Environment and Ecology 37 (1B) : 419—426, January—March 2019
Website: environmentandecology.com ISSN 0970-0420

Evaluation of Geo-Morphological Characteristics for Chhatra Sub Watershed in Raichur District, Karnataka

Thejaswi Jagalurkar, G. V. Srinivasa Reddy, M. Nemichandrappa, B. Maheshwara Babu, S. N. Bhat

Received 15 October 2018; Accepted 20 November 2018; Published on 11 December 2018

Abstract Chhatra sub watershed lies between 76°24´ to 76°29´ East logitudes and 15°51´ to 15°55´ North latitudes in Raichur district of Karnataka. The drainage networks of watershed were delineated from the Survey of India topomaps of 1 : 50,000 scale. ArcGIS software was used in evaluation of linear, areal and relief aspects of the watershed. The present study reveals that, drainage pattern of the study area is dendritic with trunk order number 4. The watershed area, maximum length and with of the watershed are 2134.6 ha, 5.84 km and 3.65 km respectively. The mean value of bifurcation ratio is 3.34 indicating, the watershed has suffered less structural disturbance and drainage pattern has not been distorted. The value of drainage density is 2.19 km km^{-2} which indicated that, the region is having permeable subsoil material and good vegetation cover. The value of farm factor indicates watershed is approaching towards elongated shape of watershed. The present study revealed that, GIS based approach in evaluation of geo-morphological characteristics is more appropriate than conventional techniques.

Keywords Watershed, Geo-morphology, GIS, Topomap.

Thejaswi Jagalurkar*, G. V. Srinivasa Reddy,
B. Maheshwara Babu
Department of Soil and Water Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur 584104, Karnataka, India

M. Nemichandrappa
Department of Agricultural Engineering, College of Agriculture, Bheemarayanagudi, India

S. N. Bhat
Institute of Organic Farming, Main Agriculture Research Station,University of Agricultural Sciences, Raichur 584104, Karnataka, India
e-mail : thejasvi.777@gmail.com
*Corresponding author

Introduction

The assessment of hydrological characteristics of drainage basin is mandate for any basin management scheme. It involves detailed morphometric analysis, which includes basin size, shape, slope of drainage area, drainage density and length of the tributaries. Drainage basins are the fundamental units of the fluvial landscape and a great amount of research has focused on their geometric characteristics, which include the topology of the stream networks and quantitative description of drainage texture, pattern, shape and relief characteristics. 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). Geology, relief and climate are the primary determinants of running water systems functioning at the basin scale (Mesa 2006).

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal 1998). Morphometric studies in the field of hydrology were first initiated by Horton (1940) and Strahler (1950). The morphometric analysis of the drainage basin and channel network play an important role in understanding the geo hydrological behavior of drainage basin and expresses the prevailing climate, geology, geomorphology and structural antecedents of the catchment.

In India, some of the recent studies on morphometric analysis using remote sensing and GIS techniques were carried out by Guha (2015), Kulkarni (2015), Ramesh and Prasad (2015), Nagaraju et al. (2015), Sreenivasa et al. (2016), Prithiviraj and Venkateswaran (2016) and Sah and Das (2017).

Location

The study area forms part of Chhatra sub watershed located in Lingasugur taluk of Raichur district, Karnataka State and having total area of 2134.6 hectares and lies between76°24´ to 76°29´ east longitudes and 15°51´ to 15°55´ North latitudes with an average altitude of 543 m above mean sea level (MSL) and located in the western part of Raichur district boundary. The Figs. 1 and 2 represent location map and drainage map of Chhatra sub watershed respectively.

