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ORIGINAL ARTICLE

Quantitative morphometric infer in the hard rock Terrain based on SRTM-DEM and GIS-Chintamani Watershed, Chikkaballapur District, Karnataka, India

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Abstract
The Chikkaballapur district has been identified as one of the chronically drought-prone areas. The Rainfall data indicate that out of 11 consecutive years, 8–9 years of the district has faced the drought. The occurrence of drought is on several factors, such as unorganized cropping method, soil types, lack of conservation of water, drainage system, etc. There are no perennial rivers in Chickballapur district. In this study area, a part of the Palar river basin originates at Ambajidurga hillocks in Chintamani taluk and flows in NW–SE direction. The drainage pattern in the study area varies from dendritic to sub-dendritic and is designated as a fifth-order stream. The order of the stream is mainly regulated by the physiography and lithological conditions of the region. The drainage density (0.564 km/km^2) and drainage texture values suggest that the study area comprises primarily Precambrian age impermeable rocks. The higher mean bifurcation ratio is indicative of good structural control over drainage growth. Values of the form factor, circulatory ratio, and elongation ratio indicate the sub-watersheds are elongated in shape. These quantitative forecasts can aid in the achievement and implementation of long-term strategies to tackle drought and areas affected to prepare adequate groundwater management plans.

Keywords Hard rock · SRTM DEM · GIS · Prioritization of sub-watershed

Introduction

The scarcity of water for drinking and agriculture is commonly noticed all around the world in arid and semi-arid regions (Singh et al. 2013). It is a challenging task in the hard rock terrain to establish the demand, and supply of water resources. A morphometric study is an estimation and numerical assessment of the earth's surface, shape, and dimension of its landform (Vittala et al. 2004; Rudraiah et al. 2008; Resmi et al. 2019). Concern to the drainage and their quantitatively measured relative parameters gives an important input for preparing the plan of development, and management activities for the sustainable water resource (Chowdary et al. 2009; Dinagara Pandi et al. 2017). In the last decade, the application of remote sensing and GIS plays the most influential role in the study of watershed management (Prabhakaran et al. 2018; Ramaiah et al. 2012). RS and GIS reveal the successful study on drainage characteristics, hydrological behavior, and morphometric interpretation of basin through drainage pattern indicates the existing condition of the terrain-like rock structure, climatic condition, permeability, runoff, relief (Machiwal et al. 2014; Patil et al. 2019). The drainage distinctiveness of many river basins and sub-basins in different parts of the earth has been deliberated using conventional methods. The morphometric assessment was done using remote sensing, and geographical information systems for assessing the different parameters to improve the plan of drought susceptible at Chintamani watershed, Chintamani taluk, Chickaballapur district. Generation of stream network and thematic maps of hydrological system of terrain using the processed DEM of Shuttle Radar Topographic Mission (SRTM) resulted in a precise accuracy, fast and inexpensive (Sreedevi et al. 2013; Yang et al. 2011).

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Study area

The study area is a part of the Palar river basin. Geographically study area located between 77°97′, 78°22′ E longitudes and 13°24′, 13°44′ N latitudes in Chintamani taluk, Chikkbalapur district, Karnataka, India (Fig. 1). As per the report of Disaster Management Plan, 2019–20 noted that Chikkaballapur district has challenged chronically drought for about 8–9 years out of 11 consecutive years. The watershed is named as Chintamani watershed and divided into two sub-watersheds, namely Jannapalli and Annenahally. Sub-watersheds were assigned with the name of the starting point of the tributary of the basin in the study area. The area is covered with Gneisses and Granites, which are superlative for agriculture production. Physiography indicates the flat landscape, where the elevation ranges from 805 to 1343 m msl. The overview of the terrain is depicted by visual interpretation using a sentinel 2A satellite image (Fig. 2).

Rainfall

The climate in Chintamani taluk ranges from semiarid to arid. In a large part of the region, the weather is dry and hot. The study region is located in Karnataka's Eastern Dry Agro-climatic Zone and classified under drought susceptible zone. The normal annual rainfall in Chintamani taluk for the period 29-year blocks of 1990–2019 is 792 mm (Source: Karnataka State Natural Disaster management center, Bangalore). The major quantity of rainfall (404 mm) was recorded during the south-west monsoon seasons, according to the seasonal rainfall pattern.

Materials and methods

Freely available DEM — Shuttle Radar Topography Mission (SRTM 30 m) data were used as basic input for generating the stream network and watershed boundary, flow chart methodology is depicted in Fig. 3. It was downloaded from the website (https://earthexplorer.usgs.gov/). The Open series maps were downloaded from the portal 'Nakshe mapping', Survey of India bearing the sheet no: D44M3-57/3 and D44M4-57/4. These maps were georeferenced and projected for the coordinate system WGS-1984 UTM 43 N Zone using QGIS. The Sentinel 2A satellite image of 10 m resolution dated 14-04-2019 is referred for the visual interpretation. The boundary of the Chintamani watershed was delineated using a reference of OSM, DEM, and Sentinel 2A satellite image.

