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Original Article

ANALYSIS OF HYDROLOGICAL INFERENCES THROUGH MORPHOMETRIC ANALYSIS: A REMOTE SENSING-GIS BASED STUDY OF KANAKANALA RESERVOIR SUBWATERSHED

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ABSTRACT

Morphometry means, mathematically quantifying various aspects of a drainage basin. Morphometric parameters bring an idea, to know about rock structure, runoff, infiltration rate, erosion of the soil in the watershed etc. So that the study of morphometric characteristics is in demand, in order to work out a comprehensive development plan, for optimum use of watershed resources. The analysis could be achieved through measurement of linear, aerial and relief aspects. The present study has been undertaken, to compute morphological features of Kanakanala Reservoir Subwatershed, Karnataka. Computed values of Farm factor (R_f =0.65), Circulatory ratio (R_c=0.7) and Elongation ratio (Re=1) indicated that, the watershed is nearly circular in shape. The texture (7.9) indicated the intermediate texture, lying between coarse and fine. The drainage density (D_d=2.37 km/km^2) indicated that, the area has a gentle slope, low rainfall and permeable bedrock. Hence, from the study, it is concluded that, the morphometric investigation is useful to bring an idea of watershed characterization so that we could make decision, about watershed prioritization, soil and water conservation and management of natural resources etc.

KEYWORDS: Morphometric Parameters, Remote Sensing (RS), Geographical Information System (GIS), Watershed & Prioritization Etc

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INTRODUCTION

A drainage basin represents a natural hydrological entity which enables surface runoff to a defined channel, ravine, stream or river at a particular point (Chopra *et al.*, 2005). It is identifiable as being of fluvial erosive origin is considered a fundamental topographic, geomorphic and hydrologic areal unit for watershed management (Chorely, 1971). It is the supreme element for management and sustainable development of natural resources. More considerably, it provides the basis for geomorphometric analysis. This technique was introduced earlier, by Horton (1932 and 1945) and elaborated by Strahler (1952a and 1964), Langbein (1947), Melton (1958), Smith (1950), Miller (1953) and Schumm (1956), those who later established the quantitative fluvial geomorphic research (2007). They were transformed from a purely qualitative and deductive study to a rigorous quantitative science providing hydrologists with numerical data of practical values (Choudhari *et al*., 2014). It is necessary to manage watershed, by incorporating technologies within the natural boundaries of a drainage area, for optimum development of land, water and plant resources. Also, watershed development programme protects and conserves the environment (Muthamilselvan and Dhivya, 2017).

Clarke (1966), defined morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimensions of its landforms. This analysis could be achieved through measurement of linear, aerial and relief aspects of basin (Horton, 1945). This provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds (Strahler, 1964). The morphometric characteristics at the watershed scale, may contain important information regarding its formation and development because, all hydrologic and geomorphic processes occur within the watershed (Singh, 1992). The influence of drainage morphometry is very significant, in understanding the landform processes, soil physical properties, erosional characteristics in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management. In addition to that, it implies the proper utilization of land and water resources of a watershed for best production with minimum hazard to environmental resources, including people who live across the watershed (Hlaing *et al*., 2008 and Patel *et al*., 2013). The morphometric analysis of a drainage basin/watershed is important in understanding the hydrologic behavior, as well as groundwater and hydrogeology conditions of the area. Therefore, it is very important to obtain the morphometric parameters, for management and developmental study of watershed (Muthamilselvan and Dhivya, 2017).

In recent years, the importance of remote sensing technology for geomorphological studies has increased because, it is not only cost effective, but also reliable and timely (Murthy, 2000; Leblanc *et al*., 2003; Tweed *et al*., 2007 and Magesh *et al*., 2012). Integration of Remote Sensing (RS) and Geographic Information System (GIS) technologies have been utilized worldwide, to identify and examine changes in the landscape and the consequential environmental impacts like gully erosion, flooding, etc. So that, RS and GIS techniques have also proven to be capable tools in the delineation, characterization and morphometric analysis of drainage basins worldwide (Paulinus *et al*., 2016).

