Stream length ratio Lu = Total stream length of the order 'u' Lu – 1 = Total stream length of next lower order	Horton (1945)
5	Bifurcation ratio (Rb)	Rb = Nu / Nu + 1 Where, Rb = Bifurcation ratio Nu = Total no. of stream segments of order 'u' Nu+1 = No. of segments of the next higher order	Schumn (1956)
6	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders	Strahler (1957)
7	Relief ratio (Rh)	Rh = H / Lb Where, Rh = Relief ratio H = Total relief (Relative relief) of the basin (km) Lb = Basin length	Schumm (1956)
8	Drainage density (Dd)	Dd = Lu / A Where, Dd = Drainage density, Lu = Total stream length of all orders, A = Area of the basin (km2)	Horton (1932)
9	Stream frequency (Fs)	Fs = Nu / A Where, Fs = Stream frequency Nu = Total no. of streams of all orders A = Area of the basin (km2)	Horton (1932)
10	Drainage texture (Rt)	Rt = Nu / P Where, Rt = Drainage texture Nu = Total no. of streams of all orders P = Perimeter (km)	Horton (1945)
11	Form factor (Rf)	Rf = A / Lb^2 Where, Rf = Form factor A = Area of the basin (km2) Lb^2 = Square of basin length	Horton (1932)
12	Circularity ratio (Rc)	Rc = 4 * Pi * A / P^2 Where, Rc = Circularity ratio Pi = 'Pi' value i.e., 3.14 A = Area of the basin (km2) P^2 = Square of the perimeter (km)	Miller (1953)
13	Elongation ratio (Re)	Re=(2/Lb)*(A/Pi)0.5 Where, Re = Elongation ratio A = Area of the basin (km2) Pi = 'Pi' value i.e., 3.14, Lb = Basin length	Schumn (1956)
14	Length of overland flow (Lg)	Lg = 1 / D * 2 Where, Lg = Length of overland flow D = Drainage density	Horton (1945)
15	Compactness constant (Cc)	Cc= 0.2821P/A0.5 Where P= basin parimeter, A= area of basin	Nooka Ratnam et al. (2005)
16	Shape Factor	Bs=Lb2/A	(Horton, 1945)

Table 2. Morphometric Parameters of Dudhganga-Shaliganga watershed

Sub Watershed	Area (Km^2)	Stream Frequency (Km/Km^2)	Basin Length (Km)	Form Factor	Elongation Ratio	Circulatory ratio
RSMW1	223.344	0.617	32.44	0.21	0.52	0.39
RSMW2	133.753	0.93	21.71	0.28	0.60	0.50
RSMW3	84.031	2.08	19.730	0.22	0.52	0.53
RSMW4	77.607	2.69	23.749	0.14	0.42	0.30
RSMW5	95.770	2.55	27.509	0.13	0.40	0.24

Table 3. Stream Analysis of seven sub-watersheds of the catchment.

Sub watershed	Stream Numbers						Stream Length						Length Ratio				
	1	2	3	4	5	6	1	2	3	4	5	6	2/1	3/2	4/3	5/4	6/5
RSMW1	108	22	4	2	1	1	121.14	26.725	8.817	11.378	26.446	23.781	0.22	0.32	1.29	2.32	0.89
RSMW2	91	21	4	1	-	1	82.74	48.593	14.912	6.526	-	23.78	0.58	0.30	0.43	-	-
RSMW3	133	30	9	2	1	-	120.74	55.411	38.68	7.839	1.515	-	0.45	0.69	0.20	0.19	-
RSMW4	159	32	14	3	1	-	128.39	47.835	43.033	13.297	.778	-	0.37	0.89	0.30	0.05	-
RSMW5	187	40	12	5	1	-	139.03	47.272	38.852	20.813	4.443	-	0.34	0.82	0.53	0.21	-

Table 4. Values of drainage density, texture and bifurcation ratios for Sub-watershed