Morphometric parameters were extracted using pre-processed DEM. The sink in the DEM indicates the improper value lower than the values of its region. To generate the drainage network these sinks had to be filled by a high value of

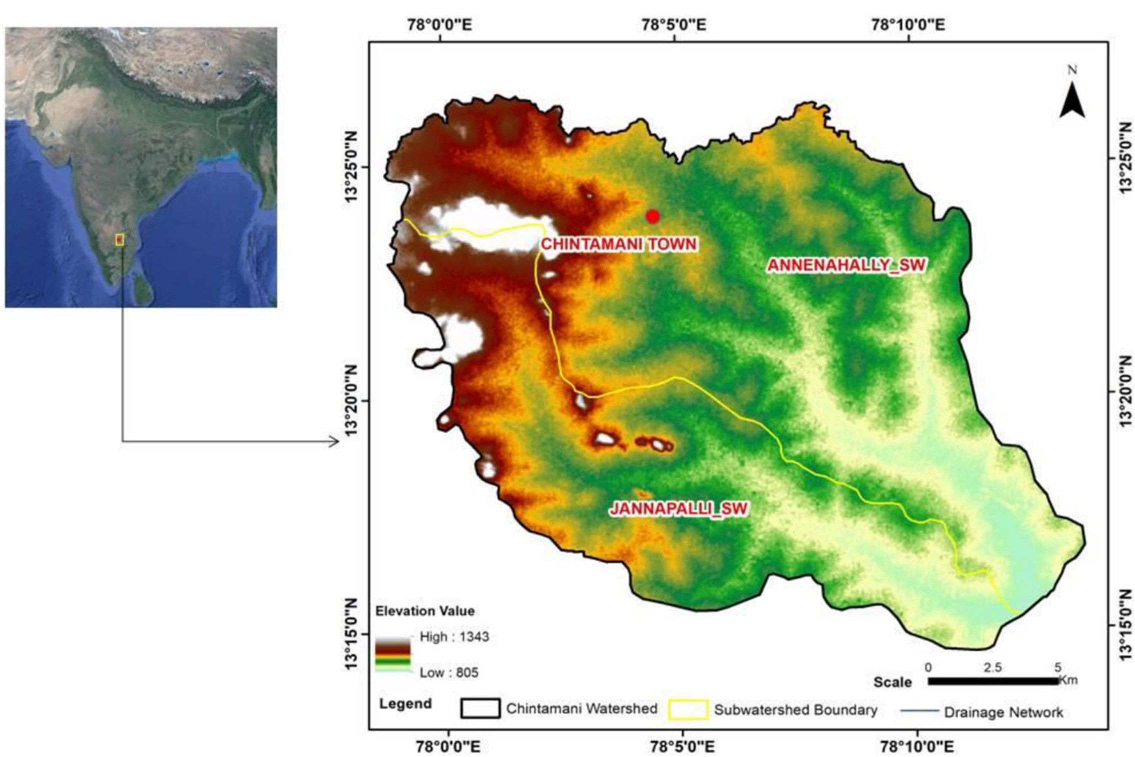

Fig. 1 Location map of the study area

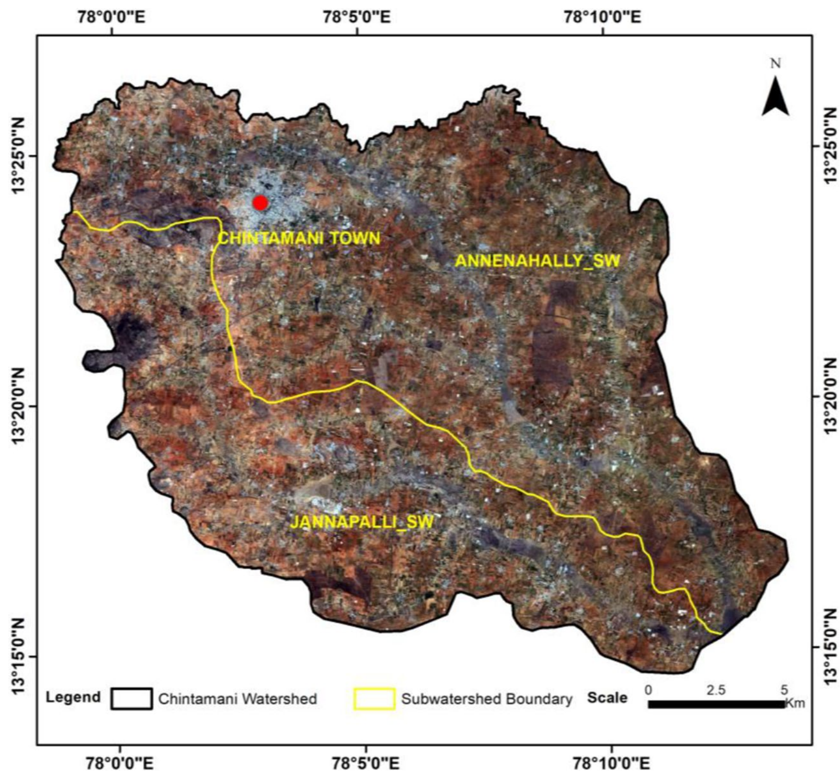

Fig. 2 Sentinel 2A Satellite image of the study area

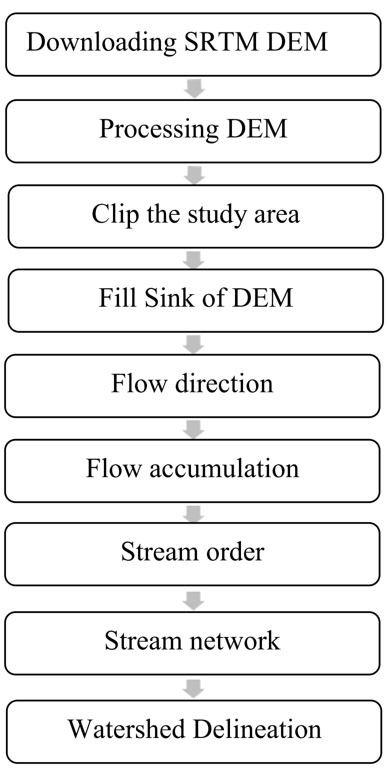

Fig. 3 The methodology flowchart of watershed delineation

elevations from surrounding. Flow Direction was generated using eight-direction flow model, where the values range from 1, 2, 4, 8, 16, 32, 64, to 128, and each grid cell assigned in the direction with the steepest downward slope from its eight adjacent cells (Arabameri et al. 2020). Flow accumulation is computed based on the direction of the flow of water in the raster. This is further used to generate a stream channel using a trial-and-error approach by taking into consideration the number of pixels having a threshold value of more than 150. The workflow of stream network delineation is represented in Fig. 4. The generated stream order will convert to vector format for computation of morphometric parameters shown in Fig. 5.