MATERIALS AND METHODS

Description of Study Area

Kanakanala Reservoir Subwatershed covered a maximum part of the Koppal and minimum part of Raichur districts. This comes under D43E5 toposheet and located at 15° 46' 13.30" to 15° 54' 21.45" North latitude and 76° 19' 54.08" to 76° 27' 15.91" East longitude. It covers an average area of 195 km^2 with an elevation of 500 meters. The major agricultural crops grown in the study area are Paddy, Jowar, Maize, Cotton, Pulses and Oil seeds. The study area is prevailed with subtropical climate with mild winters and hot summers. December is the coldest month with mean daily minimum temperature of 16.85 ºC, while April/May is the hottest month with maximum temperature of 45 ºC. The average annual rainfall is 580-600 mm with the annual numbers of the rainy days 48 days. The location of the Kanakanala Reservoir Subwatershed is shown in the figure 1.

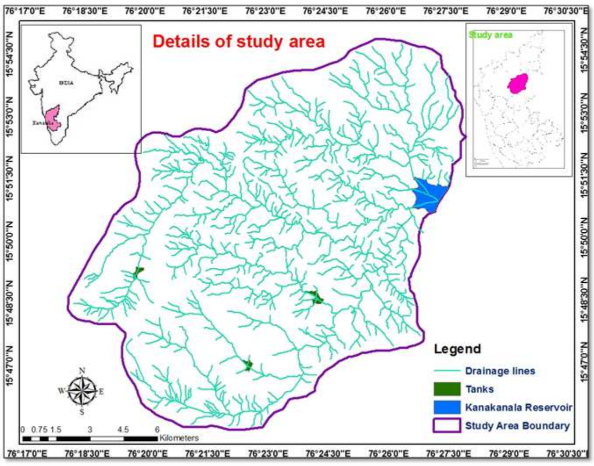

Figure 1: Location Map of the Kanakanala Reservoir Subwatershed, Karnataka

Morphometric analysis of a basin needs delineation of the basin boundary and existing drainage network of different extent and patterns. Survey of India (SOI) toposheets on 1:50000 scale was utilized, for digitization of drainage networks of all existing orders, after geometric rectification to global coordinate system using ArcGIS 10.1 software. The stream order map is given in figure 2. The purpose of this work is also, to identify the holistic stream properties and hydrological behavior, from the measurement of various morphometric attributes, which gives the impetus to forecast the river discharge, drainage basin characteristics and simulation (Sarmah *et al.*, 2012).

The linear, areal and relief aspects for Kanakanala Reservoir Subwatershed were computed, using standard methods and formulae are listed, respectivelyinthetable1, 2 and3.

Table 1: Formulae Used for the Computation of Linear Parameters

Sr. no.	Parameters	Symbol	Unit	Formula/Definition	Description	Reference
Linear Aspects						
1	Stream Order		Dimensionless	Hierarchical Rank	-	Strahler (1964)
2	Basin length	L_b	Km	Maximum length of the basin measured from the outlet	-	Schumm (1956)
3	Average basin width	B	Km	$B = \left(\frac{A}{L_b}\right)$	A=basin area (km^2) and L_b =basin length (km)	-
4	Bifurcation ratio	R_b	Dimensionless	$R_b = \left(\frac{N_u}{N_{u+1}}\right)$	N_u =number of stream segments of order 'u' and N_{u+1}=number of stream segments of next higher order 'u+1'	Schumm (1956)
5	Stream length	L_u	Km	Length of the stream	-	Horton (1945)
6	Stream length ratio	R_L	Dimensionless	$R_L = \frac{\bar{L}_u}{\bar{L}_{u-1}}$	$\bar{L}_u$= average length of stream of order u $\bar{L}_{u-1}$=average length of stream of order u-1	Horton (1945)
7	Length of overland flow	L_g	Km	$L_g = \frac{1}{2D_d}$	L_g = length of overland flow D_d =drainage density (km/km^2)	Horton (1945)