Materials and Methods

The SoI toposheet 57A/5 of 1 : 50,000 scale with a

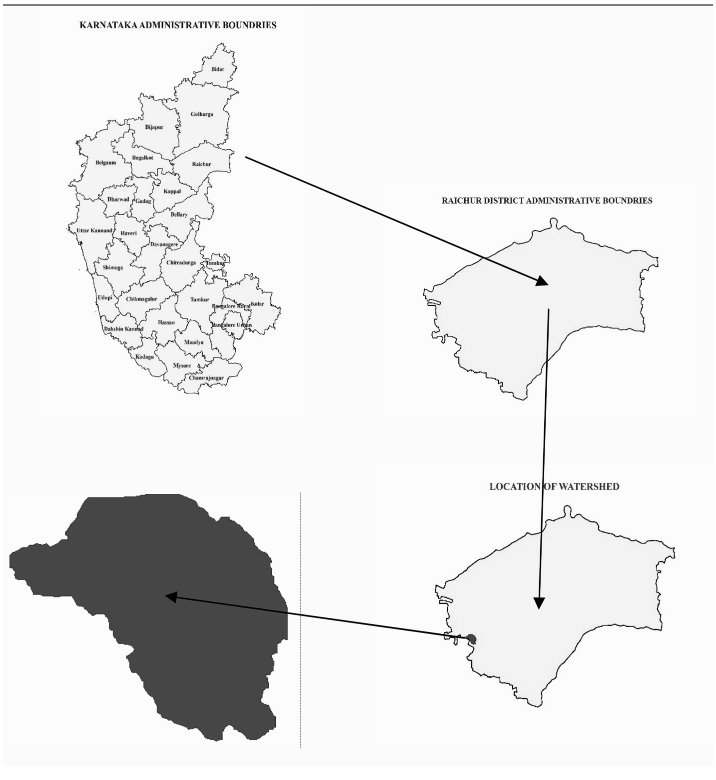

Fig. 1. Location map of Chhatra sub watershed.

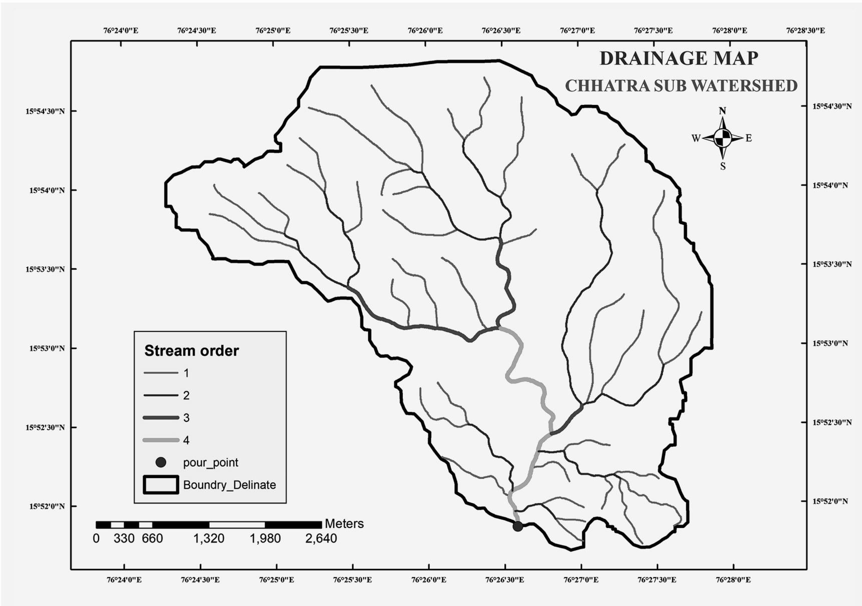

Fig.2. Drainage map of Chhatra sub watershed.

contour interval of 10 m was obtained from Survey of India, Bengaluru has been used for delineation of watershed and analysis of linear, areal and relief aspects of watershed. Obtained toposheet was georeferenced and analyzed under ArcGIS 10.2 version software. The first step in quantitative analysis of drainage basin is designation of stream order. In the present study, for the ordering of streams Strahler's ordering system was adopted. The parameters computed in the present paper using GIS technique includes stream number, stream order, stream length, bifurcation ratio, stream, length ratio, drainage density, drainage texture, stream frequency, form, factor, circulatory ratio, elongation ratio, maximum watershed relief, relief ratio and ruggedness number were evaluated with established mathematical formulae represented in the Table 1.

Results and Discussion

The total area of watershed was found to be 2134.6 ha. The length, width and perimeter of the watershed were found to be 5.84, 3.65 and 22.34 km respectively. The values of different geomorphological parameters were calculated by using the methodology as discussed in materials and methods. The calculated values of linear, areal and relief parameters are presented in the Tables 2, 3 and 4 respectively.

Linear aspects of watershed

After the analysis it was found that, the watershed is of 4th order type and drainage pattern is dendrite, which indicates the homogeneity in texture and lack of structural control. The maximum length and width of the watershed was found to be 5.84 and 3.65 km respectively. The various linear parameters viz., stream order, stream number for all 4 order streams, bifurcation ratio and stream length ratio are described below.