Methods and formulas used for computation of morphometric parameters related to the drainage network, such as areal, linear, and reliefs, are deliberate and presented in Table 1 for the sub-watersheds. The basic entities of the morphometric analysis like basin area, perimeter, and basin length are represented in Table 2. The distance between the two most distant points in the basin is referred to as basin length (Schumm 1956).

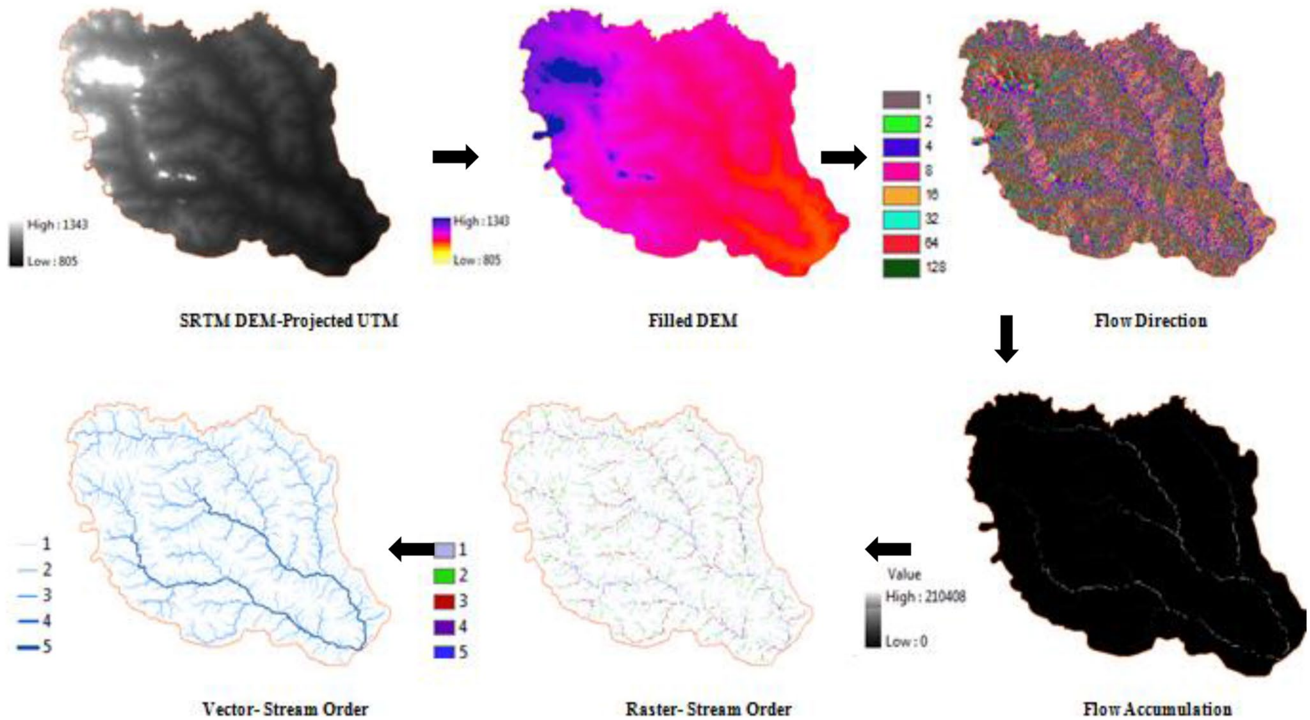

Fig. 4 Workflow drainage network extraction from SRTM DEM for the study area

Fig. 5 Drainage network of the study area

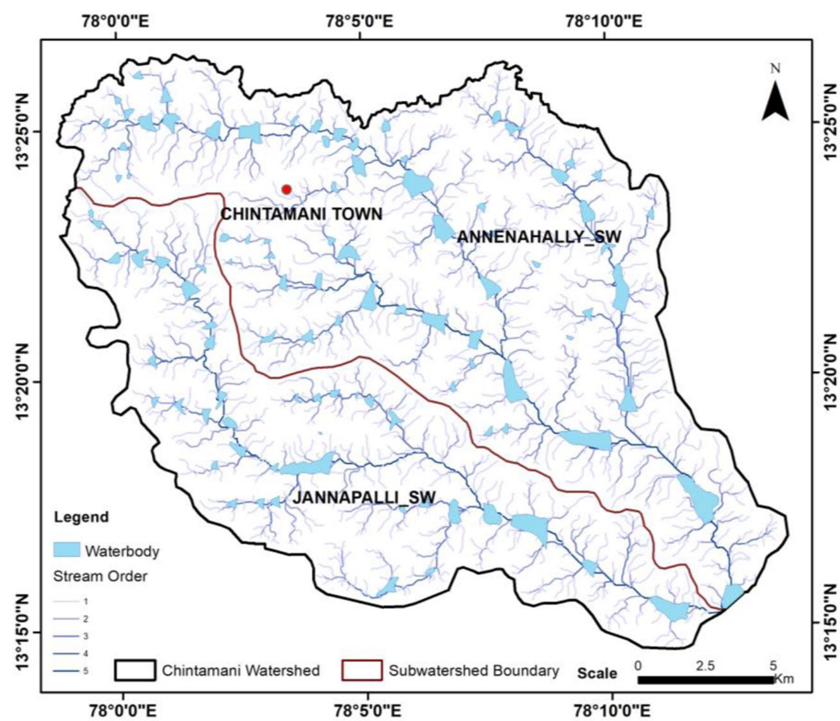

Table 1 Methods of computation of Morphometric parameters

Parameters	Parameters	Formula	References
Linear aspects	Stream order (Nu)	Hierarchical ordering	Strahler (1957)
	Stream length (Lu)	Length of the stream	Horton (1945)
	Mean stream length (Lsm)	Lm = Lu/Nu	Horton (1945)
	Stream length ratio (Rl)	Rl = Lu/L(u−1), where Lu is stream length order u and L(u_1) is stream segment length of the next lower order	Horton (1945)
	Bifurcation ratio (Rb)	Rb = Nu/N(u−1), where Nu is number of streams of any order	Horton (1945)
	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all order	Strahler (1957)
Areal aspects	Drainage density (Dd)	Dd = L/A, where L is total stream length, A is area of basin	Horton (1945)
	Drainage texture (Dt)	Dt = Dd*Fs	Smith (1950)
	Stream frequency (Fs)	Fs = N/A, where N is total number of streams and A is area of watershed	Horton (1945)
	Form factor (Ff)	Ff = A/Lb^2 where Lb is basin length	Horton (1945)
	Circularity ratio (Rc)	Rc = 4pA/P2	Miller (1953)
	Elongation ratio (Re)	Re = 2H(A/p)/Lb, where A is area of watershed, p is 3.14	Schumm (1956)
	Length of overland flow (Lg)	Lg = ½ Dd	Horton (1945)
Relief aspects	Basin relief (R)	R = H−h, where H is maximum elevation and h is minimum elevation within the basin	Schumm (1956)
	Relief ratio (Rr)	Rr = R/Lb	Schumm (1956)
	Ruggedness number (Rn)	Rn = Dd × (H/1000). Where, Dd = drainage density and *H* total relief of the basin	Strahler (1958)

Table 2 Morphometric parameters-Basic aspects of the study area

SW No	SW Name	Basin area (Sq.km)	Perimeter (P) (KM)	Basin length (Lb) (KM)
1	Jannapalli	149.29	78.75	28
2	Annenahally	239.55	94.75	30

Results and discussion

Morphometric study

Linear aspects

These include one-dimensional parameters, such as stream order, stream length, mean stream length, stream length ratio, and bifurcation ratio, and quantified with the help of standard formulae, and results have been presented in Table 3.