Table 2: Formulae Used for the Computation of Areal Parameters

S. No	Parameters	Symbol	Unit	Formula/Definition	Description	Reference
1	Form factor	R_f	Dimensionless	$R_f = \frac{A}{L_b^2}$	A =area of the basin (km^2) and L_b = length of the basin (km)	Horton (1945)
2	Shape factor	S_b	Dimensionless	$S_{b=L^2{}_b/A}$	L=Basin length (km), A=Area of the basin (km^2)	Horton (1945)
3	Circulatory ratio	Rc	Dimensionless	$R_c = \frac{Au}{A_c}$	A_u =area of the basin (km^2), A_c =area of circle having equal perimeter of basin	Miller (1953), Strahler (1964)
4	Circulatory index	Ic	Dimensionless	$I_C = \frac{A}{A_c} = \frac{4\pi A}{P^2}$	A=area of the basin (km^2), P=basin perimeter (km) and A_c =area of the circle having equal perimeter as that of drainage basin (km^2)	Miller (1953), Strahler (1964
5	Compactness coefficient	Cc	Dimensionless	$C_C = \frac{P}{2\sqrt{\pi A}}$	A =area of the basin (km^2) and P = basin perimeter (km)	-
6	Elongation ratio	R_e	Dimensionless	$R_e = \left(\frac{D_C}{L_b}\right) = \left(\frac{2}{L_b}\right)\sqrt{\frac{A}{\pi}}$	D_c = diameter of the circle having same area as that of the basin (km), Lb = basin length (km)	Schumm (1956)
7	Texture ratio	R_t	No. km^{-1}	$R_t = \left(\frac{N_1}{P}\right)$	N_1 =number of first order streams and P = basin perimeter (km).	Horton (1945)
8	Drainage density	D_d	km/km^2	$D_d = \frac{\sum_{i-1}^{K}\sum_{i-1}^{N} L_u}{A}$	D_d =drainage density (km^{-1}), L_u =length of all stream segments (km), A_u = area of the basin (km^2), K =trunk order of the stream segment and N = total number of streams.	Horton (1932, 1945)
9	Stream frequency	Fs	km^{-1}	$F_u = \left(\frac{N}{A}\right)$	N =total number of stream segments of all orders, A =basin area (km^2).	Horton (1932, 1945)
10	Constant of channel maintenance	C	km^2/km	$C = \frac{1}{D_d}$	C = constant of channel maintenance Dd =drainage density (km^{-1})	Schumm (1956)

Table 3: Formulae Used for the Computation of Relief Parameters

Sl. No.	Parameters	Symbol	Unit	Formula/Definition	Description	Reference
1	Watershed relief	H	M	Elevation difference between highest and the lowest point	-	Strahler (1952)
2	Relative relief	R_R	%	$R_R = \frac{H}{L_p} \times 100$	R_R=Relative relief (%), H=watershed relief (m) and Lp=Length of perimeter (m)	Melton (1957)
3	Relief ratio	R_r	Dimensionless	$R_r = \left(\frac{H}{L_b}\right)$	H =watershed relief (m) and L_b =basin length (m)	Schumm (1956)
4	Ruggedness number	R_N	Dimensionless	$R_N = H \times D_d$	H = watershed relief (km) and Dd=drainage density (km/km^2)	Schumm (1956)
5	Geometric number		Dimensionless	Geometric number $= \frac{H \times D_d}{S_g}$	H = watershed relief (km), D_d=drainage density (km/km^2) and S_g =slope of ground surface (Sg=2.H.Dd)	Suresh (2012)

RESULTS AND DISCUSSIONS

Linear Aspects of Drainage Network

It refers to the analysis of stream order, stream number, bifurcation ratio, stream length ratio and length of overland flow. The streams present in the study area have been ordered (figure 2) using Strahler's system of stream ordering (Strahler, 1957). The results of the linear aspects are presented in table 4.

Stream Order

Stream ordering is the first step of quantitative morphometric analysis. The stream taxonomy system developed by Horton (1945) and complemented by Strahler (1952), has been adopted because; it is having a genetic basis and allows comparative analysis of drainage basins (Sharma, 2014). In the Strahler method for ordering the network, all the "fingertips" tributaries are nominated as first order streams and where two of them connect, they form a second order stream. Similarly, two second order streams join to form a third order stream and so on to the streams of fourth, fifth and higher order. If a sufficiently large sample is treated, order number is directly proportional to the size of contributing watershed, channel dimensions and to the stream discharge (Sarmah *et al.*, 2012), because order number is dimensionless. As water travels from headwater stream towards the mouth, streams gradually increase their width and as well as depth with increasing amount of water discharge (Sarmah *et al.*, 2012). The trunk stream, through which all discharge of water and sediment passes is therefore the stream segment of highest order (Nagaraju *et al.*, 2015) and is associated with greater discharge. The drainage pattern in the Kanakanala Reservoir Subwatershed was found dendritic pattern, which indicates that, the study area is occupied by homogenous rocks. Drainage pattern replicates surface characteristics, including subsurface formation (Horton, 1945).