Stream order (U) and stream number (N_u)

The designation of stream order is the first step in the drainage basin analysis. The streams of the Chhatra sub watershed have been ranked according to Strahler's (1964) stream ordering system and the number of streams of each segment (N_u) of the order (U) is presented in Table 2.

The stream numbers (N_u) of 1st, 2nd, 3rd and 4th order streams were found to be 36, 9, 3 and 1 respectively (Table 2). Horton's (1945) laws of stream

Table 1. Formulae adopted for evaluation of geo-morphological characteristics.

Sl. No.	Parameters	Formulae		References
1	Stream order (U)	Hierachical rank	–	Strahlern (1964)
2	Stream length (L_u)	Length of the stream	–	Horton (1945)
3	Mean stream length ($\bar{L}_u$)	$\bar{L}_u = \frac{\sum_{i=1}^{N} L_u}{N_u}$	L_u =Stream length (km) N_u = Number of streams of order 'u'	Strahler (1964)
4	Bifurcation ratio (R_b)	$R_b = \left(\frac{N_u}{N_{u+1}}\right)$	N_u = Number of streams of order 'u' N_{u+1} = Number of streams of next higher order 'u + l'	Schumn (1956)
5	Stream length ratio (R_L)	$R_L = \frac{\bar{L}_u}{\bar{L}_{u-l}}$	L_u = The total stream length of the order 'u' (km) L_{u-1} = The total stream length of its next lower order (km)	Horton (1945)
6	Drainage density (Dd)	$D_d = \frac{L}{A}$	L = Total length of all stream segments (km^2) A = Area of the basin (km^2)	Horton (1932)
7	Drainage texture (D_t)	$D_t = \frac{N}{P}$	N = Total number of stream segments of all orders P = Perimeter of the watershed (km)	Smith (1950)
8	Stream frequency (F)	$F = \frac{N}{A}$	N = Total number of stream segments of all orders A = Basin area (km^2)	Horton (1945)
9	Form factor (R_f)	$R_f = \frac{A}{(L_b)^2}$	A = Area of watershed (km^2) L_b = Length of basin (km)	Horton (1945)
10	Circulatory ratio (R_c)	$R_c = \frac{4IIA}{(A_c)^2}$	A = Area of watershed (km^2) A_c = Perimeter of the watershed (km)	Strahler (1964)
11	Elongation ratio (R_e)	$R_e = \left(\frac{L}{B}\right) \left(\frac{2}{L}\right) \sqrt{\frac{A}{II}}$	D_c = Diameter of the circle having same area as that of the basin (km) L_b = Basin length (km) A = Basin area (km^2)	Schumn (1956)
12	Maximum waterhed relief (H)	$H = h_{max} - h_{min}$	h_{max} = Elevation of highest elevated point (m) h_{min} = Elevation at outlet (m)	Schumn (1956)
13	Relief ratio (R_r)	$R_r = \frac{H}{L_b}$	H = Maximum watershed relief (m) L_b = Maximum watershed length (km)	Schumn (1956)
14	Ruggedness number (R_n)	$R_n = \frac{H D_d}{1000}$	H = Maximum watershed relief (m) D_d = Drainage density, km (km^{-2})	Melton (1957)

numbers states that, the number of stream segments of each order form an inverse geometric sequence with stream order. Most of the drainage networks show a linear relationship, with small deviation from a straight line. The plotting of logarithm of number of streams against stream order is given in Fig. 3. The graph shows a straight line, satisfying the Horton's law.

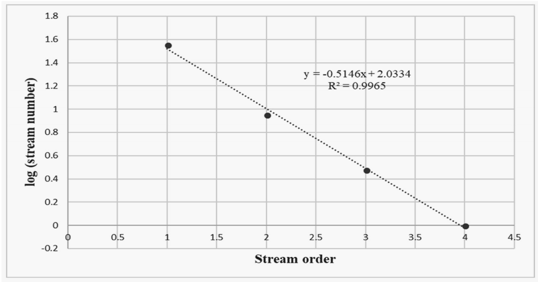

Fig. 3. Regression of logarithum of stream number and stream order.