Table 3 Morphometric parameters-Linear aspects of the study area

SW No.	SW Name	Stream order (Nu)					Stream length in Km (Lu)				
		I	II	III	IV	V	I	II	III	IV	V
1	Jannapalli	468	117	22	4	1	211.4	86.3	34.9	10.5	26.5
2	Annenahally	757	174	41	4	1	351	142	56.5	38.2	22.9

SW No.	SW name	Mean stream length in Km (Lsm)					Stream length ratio (Rl)			
		I	II	III	IV	V	II/I	III/II	IV/III	V/IV
1	Jannapalli	0.45	0.74	1.6	2.65	26.5	1.64	2.16	1.66	10.00
2	Annenahally	0.46	0.8	1.38	9.5	22.9	1.74	1.73	6.88	2.41

SW No.	SW name	Bifurcation ratio (Rb)				Mean Bifurcation Ratio (Rbm)
		I/II	II/III	III/IV	IV/V	
1	Jannapalli	4.00	5.32	5.50	4.00	4.70
2	Annenahally	4.35	4.24	10.25	4.00	5.71

Stream order Stream orders are the indicator of a stream's position within the tributary hierarchy. In the present analysis, ranking of streams was done primarily based on (Strahler 1964) proposed system. In the study area, the highest order obtained is 5th order and hence designated as 5th-order watershed. Numbering was allocated to each stream segment of sub-watershed starting from the first order to the maximum orders present. After assigning the order numbers, each segment of each order is counted to produce the total segment of the specified order (Rama 2014). The utmost frequency is noted only in streams of the first order. It was also found that there was a decline in the stream frequency as the order of stream increases. This indicates that the entire region has uniform underlying lithology, and geologically, there has been no probably uplifted within the watershed (Mokarram and Sathyamoorthy 2015).

Stream length (Lu) It is the most significant hydrological feature of the basin as it reveals surface runoff characteristics. Longer 'Lu' is usually indicative of gentle slopes. Normally, in first-order streams, the total length of stream segments is higher and decreases within the next higher-order stream (Rai et al. 2018). Then, the entire length of the stream of increasing order (Lu) is determined after adding every stream for a given order. In total, stream networks of length, 980 km were extracted from SRTM DEM data, out of which 369 km belongs to the Jannapalli sub-watershed and 610 km Annenahally sub-watershed. Around 562 km (57.37%) is first-order, 228.3 km (23.29%) second-order, 91.4 km, (9.3%) third-order, 48.7 km (4.8%) fourth-order, 49.4 km (5%), respectively.