Horton (1945), Schumm (1956) and others discussed the relationship between stream order and factors, composing a drainage basin. The most important results contains, as stream order increases, the number and the mean gradient of streams decrease in an inverse geometric ratio and as stream order increases, the mean length of streams and the mean area of drainage basin increase. The shortest and the steepest streams have the smallest drainage basins (Sharma, 2014). The higher amount of stream order indicates lesser permeability and infiltration (Wandre and Rank, 2013), similarly the lesser amount of stream order indicates higher permeability and infiltration. The stream orders in Kanakanala Reservoir Subwatershed have gone up to V orders. The stream order map of the Kanakanala Reservoir Subwatershed is shown in figure 2.

Stream Length (Lu)

Stream length is one of the most significant hydrological features of the drainage basin as it reveals surface runoff characteristics (Dubey *et al*., 2015). It is indicative of the contributing area of the basin of that is given stream order (Choudhari *et al*., 2014). Total stream length could be obtained, by adding lengths of all streams in a particular order (Nagaraju *et al.*, 2015). The total stream length of stream segment is maximum, in the first order stream (282.04 km) and it decrease as the stream order increase as 86.26 km, 54.26 km, 28.26 km and 12.11 km, respectively for II, III, IV and V. This might be due to the streams flowing from a region of higher to lower altitude, change in rock type and moderately steep slopes and probable uplift across the basin (Vittala *et al*., 2005 and Chopra *et al*., 2005).

The regression line of stream order and log of stream number is shown in figure 3, which was drawn to validate the Horton's law of stream numbers. The coefficient of determination was obtained about 0.99. An R^2 of 1 indicated that the regression line perfectly fits the data. The linear pattern indicates the homogenous rock material subjected to weathering-erosion characteristics of the watershed (Sharma, 2014). Deviation from its general behavior indicates that the terrain is characterized by variation in lithology and topography (Sharma, 2014). The regression line of log of cumulative stream lengths and stream order was drawn, to validate the Horton's law of stream lengths, which is shown in figure 4. The coefficient of determination was found about 0.86.