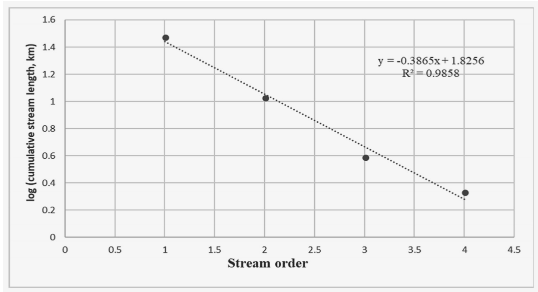

Fig. 4. Regression of logarithm of cumulative stream length and stream order.

Cumulative stream length (L_u)

The values of cumulative stream length for 1st, 2nd, 3rd and 4th order streams (Table 2) were found to be 30.04, 10.77, 3.90 and 2.17 km respectively. The steam length of different orders and respective mean stream lengths were found out by digitizing the stream networks using ArcGIS software. In the present study, an attempt has been made to establish the relation between cumulative stream length and stream order (U). In order to find the correlation, logarithm of cumulative stream length as ordinate and stream order (U) as abscissa, plotted on normal log paper to investigate the geometric property. The results straight line satisfies the Horton's law and it indicates that generally, the total length of stream segments is high in first order streams and decreases as the stream order increases. The plotting of logarithm of cumulative stream length against stream order is given in Fig.4.

Bifurcation ratio (R_b)

The bifurcation ratio (R_b) reflects about geological and tectonic characteristics of the watershed and the mean value is estimated as 3.34 indicates that, the watershed has suffered less structural disturbance and the drainage pattern has not been distorted by structural disturbance (Nag 1998).

Stream length ratio (R_L)

The value of stream length ratios for 2nd, 3rd and 4th order streams were found to be 1.45, 1.08 and 1.67 respectively (Table 2). The variation in stream length ratio might be due to change in slope and topography. The study area showed a decreasing trend in stream length ration of 3rd to 2nd order which indicates its late youth stage of geomorphic development. Whereas, for 4th to 3rd order stream length ratio is increasing as compared to 3rd to 2nd which indicates, their mature geographic stage (Singh and Singh 1997).

Areal aspects of watershed

The results of the areal aspects of Chhatra sub watershed are presented in the Table 3.

Table 2. Linear aspects of Chhatra sub watershed.

Stream order (U)	Stream number (N_u)	Cumulative stream length (L_u), km	Mean stream length ($\bar{L}_u$) km	Bifurcation ratio (R_b)	Stream length ratio (R_L)
1	36	30.04	0.83	4	–
2	9	10.77	1.20	3	1.45
3	3	3.90	1.30	3	1.08
4	1	2.17	2.17	–	1.67

Table 3. Areal aspects of Chhatra sub watershed.

Sl. No.	Areal aspects	Value
1	Drainage area (A), ha	2134.60
2	Basin length (L), km	5.84
3	Basin width (B), km	3.65
4	Basin perimeter (P), km	22.34
5	Drainage density (D_d), km km^{-2}	2.19
6	Drainage texture (D_t), km^{-1}	2.19
7	Stream frequency (F), km^{-2}	2.29
8	Form factor (R_f)	0.62
9	Circulatory ratio (R_c)	0.54
10	Elongation ratio (R_e)	0.89

Drainage density (D_d)

The watersheds can be grouped into four categories on the basis of drainage density : Low (<2.0 km km^{-2}), moderate (2.0–2.5 km km^{-2}), high (2.5-3.0 km km^{-2}) and very high (>3.0 km km^{-2}) (Mallik et al. 2011). The drainage density value indicates the closeness of spacing of channels, thus providing a quantitative measure of average length of stream channel for the whole watershed. Further, it gives an idea about the physiographical properties of underlaying soils. The value of drainage density (D_d) was found to be 2.19 km km^{-2} (Table 3), which falls in the range of 2.0 to 2.5 km km^{-2}, which indicated that, the region is having permeable subsoil material and good vegetation cover (Sreedevi et al. 2013).

Drainage texture (D_t)

Drainage texture is one of the important concept of geomorphology which means, the relative spacing of drainage lines. Drainage texture indicates underlying lithology, infiltration capacity and relief aspect of the Terrain. Drainage texture can be classified into five different textures i.e. very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8) (Smith 1950). The value of drainage texture (D_t) for Chhatra sub watershed is found to be 2.19 km^{-1} (Table 3), which indicates about the coarse drainage texture of the watershed (Smith 1950). The coarse drainage texture indicates a good permeability of sub surface material and infiltration and lower runoff rate (Hajam et al. 2013).

