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 (Rf=0.65), Circulatory ratio (Rc=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 (Dd=2.37 km/km²) 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

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.
Analysis of Hydrological Inferences through Morphometric Analysis: A Remote Sensing- GIS Based Study of Kanakanala Reservoir Subwatershed

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, respectively in the table1, 2 and 3.

Table 1: Formulae Used for the Computation of Linear Parameters

<table>
<thead>
<tr>
<th>Sr. no.</th>
<th>Parameters</th>
<th>Symbol</th>
<th>Unit</th>
<th>Formula Definition</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stream Order</td>
<td></td>
<td></td>
<td>Hierarchical Rank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Basin length</td>
<td>L_b</td>
<td>Km</td>
<td>Maximum length of the basin measured from the outlet</td>
<td></td>
<td>Strahler (1964)</td>
</tr>
<tr>
<td>3</td>
<td>Average basin width</td>
<td>B</td>
<td>Km</td>
<td>$B = \frac{A}{L_b}$</td>
<td>A=basin area (km²) and $L_b$=basin length (km)</td>
<td>Schumm (1956)</td>
</tr>
<tr>
<td>4</td>
<td>Bifurcation ratio</td>
<td>$R_b$</td>
<td>Dimensionless</td>
<td>$R_b = \frac{N_u}{N_{u+1}}$</td>
<td>$N_u$=number of stream segments of order $u$ and $N_{u+1}$=number of stream segments of next higher order $u+1$</td>
<td>Schumm (1956)</td>
</tr>
<tr>
<td>5</td>
<td>Stream length</td>
<td>L_s</td>
<td>Km</td>
<td>Length of the stream</td>
<td></td>
<td>Horton (1945)</td>
</tr>
<tr>
<td>6</td>
<td>Stream length ratio</td>
<td>$R_L$</td>
<td>Dimensionless</td>
<td>$R_L = \frac{L_u}{L_{u-1}}$</td>
<td>$L_u$=average length of stream of order $u$ and $L_{u-1}$=average length of stream of order $u-1$</td>
<td>Horton (1945)</td>
</tr>
<tr>
<td>7</td>
<td>Length of overland flow</td>
<td>L_o</td>
<td>Km</td>
<td>$L_o = \frac{1}{2D_o}$</td>
<td>$L_o$=length of overland flow and $D_o$=drainage density (km/km²)</td>
<td>Horton (1945)</td>
</tr>
</tbody>
</table>
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 (Vittal 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 (Schumm, 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 Kanakanala 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>
<thead>
<tr>
<th>S. No</th>
<th>Parameters</th>
<th>Estimated Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Area</td>
<td>19500 ha</td>
</tr>
<tr>
<td>2</td>
<td>Perimeter</td>
<td>59035.6 m</td>
</tr>
<tr>
<td>3</td>
<td>Length of Basin</td>
<td>17298 m or 17.29 km</td>
</tr>
<tr>
<td>4</td>
<td>Average basin width</td>
<td>11270 m or 11.27 km</td>
</tr>
<tr>
<td>5</td>
<td>Length of overland flow</td>
<td>2109 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stream Orders</th>
<th>Number of Stream Order</th>
<th>Stream Length ($L_u$)</th>
<th>Average Stream Length</th>
<th>Bifurcation Ratio ($R_b$)</th>
<th>Stream Length Ratio ($L/L_u$)</th>
</tr>
</thead>
<tbody>
<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>
</tr>
<tr>
<td>II</td>
<td>160</td>
<td>86269.02 m</td>
<td>539.18 m</td>
<td>B $R_2$</td>
<td>2.86</td>
</tr>
<tr>
<td>III</td>
<td>56</td>
<td>54359.94 m</td>
<td>968.93 m</td>
<td>B $R_3$</td>
<td>2.67</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>
</tr>
<tr>
<td>V</td>
<td>6</td>
<td>12118.23 m</td>
<td>2019.71 m</td>
<td>Average</td>
<td>2.98</td>
</tr>
</tbody>
</table>

Length of Overland Flow

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).

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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 flow 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, whereas low value is 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 \( (R_c) \)**

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 \( R_c \) 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 \( (C_c) \)**

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 (Re)**

Elongation ratio (Re) 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 (Rt)**

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 land and topography)

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

**Drainage Density (Dd)**

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 (Dd) 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/km² in areas, where the slopes are gentle, low rainfall and permeable bedrock (e.g. sandstones). Similarly larger values i.e., more than 500 km/km² found in upland areas where rocks are impermeable, steep slopes and total rainfall is high (Sharma, 2014). The drainage density (Dd) of the study area is found 2.37 km/km² so that it falls less than 5 km/km² 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/km²) 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 (Sb)

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

<table>
<thead>
<tr>
<th>S. No</th>
<th>Aerial Factor</th>
<th>Estimated Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Form factor (Rf)</td>
<td>0.65</td>
</tr>
<tr>
<td>2</td>
<td>Circulatory ratio (Rc)</td>
<td>0.7</td>
</tr>
<tr>
<td>3</td>
<td>Compactness Co-efficient (Cc)</td>
<td>1.19</td>
</tr>
<tr>
<td>4</td>
<td>Elongation ratio (Re)</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>Texture ratio (Rt)</td>
<td>7.9 km⁻¹</td>
</tr>
<tr>
<td>6</td>
<td>Drainage density (Dd)</td>
<td>2.37 Km/ km²</td>
</tr>
<tr>
<td>7</td>
<td>Stream frequency (F)</td>
<td>3.63 km⁻¹</td>
</tr>
<tr>
<td>8</td>
<td>Shape factor (Sb)</td>
<td>1.53</td>
</tr>
<tr>
<td>9</td>
<td>Constant of channel mainte</td>
<td>0.42 km</td>
</tr>
<tr>
<td>10</td>
<td>Drainage texture</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Drainage Texture (Rt)

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.

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

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.

REFERENCES


Impact Factor (JCC): 5.9857

NAAS Rating: 4.13