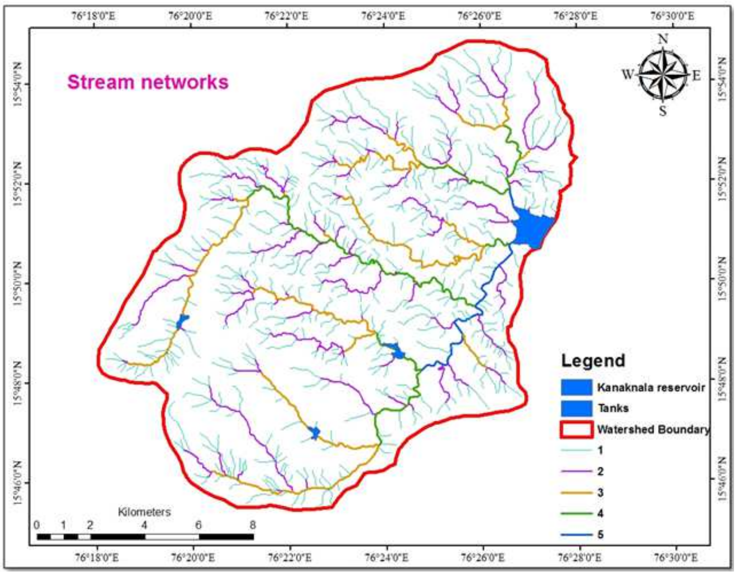

Figure 2: Drainage Map of the Kanakanala Reservoir Subwatershed

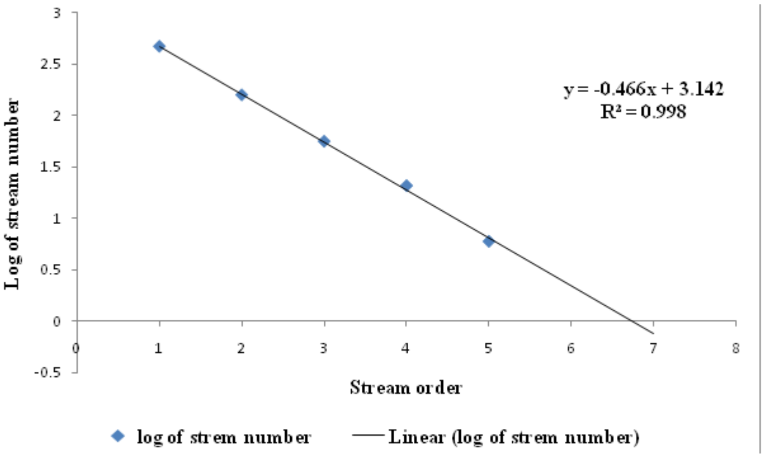

Figure 3: Regression of Logarithm of Number of Streams and Stream Order

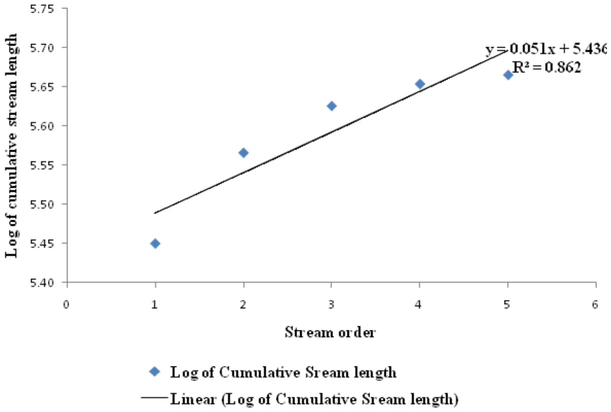

Figure 4: Regression of Logarithm of Cumulative Stream Length and Stream Order

Bifurcation Ratio

Bifurcation ratio is associated to the branching pattern of a stream network and is defined as the ratio between the total numbers of stream segments of one order, to that of the next higher order in a drainage basin (Schumn, 1956). Horton (1945) considered bifurcation ratio is an index of reliefs and dissections. Bifurcation ratio influences the landscape morphometry and plays significant control, over the "peak" of the runoff hydrograph especially in homogeneous bedrock, (Chorley, 1957). Strahler (1957) confirmed that, bifurcation ratio shows only a small variation for different regions with different environments, except where powerful geological control dominates. In 1964 he also noted that, the shape of a drainage basin might possibly affect stream discharge characteristics.

Bifurcation ratios normally range between 3.0 and 5.0 for basins in which the geologic structures do not distort the drainage pattern (Suresh, 2012). The lower values of R_b are characteristics of the watersheds, which have suffered less structural disturbances (Strahler, 1964). High bifurcations with long narrow basins would be expected, to have attenuated flood discharge periods, whereas round basins of low bifurcation ratio would be expected to have sharply peaked flood discharges. For the Kanaknala Reservoir Subwatershed the mean bifurcation ratio is found 2.98 which indicated that, watershed has suffered less structural disturbance (Choudhari *et al*., 2014). Similar results were obtained by, Waikar and Nilawar, 2014; Eze and Efiong, 2010 and Choudhari *et al*., 2014. All linear parameters estimated for Kanakanala Reservoir Subwatershed are listed in table 4.

Table 4: Linear Parameters of the Kanakanala Reservoir Subwatershed

<table>
<tr><th>S. No</th><th colspan="3">Parameters</th><th colspan="5">Estimated Values</th></tr>
<tr><td>1</td><td colspan="3">Area</td><td colspan="5">19500 ha</td></tr>
<tr><td>2</td><td colspan="3">Perimeter</td><td colspan="5">59035.6 m</td></tr>
<tr><td>3</td><td colspan="3">Length of Basin</td><td colspan="5">17298 m or 17.29 km</td></tr>
<tr><td>4</td><td colspan="3">Average basin width</td><td colspan="5">11270 m or 11..27 km</td></tr>
<tr><td>5</td><td colspan="3">Length of overland flow</td><td colspan="5">2109 m</td></tr>
<tr><td rowspan="6">6</td><th>Stream Orders</th><th>Number of Stream Order</th><th>Stream Length (L_u)</th><th>Average Stream Length</th><th colspan="2">Bifurcation Ratio (R_b)</th><th colspan="2">Stream Length Ratio (L_u)</th></tr>
<tr><td>I</td><td>465</td><td>282040.63 m</td><td>606.54 m</td><td>B R_1</td><td>2.90</td><td>RL_1</td><td>0.30</td></tr>
<tr><td>II</td><td>160</td><td>86269.02m</td><td>539.18 m</td><td>B R_2</td><td>2.86</td><td>RL_2</td><td>0.63</td></tr>
<tr><td>III</td><td>56</td><td>54259.94 m</td><td>968.93 m</td><td>B R_3</td><td>2.67</td><td>RL_3</td><td>0.52</td></tr>
<tr><td>IV</td><td>21</td><td>28263.94 m</td><td>1345.90 m</td><td>B R_4</td><td>3.5</td><td>RL_4</td><td>0.42</td></tr>
<tr><td>V</td><td>6</td><td>12118.23m</td><td>2019.71 m</td><td>Average</td><td>2.98</td><td>Average</td><td>0.46</td></tr>
</table>