Sub Watershed	Perimeter	Drainage Texture	Drainage Density	Bifurcation Ratio Rb					Mean Bifurcation Ratio
				1/2	2/3	3/4	4/5	5/6	
RSMW1	84.899	1.63	0.99	4.90	5.5	2	2	1	3.08
RSMW2	58.208	2.15	1.32	4.66	5.25	4	0.00	0.00	2.78
RSMW3	44.814	3.91	2.67	4.43	3.33	4.5	2	0.00	2.85
RSMW4	56.925	3.67	3.00	4.97	2.28	4.67	3	0.00	2.98
RSMW5	70.198	3.47	2.61	4.68	3.33	2.4	5	0.00	3.08

Table 5. Values of Shape Factor, Compactness Coefficient, Length of Over Land Flow and Mean Stream Length for Sub-watersheds

Sub Watershed	Shape Factor	Compactness Coefficient	Length of Over Land Flow	Mean Stream Length					
				1st order	2nd Order	3rd order	4th order	5th order	6th order
RSMW1	4.71	1.60	0.51	1.12	1.21	2.20	5.60	26.44	23.781
RSMW2	3.52	1.42	0.38	0.84	2.31	3.73	6.526	-	23.78
RSMW3	4.63	1.38	0.19	0.91	1.85	4.30	3.92	1.515	-
RSMW4	7.27	1.82	0.17	0.81	1.49	3.07	4.43	0.778	-
RSMW5	7.90	2.02	0.19	0.74	1.18	3.24	4.16	4.443	-

Table 6. Relief Aspects of Sub-watersheds

Sub-watersheds	Basin Relif (H)	Relief Ratio (Rh)	Relative Relief (Rr)	Ruggedness Number (Rn)
RSMW1	874m	0.032	0.010	0.865
RSMW2	259m	0.027	0.009	0.698
RSMW3	1348m	0.074	0.030	3.599
RSMW4	2355m	0.103	0.041	7.065
RSMW5	2318m	0.091	0.033	6.049

Table 7. Prioritization results of Morphometric analysis

Micro Watershed	Drainage Density (Dd)	Stream Frequency (Fs)	Mean Bifurcation Ratio(Rb)	Drainage Texture (T)	Form Factor (Rf)	Shape Factor (Bs)	Circulatory Ratio (Rc)	Compactness Coefficient (Cc)	Elongation Ratio (Re)	CP	Priority rank
RSMW 1	5	5	1	5	3	3	3	3	3	3.44	4
RSMW 2	4	4	4	4	5	1	4	2	4	3.55	5
RSMW 3	2	3	3	1	4	2	5	1	3	2.66	3
RSMW 4	1	1	2	2	2	4	2	4	2	2.22	1
RSMW 5	3	2	1	3	1	5	1	5	1	2.44	2

Table 8. Prioritization Classes and the area under different priority zones.

PRIORITIZTION CLASSES		
Micro-Watersheds	**Priority Type**	**Percentage of Area**
RSMW4 and RSMW5	High	28.038 km2
RSMW 1 and RSMW 3	Medium	49.708 km2
RSMW 2	Low	21.630 km2

Conclusion

Watershed prioritization is one of the most important aspects of planning for implementation of its development and management programmes. The present study demonstrates the usefulness of Remote Sensing and GIS for morphometric analysis and prioritization of the sub-watersheds of Romushi - Sasar watershed of Kashmir Valley, India. The morphometric characteristics of different sub-watersheds show their relative characteristics with respect to hydrologic response of the watershed. Results of prioritization of sub-watersheds show that sub-watershed RSMW4 and RSMW5 fall under very high priority and are more susceptible to land degradation and soil erosion. The sub-watershed RSMW4 among the others is most susceptible to land-sliding because of the steep slopes and deep gullies present in the area. Therefore, immediate attention towards soil and water conservation measures are required in these sub-watersheds to preserve the land from further erosion and to reduce natural hazards possible due to land-sliding. The results indicate that the analysis of various morphometric parameters in GIS environment can be effectively used for prioritization of watersheds, soil and water conservation and natural resources management at the watershed level.

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