Mean stream length (Lsm) Lsm is divulged as the characteristic size of the drainage network components, i.e., dimensional property of a channel and its contribution to watershed surfaces (Strahler 1964). Generally, it is observed that the mean stream length of a given order is greater than that of the lower order. It is noted in Table 3, validation of Horton's law of 'Nu' and 'Lu' favors the geometrical relationship theory usually found in a stream basin or watershed with an increasing stream order (Strahler 1953; Rai et al. 2018).

A semi-logarithmic plot of the stream number against stream orders for the two sub-basins. The drainage network's linear features reflect the behavior of a river and its tributaries from head to mouth, as well as the drainage basin's lithological and structural

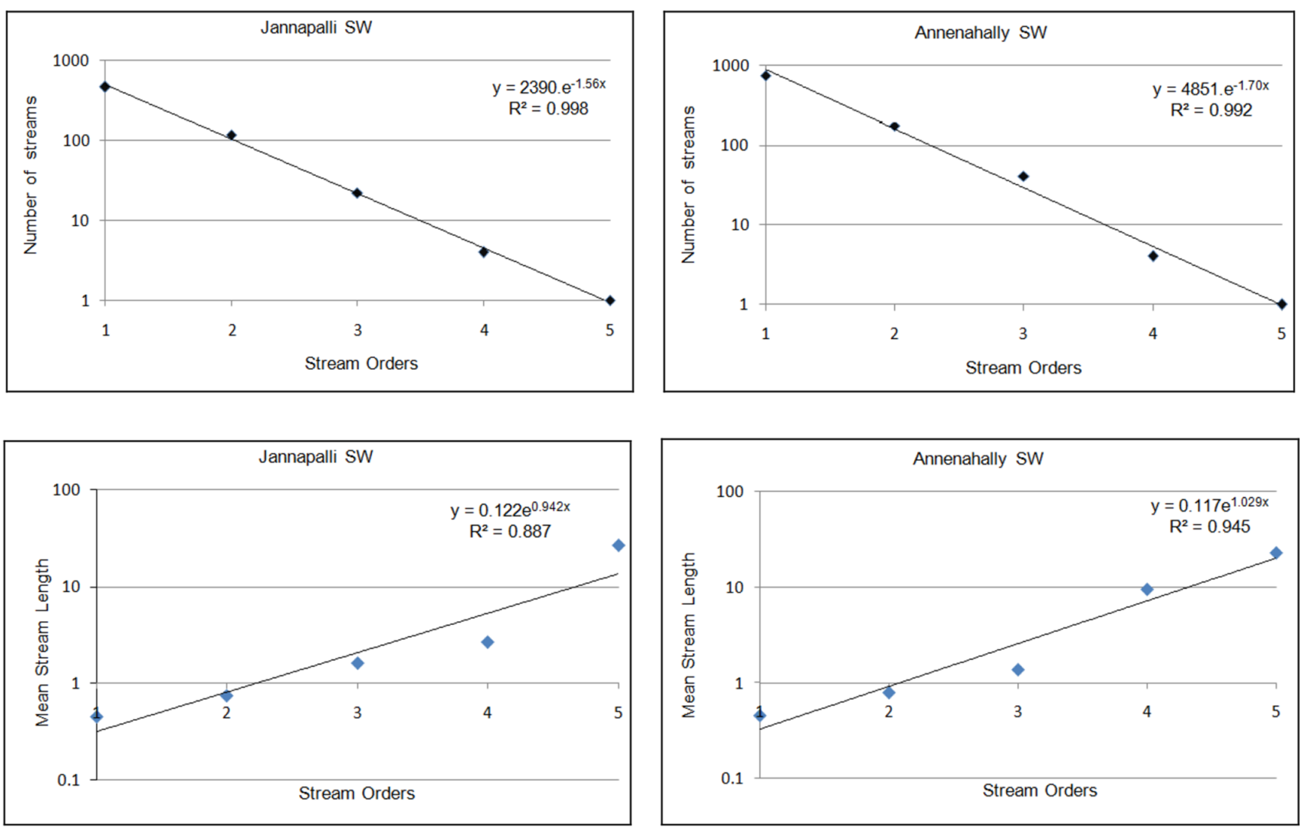

Fig. 6 Semi logarithmic plot of stream number against stream order and stream length for the study area

controls. R2 values suggest that the exponential trend line is the best model to describe the relationship between stream order and stream number (Fig. 6).

Stream length ratio (Rl) Horton's law (1945) of stream length reveals the mean stream length components of a drainage network of every successive order of a basin tending to be constant throughout the successive orders of a basin. The stream length ratio varies from 1.64 to 10.0 in the Jannapalli sub-watershed and 1.74–6.88 Annenahally sub-watershed. Many smaller streams were formed in the area on low permeable formations of weathered granites and granitic gneisses. High values of Rl were observed at extreme upstream regions in impermeable formations of granites and granitic gneisses. There is a deviation within the increasing trend of the length ratio indicating the late youth stage of geomorphic development (Hema et al. 2012; Singh et al. 1997).

Bifurcation ratio (Rb) Rb is the ratio of the number of stream divisions of the specified order to the number of divisions of the subsequently higher-order (Schumn 1956). Strahler (1957) stated the Rb as a small range of difference for the special environment except where the dominant geological control takes place. Rb for the study area shows irregularities from one order to its next higher order. The bifurcation ratio varied from 4.0 to 10.25 Annenahally in sub-watershed and 4.0–5.5 in Jannapalli sub-watersheds. This might also due to the underlying geological and lithological improvement of the drainage basin. The decreased values of Rb are traits of the sub-watersheds that suffered much less structural disturbances (Strahler 1964) and drainage patterns have no longer been imprecise due to the structural disturbances (Nag 1998; Nag et al. 2003).