Stream Length Ratio

If there is a change of stream length ratio from one order to another order, it indicates their late youth stage of geomorphic development (Singh and Singh, 1997). The variation in stream length ratio is due to change in slope and topography (Moharir and Pande, 2014). The mean stream length ratio of the Kanakanala Reservoir Subwatershed is found 0.46 and similar results were obtained, by Khare *et al*., (2014) and Nagaraju *et al*., (2015).

Length of Overland Flow

It is one of the most important independent variables, affecting both the hydrological and physiographical developments of the drainage basin (Horton, 1945). He expressed it as equal to half of the reciprocal of Drainage Density (D_d). Length of overland is used to explain the length of flow of water over the ground before it becomes concentrated in definite stream channels. Generally higher value of length of overland flow is indicative of low relief, where as low value is an indicative of high relief (Kanth and Hassan, 2012). The shorter the length of overland flow, the quicker the surface runoff from the streams. The watershed having length of overland flow greater than 0.25 are under very less structural disturbance because of low runoff and higher overland flow (Patil *et al.*, 2015). For Kanakanala Reservoir Subwatershed, the length of overland flow is found 2.1 km and similar results were obtained, by Waikar and Nilawar, (2014).

AERIAL ASPECTS OF DRAINAGE BASIN

This aspect of morphological study of drainage basin includes the description of arrangement of areal elements. The evaluation of basin shape has significant importance, to predict its effect on stream-discharge relationships. The results obtained are listed in table 5.

Form Factor (R_f)

It is the numerical index normally used to represent different basin shapes, with values to range from (0.1 to 0.8) (Thronbury, 1966) and it indicates the flow intensity of a basin. If the form factor value is 0.7854 then it represents a perfectly circular basin (Choudhari *et al.*, 2014), if it is nearer to 0 indicates a highly elongated shape and the value that is closer to 1 indicates circular shape. The drainage basins with high form factor have high peak flow for shorter duration whereas elongated basin with low form factor would have a flatter peak flow of longer duration. The form factor would be comparatively higher, if the basin is wider. Consequently, much narrower basins have low form factor values (Sharma, 2014). In the present study, the value of R_f is estimated about 0.65 (which is less than 0.7854), showing the nature of the watershed to be nearly circular and similar value obtained by (Nagal *et al*., 2014).

Circulatory Ratio (Rc)

It is influenced more by the length, frequency and gradient of streams than slope and drainage pattern of the basin (Strahler, 1957), with value ranging from 0.2 to 0.8. It is one of the significant ratios, which indicates the stage of dissection in the study region. Its low, medium and high values are correlated with youth, mature and old stage of the cycle of the tributary of watershed respectively (Aravinda and Balakrishna, 2013). If, the Rc values approaching 1, which indicates that, the basin shapes are like circular with uniform infiltration and takes longer time to reach excess water at basin outlet (depends on the prevalent geology, slope and land cover). For the present study the value of circulatory ratio is found 0.7 and similar results were found by Patil *et al.*, (2015) and Waikar and Nilawar, (2014) by indicating that, the watershed is nearly circular in shape.

Compactness Coefficient (Cc)

It is used to express the relationship of a basin with that of a circular basin having the same area as the basin (Kanth and Hassan, 2012). It is independent of size of watershed and dependent on the slope (Pareta and Pareta, 2012). 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 (Ali and

Ali, 2014). The compactness coefficient (Cc) for the Kanakanala Reservoir Subwatershed is found 1.19 and similar results were found by Pareta and Pareta, (2012).