Stream frequency (F)

It is another measure to describe the capacity of stream network to carry the discharge and is derived as number of stream segments per unit area. Higher the value of stream frequency, lower the permeability of the area and higher is the runoff and vice versa. The value of stream frequency for the Chhatra sub watershed was found to be 2.29 km^{-2} which indicates, watershed is having resistant or permeable sub-surface material with good infiltration rate, good vegetation cover and low relief. The stream frequency shows positive correlation with drainage density (Hajam et al. 2013).

Form factor (R_f)

It is the ratio of the watershed area to the square of watershed length. If the value of form factor is less than 0.7854, it indicates a perfectly circular basin (Horton 1932). Smaller the value of form factor more elongated is the basin. From the results, it was observed that, the value of farm factor (R_f) was found to be 0.62 (Table 3). Since the value of form factor is less than 0.7854, it indicates an elongated shape of the watershed (Horton 1932). An elongated basin with low farm factor shows flatter peak flow for longer duration. Hence flood flow will be there for longer duration.

Circulatory ratio (R_c)

The value of circulatory ratio varies from zero to one. Higher the values of circulatory ratio, more circular will be the shape of the basin. The value of circulatory ratio (R_c) for Chhatra sub watershed is found to be 0.54.

Elongation ratio (R_e)

Strahler (1964) states that, this ratio runs between 0.6 and 1.0 over a wide variety of climatic and geologic types. The varying slopes of watershed can be classified with the help of the index of elongation ratio i.e., circular (0.9-1.0), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5 -0.7) and more elongated (<0.5). The value of elongation ratio for the present study, is found to be 0.89. The greater elongation ratio that circulatory ratio results in elongated formation of watershed than circular watershed. The value of elongation ratio (0.89) indicates about oval shaped watershed (Strahler 1964).

Relief aspects of watershed

The relief aspects of watershed viz., maximum watershed relief (H), relief ratio (R_r) and ruggedness number (R_n) were computed and represented in the Table 4.

Maximum watershed relief (H)

In high relief regions, there will be high gravity force

Table 4. Relief aspects of Chhatra sub watershed.

Sl. No.	Relief aspects	Value
1	Maximum watershed relief (H)	95
2	Relief ratio (R_r)	0.016
3	Ruggedness number (Rn)	0.24

for the water and which cause less infiltration and high runoff (Magesh and Chandrashekar 2012). But in low relief region the condition is reverse. Maximum watershed relief for the present study was determined from the DEM. For the present study the value of relief ratio was found to be 95m.

Relief ratio (R_r)

The relief ratio is the indicator of erosion processes operating on the slopes and overall steepness of the drainage line (Magesh and Chandrashekar 2012). For the present study, the relief ratio for Chhatra sub watershed is found to be 0.016. The lower value of relief ratio indicates a presence of basement rocks that are exposed in the form of small ridges and mounds with lower degree of slope (Praveen et al. 2012).

Ruggedness number (R_n)

Excessively high ruggedness number occurs for a high relief region with high stream density and vice-versa. For the present study, the value of ruggedness number is found to be 0.24. The lower value of ruggedness number indicates that, the area is less prone to soil erosion and have an intrinsic structural complexity in association with relief and drainage density (Guha 2015).

Conclusion

A study was conducted for evaluation geo-morphological charcteristics for Chhatra sub watershed using GIS technique. The Chhatra sub watershed lies between 76°24′ to 76°29′ East longitudes and 15°5′1 to 15°55′ North latitudes. Chhatra is a village in Lingasuru taluk in Raichur district of Karnataka State. It was realised in the process of study that, use of GIS can make the cumbersome geomorphological analysis as an easy task as compared to traditional methods. It saves time and helpful in planning of resource conservation techniques in the watershed area for sustainable development. The determination of geomorphological characteristics includes area and perimeter, linear aspects viz., stream number (N_u) stream order (U), stream length (L_u) bifurcation ratio (R_b) ;stream length ratio (R_L); areal aspects viz drainage density (D_d) drainage texture (D_t) stream frequency (F), form factor (R_f) circulatory ratio (R_c), elongation ratio (R_e); relief aspects viz., maximum watershed relief (H) relief ratio (R_r) and ruggedness number (R_n).

This study indicates that, systematic analysis of morphometric parameters using GIS can provide significant value in understanding basin hydrological characteristics for watershed planning and management.