Mean bifurcation ratio(Rbm) Rbm states the average of bifurcation ratios of all orders. The mean bifurcation ratio is 4.7 and 5.7 in the Jannapalli sub-watershed and Annenahally sub-watersheds. These sub-watersheds indicate the normal basin category (Strahler 1957). The greater values of Rb show strong structural control on the drainage pattern while a decrease in the values indicates the sub-watersheds are not affected by structural disturbances (Vittala et al. 2004).

Areal aspect

The two-dimensional areal morphometric parameters include stream frequency (Fs), drainage density (Dd), form factor (Ff), elongation ratio (Re), circulatory ratio (Rc), texture ratio (Rt), and length of overland flow (Lg). These factors are governed by the lithology, hydrogeomorphic and climatic conditions of the terrain and very useful for obtaining the relationship between the basin area and stream discharge (Veeranna et al. 2017). The derived values of areal parameters are shown in Table 4.

Drainage density (Dd) Dd is defined as the total length of streams by drainage area of all orders (Strahler 1958) indicating the closeness of spacing of streams. Drainage density results with lower value indicate the region is a low relief area extremely covered with resistance rocks or permeable characteristics of subsoil with dense vegetation and in contradiction, higher drainage density values indicate high relief reflects the fast runoff, weak subsurface material, sparse vegetation (Nag 1998; Tolche 2020). Low drainage density values result in the coarse drainage texture and high drainage density values result in the fine drainage texture (Smith 1950).

It is noted that the drainage density 2.48 is in the Jannapalli sub-watershed and 2.55 in Annenahally sub-watershed km/sq.km. A low value of drainage density indicated coarse drainage texture and region had some extent permeable subsoil and basin is low relief.

Spatial analysis endows with the identification and explanation of spatial patterns. The fundamental benefit of spatial analysis is that it visually recognizes the resulting spatial patterns. The spatial pattern of drainage density is depicted in the map (Fig. 7) with three categories are distinct low, medium and high. The drainage density is the product of a geomorphic system of both known and unknown variables. With help of the Arc GIS platform, the drainage density map of the study area was prepared from the digital elevation model (30 m × 30 m resolution). The region with a higher drainage density allows low penetration and the movement of the surface run-off is quicker, thereby causing more erosion (Avtar et al. 2011).

Table 4 Morphometric parameters-Areal aspects of the study area

SW No	SW Name	Drainage Density (Dd) (Km/Sq.Km)	Stream Frequency (Fs)	Form Factor (Ff)	Circularity Ratio (Rc)	Length of Overland Flow (Lg)	Elongation Ratio (Re)	Texture Ratio (Rt)
1	Jannapalli	2.48	4.10	0.19	0.30	0.20	0.49	7.77
2	Annenahally	2.55	4.08	0.27	0.34	0.20	0.58	10.31

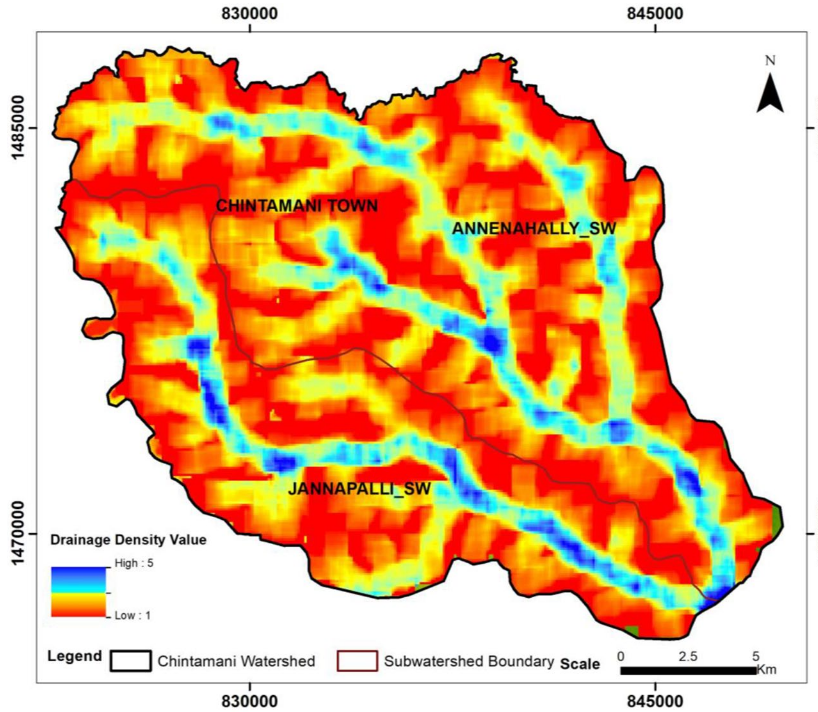

Fig. 7 Drainage density map of the study area

Drainage texture (Dt)

According to Horton (1945), Dt is the complete measure of the number of circulating segments of all orders per perimeter of that basin. The relative spacing of drainage lines is more in impermeable areas than in the permeable region. Smith (1950) has classified drainage density into five special textures like < 2 specify very coarse, 2–4 is specified to coarse, 4–6 is moderate, 6–8 is fine, and > 8 is very fine. In drainage texture, vegetation cover also plays an important role. The finer texture was expected in the region of soft rock where it was unprotected by vegetation, coarse drainage texture results in massive and resistant rocks. On identical rocks, the sparse vegetation of an arid climate produces finer textures than those created in a humid climate (Soni 2017). The present study, reveals that the texture ratio is 7.7 in the Jannapalli sub-watershed and 10.3 in Annenahally sub-watershed falls under fine to very fine category and indicates low permeability hard rock with low resistance against erosion (Fenta et al. 2017).