Elongation Ratio (R_e)

Elongation ratio (R_e) is a very significant index, in the analysis of watershed shape which helps to give information about the hydrological character of a basin (vinoth *et al*., 2014). The values of re generally vary from 0.6 to 1.0, over a wide variety of climatic and geologic types. Values of re are close to 1 for areas of very low relief and varies between 0.6 to 0.9, for regions of strong relief and steep ground slope (patil *et al*., 2015). The values of elongation ratios could be grouped into four categories namely (a) circular (>0.9), (b) oval (0.9 to 0.8), (c) elongated (0.8 to 0.7) and (d) less elongated (<0.7) (choudhari *et al*., 2014). Thus, the higher the value of elongation ratio the more circular shape of the basin and vice-versa. The value of elongation ratio (re) of the study area is 1, which indicated the shape of watershed is nearly circular.

Texture Ratio (R_t)

It indicates the relative spacing of the drainage lines and also it is the measure of the total number of segments of all order per perimeter of that area (Horton, 1945). Texture ratio depends on a number of natural factors such as climate, vegetation, rock, rainfall, soil type, infiltration capacity and relief (Choudhari, *et al*., 2014). The drainage density and drainage frequency have been collectively defined as drainage texture. Based on the values of Smith in 1950 classified the ranges as

- 0-4 – Coarse
- 4-10 – Intermediate
- 10-15 – Fine
- >15 – Ultra Fine (bad l and topography)

For Kanakanala Reservoir Subwatershed, the texture ratio is about 7.9 indicated the intermediate texture lying between coarse and fine.

Drainage Density (D_d)

It is the important element of drainage analysis which provides a better quantitative expression to the dissection and analysis of land forms (Srivastava *et al*., 2014). Drainage density is affected by the factors that control the resistance to weathering, permeability of rock formations, vegetations and climate. Horton (1932) introduced drainage density (D_d) into literature as an expression to indicate the closeness of spacing of channels so that, it determines the time of travel by water. Drainage densities range from less than 5 km/km^2 in areas, where the slopes are gentle, low rainfall and permeable bedrock (e.g. sandstones). Similarly larger values *i.e*., more than 500 km/km^2 found in upland areas where rocks are impermeable, steep slopes and total rainfall is high (Sharma, 2014). The drainage density (D_d) of the study area is found 2.37 km/km^2 so that it falls less than 5 km/km^2 which indicates that the area has a gentle slope, low rainfall and permeable bedrock (Sharma, 2014). The value is in line with the Mittal (2002). The low value of drainage density influences greater infiltration and hence the wells in this region would have good water potential leading to higher specific capacity of wells vice versa (Aravinda and Balakrishna, 2013).

Stream Frequency (f)

It might be directly related to the lithological characteristics (Durgesh *et al*., 2015) and dependant more or less on the temperature and rainfall of the region (Vinoth *et al*., 2014). Stream frequency exhibits positive correlation with drainage density in the watershed, which indicates an increase in stream population with respect to increase in drainage density (Sharma, 2014). It provides an indication of the slope nature and the underlying rock formation of a basin. High stream frequency values (>5/km^2) indicate, occurrence of steep ground slopes with less permeable rocks, which facilitates greater runoff, less infiltration, sparse vegetation and high relief conditions (Kumar *et al*., 2010). In the present study the stream frequency is 3.36 km^{-1} and similar value obtained by Sharma, (2014).

Shape Factor (S_b)

It is inverse proportion with form factor and for Kanakanala Reservoir Subwatershed it is found to be 1.53, which is in confirmation with the value of Pareta and Pareta, (2012).

Constant of Channel Maintenance

It indicates the requirement of units of watershed surface to bear one unit of channel length (Durgesh *et al*., 2015). Constant of channel maintenance is not only depends on climatic regime, vegetation, rock type, permeability and relief but also on the duration of erosion and climatic history. For present study it is 0.42 km, which indicated that watershed is under the influence of high structural disturbance, steeps to very steep slopes, low permeability and high surface runoff (Dahiphale *et al*., 2014 and Kumar *et al*., 2010). In table 5 the results of aerial parameters are listed.