References

Agarwal CS (1998) Study of drainage pattern through aerial data in Naugarh area of Varanasi district, UP. J Ind Soc Remote Sens 26 (4) : 169—175.

Guha S (2015) Mathematical analysis of Solani Watershed, North India. Int J Geomat and Geosci 6 (2) : 1512—1529.

Hajam RA, Hamid A, Bhat S (2013) Application of morphometric analysis for geo hydrological studies using geo-spatial technology : A case study of Vishav drainage basin. Hydrol Curr Resour 4 (3) : 2—12.

Horton RE (1932) Drainage basin characteristics. Transition Geo Union 13 (1) : 350—361.

Horton RE (1940) An approach toward a physical interpretation of infiltration-capacity. Soil Sci Soc Am J 5 : 399—417.

Horton RE (1945) Erosional development of streams and their drainage basins; hydro physical approach to quantitative morphology. Geol Soc Am Bull 56 (3) : 275—370.

Kulkarni MD (2015) The basic concept to study morphometric analysis of river drainage basin : A review. Int J Sci and Res 4 (7) : 2277—2280.

Magesh NS, Chandrashekar N (2012) GIS model-based morphometric evaluation of Tamiraparani sub basin, Tirunelveli district, Tamil Nadu, India. Arabian J Geosci 7 (1) : 131—141.

Mallik MI, Bhat MS, Kuchay NA (2011) Watershed based drainage morphometric analysis of Lidder catchment in Kashmir valley using GIS. Recent Res Sci and Technol 3 (4) : 118—126.

Melton MA (1957) An analysis of the relations among elements of climate, surface properties and geomorphology (No. CU-TR-11). Columbia Univ New York.

Mesa LM (2006) Morphometric analysis of a subtropical Andean basin (Tucuman, Argentina). Environm Geol 50 (8) : 1235—1242.

Nagaraju D, Siddalingamurthy S, Balasubramanian A, Sumithra

S (2015) Morphometric analysis of Byramangala watershed, Bangalore urban district, Karnataka, India. Int J Curr Engg and Technol 5 (3) : 2156—2164.

Nag SK (1998) Morphometric analysis using remote sensing techniques in the Chaka sub- basin, Purulia district, West Bengal. J Ind Soc Remote Sens 26 (1) : 69—76.

Praveen R, Kumar U, Singh VK (2012) Geomorphometric characterization of upper south Koel basin, Jharkhand : A remote sensing & GIS approach. J Water Resour and Protec 4 (12) : 1042—1050.

Prithiviraj G, Venkateswaran S (2016) Geomorphology and morphometric analysis used as a significant indicator for groundwater prospects : A case study of the Kousika Manadi sud basinVaigai river Tamilnadu. Ind J Appl Res 6 (2) : 314—317.

Ramesh LD, Prasad TJ (2015) Evaluation of morphometric parameters derived from CartoDEM and Aster GDEM with SoI toposheets of Kumudvathi watershed basin, Karnataka, India. Int J Adv Remote Sens and GIS 4 (1) : 1286—1294.

Sah RK, Das AK (2017) Overcoming source limitations in drainage delineation by combining the streams of toposheet and DEM in river morphometric studies. J Geol Soc Ind 90 (2) : 183—188.

Schumn SA (1956) Evaluation of drainage systems and slopes in bad land at Parth Ambo, New Jersy. Bull Geol Soc Am 67 : 597—646.

Singh S, Singh MC (1997) Morphometric analysis of Kanhar river basin. Nat Geographic J Ind 43 (1) : 31—43.

Smith (1950) Standards for grading textures of erosional topography. Am J Soc 248 : 655—668.

Sreedevi PD, Sreekanth PD, Khan HH, Ahmed S (2013) Drainage morphometry and its influence on hydrology in a semi-arid region : Using SRTM data and GIS. Environm Earth Sci 70 (2) : 839—848.

Sreenivasa A, Asode AN, Murgod S (2016) Drainage evaluation of Doddhalla sub basin, Karnataka, India using GIS. Int J Res Appl Sci & Engg Technol 4 (3) : 89—93.

Strahler AN (1950) Equilibrium theory of erosional slopes approached by frequency distribution analysis. Am J Sci 248 : 673—696.

Strahler AN (1964) Quantitative geomorphology of drainage basin and channel networks. Handbook Appl Hydrol 23 : 543—552.