Stream frequency (Fs) The total number of stream segments per unit area of all orders is known as Fs (Horton 1932). Fs parameter depends on the geology of the area and the sign of the textures of the drainage network (Horton 1945). The sub-watersheds have a high stream frequency of around ‘4’ represents high runoff. Fs of sub-watersheds is having a close correlation with the Dd values signifying the augmented in-stream population with a raise in drainage density (Chandniha et al. 2017).

Form factor (Ff) Ff is the proportion of basin area to the square of the basin length Horton (1932). The Ff value of 0 suggests a strongly elongated shape and the Ff value is more than1 suggest a circular shape with high peak flows for a short duration (Rao et al. 2012). Jannapalli and Annenahally subwatersheds Ff ranges from 0.19 to 0.27 indicating basins are elongated and narrow.

Circularity ratio (Rc) Rc is the ratio of the basin area of a circle that has the same circumference as the basin perimeter (Pareta et al. 2011; Miller 1953). The frequency of streams, geological structures, land use and land cover, climate condition, slope, and relief of the watershed (Dikpal et al. 2017) affects the value of Rc. The lower circularity ratio of 0.3 indicates an elongated shape with moderate-to-low relief and impermeable surface resulting in lower lag times in the basin (Altaf et al. 2013).

Elongation ratio (Re) According to Schumm (1965), the Re is the relationship between the circle diameter of the same basin area and the utmost length of the basin. It is a very important parameter in evaluating the shape of the basin that indicates the concept of hydrological drainage Basin character. Strahler (1958), notes that over a wide range of climatic and geologic forms, Re varies between 0.6 and 1.0. The varying watershed slopes can be classified using the index of elongation ratio, i.e., 0.9–1.0 as circular, 0.8–0.9 as oval, 0.7–0.8 less elongated, 0.5–0.7 as elongated, and less than 0.5 as more elongated. The elongation ratio represented in the Table 4 varies from

0.49 to 0.58 indicating sub-watersheds are elongated with moderate relief (Altaf, et al. 2013).

Length of overland flow (Lg) It is defined as the length of water on the ground before it gets resolute into certain stream channels (Horton 1945). The mean Lg is around half the average distance between stream channels and thus more or less equals to half of the reciprocal of drainage density (Horton 1945). In the study area, sub-watersheds show lower values of Lg (0.2 km). The rainfall is easily accumulated in stream channels. Thus, further rainfall is needed to add a substantial amount of surface runoff to the discharge system in the drainage region (Sakthivel 2019).

Relief aspect

The relief aspect pertains to the elevation point's distribution within the basin area. The variables are computed as follows:

Basin relief Relief aspects of a basin illustrate the height of the surface from the surrounding common surface (Yadav et al. 2018). The maximum 1343 m and minimum elevation of 805 m noted in the study area. The elevation value ranges from 805 to 1265 m in the Jannapalli sub-watershed and the elevation value ranges from 807 to 1343 m in the Annenahally sub-watershed. The relief parameters like basin relief (R), relief ratio (Rh), and ruggedness number (Rh) are determined and shown in Table 5.

Relief ratio (Rh) Basin relief is the difference in the elevation values of the highest and the lowest point of the basin. The relief ratio states that the relationship between basins totals relief and parallel to the main drainage line of the longest basin length (Schumm 1956). The value of relief ratio was calculated 0.05 for Jannapalli and 0.04 Annenahally sub-watersheds, respectively (Table 5). Low values of Rh may be due to the drainage basin's low gradient and resistant basement rocks (Rai et al. 2018). The high relief values indicate steep slopes with high relief (1343 m) in the area of the hills of Kailasagiri, lower readings could suggest the existence of bare rocks in the form of tiny ridges and mounds with a shallower slope.

Ruggedness no (Rn) Rn is the product of the maximum basin relief (H) and drainage density (Dd) in the same unit. When the basin relief and drainage density are high, and the slope is steep, the roughness number rises (Strahler 1956). Rn value ranges in the present study from 1.14 to 1.3, which indicates less steepness and length of the slope. (Schumm 1956; Saha et al. 2017).

Prioritization of watershed based on morphometric parameters

Morphometric analysis is an important tool for prioritizing sub-watersheds. The morphometric parameters like mean bifurcation ratio, drainage density, drainage texture, elongation ratio have a direct relation to erodability (Sujatha et al. 2015; Abdeta et al. 2020). Higher the value, more in erodibility, and so prioritization is considered in the region of higher value (Meshram and Sharma 2017). The compound factor is determined by adding the ranks of all linear and shape parameters, then dividing by the number of parameters. (Kadam 2019). The interrelationship between morphometric parameters under complex topography and climatic conditions differs from basin to basin. Knowing these relationships would make it possible to define the dominant parameters affecting that particular region (Sreedevi 2013). Priority ranking of the sub-watershed is presented in Table 6 concerning different morphometric parameters. Depending upon the value of the compound factor, Annenahally Sub-watershed needs a higher ranking for prioritization. In this study 8, water-harvesting structures are recommended. The timely placement of these structures may fulfill the criteria of drought impact in the study area.