Table 5: Aerials Aspects of Kanakanala Reservoir Subwatershed

S. No	Aerial Factor	Estimated Values
1	Form factor (R_f)	0.65
2	Circulatory ratio (R_c)	0.7
3	Compactness Co-efficient (C_c)	1.19
4	Elongation ratio (R_e)	1.00
5	Texture ratio (R_t)	7.9 km^{-1}
6	Drainage density (D_d)	2.37 Km/ km^2
7	Stream frequency (F)	3.63 km^{-1}
8	Shape factor (S_b)	1.53
9	Constant of channel maintenance	0.42 km
10	Drainage texture	0.65

Drainage Texture (R_t)

It depends on a number of natural factors such as climate, rainfall, vegetation, rock, soil, infiltration capacity, relief and stage of development (Smith, 1950) and classified drainage texture into five classes *i.e*., very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8) (Ali and Ali, 2014). It is estimated 0.65 for the Kanakanala Reservoir Subwatershed, which falls under very coarse category.

RELIEF ASPECTS OF A DRAINAGE BASIN

Relief aspects of a drainage basin replicate the topographical gradient characteristics of the basin and give a bird's eye view of the whole area (Pophare and Balpande, 2014). These aspects are important in water resources studies, direction of stream flow analysis and denudation conditions of the watershed (Ali and Ali, 2014). The high relief value indicates low gravity of water flow as well as infiltration into the ground and high runoff conditions (Wandre and Rank, 2013). Relief aspects for the Kanakanala Reservoir Subwatershed are given in table 6.

Relief (H)

Basin relief is an important factor to understand the denudational characteristics (formed as a result of weathering, mass wasting and erosion caused by different exogenetic geomorphic agents such as glaciers, water, wind etc) of the basin (Sharma, 2014). It controls the stream gradient, therefore it influences flood patterns and the amount of sediment that could be transported from basin (Paulinus, *et al*., 2016). Hadley and Schumm (1961) concluded that, the sediment load increases exponentially with basin relief. Relief of Kanakanala Reservoir Subwatershed is found to be 211 m, similar result was obtained by (Bharadwaj *et al*., 2014).

Relief Ratio (R_h)

Schumm (1956) found that, 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 operating at the watershed slopes (Suresh, 2012). It was found that the higher ratios of relief indicated steep slope and high relief, while the lower ratios indicated the presence of basement rocks that are exposed in the form of small ridges and mounds with lower degree of slope (GSI, 1981). Relief ratio of the Kanakanala Reservoir Subwatershed found to be 0.0121, indicated that the discharge capability of watershed is very high and the groundwater potential is insufficient, similar value was obtained by Eze and Efiong, (2010) and Nagal *et al*., (2014).

Relative Relief (R_{hp})

It is an important morphometric variable, used for the overall assessment of morphological characteristics of terrain (Suresh, 2012). The relative relief for Kanakanala Reservoir Subwatershed is 0.35%, similar value was obtained by Sreedevi et al., (2009).

Ruggedness Number

It is used to define the slope steepness and length (Sarmah *et al*., 2012). If ruggedness value of basin is low, which implies that area is less prone to soil erosion and have intrinsic structural complexity with relief and drainage density (Pareta and Pareta, 2012). The calculated Ruggedness number of the Kanakanala Reservoir Subwatershed is 0.49, similar results were obtained by Mondal and Mistri, (2016), indicates the watershed was less soil erosion prone and has inherent structural complexity in association with relief and drainage density.

Geometric Number

Geometric number for the Kanakanala Reservoir Subwatershed is 0.5.

Table 6: Relief aspects of Kanakanala Reservoir Subwatershed.

S. No	Relief Aspects of Stream Network	Permissible Values
1	Relief (H)	211 m
2	Relative relief (R_{hp})	0.35%
3	Relief ratio (R_h)	0.0121
4	Ruggedness number	0.49
5	Geometric number	0.5

CONCLUSIONS

Computed values of Farm factor (R_f =0.65), Circulatory ratio (R_c=0.7) and Elongation ratio (Re=1) indicated that, the watershed is nearly circular in shape. The texture (7.9) indicated the intermediate texture, lying between coarse and fine were found. The drainage density (D_d=2.37 km/km^2) indicated that the area has a gentle slope, low rainfall and permeable bedrock (Sharma, 2014). From the entire study it is concluded that the analysis of the morphometric parameters by Remote Sensing (RS) and Geographical Information System (GIS) now a day has proved to be capable and quick tool for water resources planning, conservation and management. Meanwhile morphometric investigation is useful to bring an idea about rock structure, runoff, infiltration rate and erosion of the soil in the watershed so that we could make decision about watershed prioritization, soil and water conservation and management of natural resources etc. Finally the study suggests and recommended to develop best water usage mechanism for better application of the watershed.

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