Watershed prioritization is one of the important aspects of watershed management. The ranking of distinct watersheds in a catchment according to the order in which they

Table 6 Prioritization of Morphometric parameters of the study area

Morphometric Parameter	Jannapalli	Annenahally
Total stream length (L)	2	1
Mean bifurcation ratio (Rbm)	1	2
Drainage density (Dd)	1	2
Drainage texture (Dt)	1	2
Elongation ratio (Re)	1	2
Compound factor	1.2	1.8
Priority ranking	2	1

Table 5 Morphometric parameters- Relief aspects of the study area

SW No	SW Name	Max. elevation (H) (in m)	Min. elevation (h) (m)	Basin Relief (H) (m)	Relief Ratio (Rh)	Ruggedness no (Rn)
1	Jannapalli	1265	805	460	0.05	1.14
2	Annenahally	1343	807	536	0.04	1.37

must be treated is known as watershed prioritizing. (Pandey et al. 2011). Due to a shortage of resources and financial constraints, the watershed development program may not be able to be implemented in its entirety at the same time. As a result, based on the severity of the watershed problems, priority should be given to developing the watersheds.

Morphometric parameter analysis is critical in defining and determining groundwater potential zones and high-risk areas of erosion (Choudhari et al. 2018; Yadav et al. 2018). In Table 6, the morphometric parameter of the two sub-watersheds is calculated, and the priority order is shown. This study has concentrated based on the morphometric characteristics for prioritizing the watershed's water conservation in an automated way. Suitable sites for conservation measure structures.

Suitable sites for conservation measure structures

Remote sensing and GIS technologies have proven highly useful in attempting to prioritize the river basin and have been considered suitable for identifying appropriate locations for conservation measurement systems at the sub-watershed level. Analyzing morphological factors revealed the most demanding need to address in the Annenahally sub-watershed. Total 25 suitable locations are identified for conservation measures, out of these 15 locations for recharge well, 7 locations for percolation tanks, and 3 check dam locations have been identified as suitable for adequate management techniques (Fig. 8).

Conclusion

The geospatial approach for quantitative drainage morphometric analysis is more appropriate than conventional methods. It plays an important part in understanding a drainage basin's geo-hydrological characteristics concerning the terrain function and its flow patterns. Two sub-watersheds Annenahally and Jannapalli have very slight differences in linear, areal, relief morphometric parameters. In total stream networks of length, 980 km was extracted from SRTM DEM data, out of which 369 km belongs to the Jannapalli sub-watershed and 610 km Annenahally sub-watershed. Many smaller streams were formed in the area on low permeable formations of weathered granites and granitic gneisses. High values of Ri were observed at extreme upstream regions in impermeable formations of granites and granitic gneisses. There is a deviation within the increasing trend of the length ratio indicating the late youth stage of geomorphic development. The present study, reveals that the texture ratio is 7.7 in the Jannapalli sub-watershed and 10.3 in Annenahally sub-watershed falls under fine to very fine category and indicates low permeability hard rock. Drainage density results with lower value indicate the region is a comparatively high relief area extremely covered with resistance rocks. The shape of the basin is almost elongated which is indicated by the results of texture ratio, circulatory ratio, and elongation ratio. Higher drainage density regions are beneficial to locate artificial recharge sites like percolation tanks, check dams, and recharge shafts. The complete

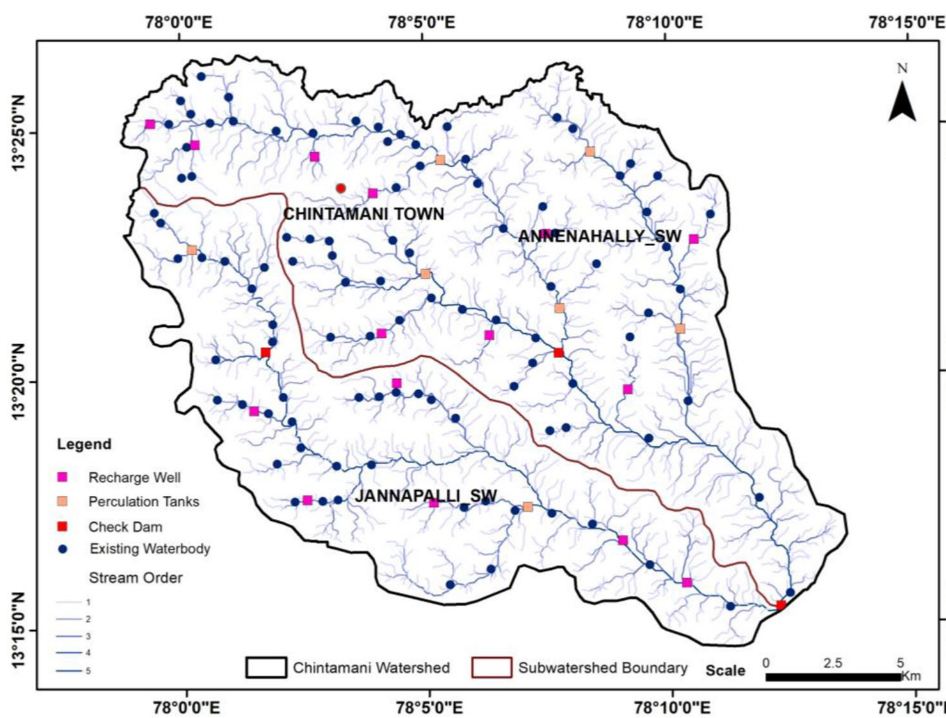

Fig. 8 Identified locations potential zones of water resource in the study area

morphometric analysis of the drainage basin indicates that increasing groundwater recharge should be planned in the Chintamani watershed. Hence, this analysis gives a key to improve the living standard of people in the watershed by making an appropriate plan for watershed management which can be taken by the decision-makers and government authorities.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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