GEOMORPHOLOGICAL ANALYSIS OF UPPER KARHA WATERSHED IN SEMI-ARID AREA, MAHARASHTRA, INDIA

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ABSTRACT

In the present paper, an attempt has been made to study the quantitative geomorphological analysis of Upper Karha watershed, Western Maharashtra, India. Geomorphological parameters are calculated on the basis of Survey of India toposheets 47F-15, 47 J-3, 4 and 7at 1: 50000 scale, and ASTER DEM (2016) with 30m spatial resolutions. The morphometric analysis of study area has been carried out using Arc GIS 9.3 software. The study area covers 400 sq.km. Morphological characteristics of the watershed as appear in shape, size, number, order, length, Dd, Sf, Rb, Fs, T, Rc are derived to trace its usefulness for surface development. The present study involves Geographic Information System (GIS) analysis technique to evaluate and compare linear, relief and aerial morphometry of Upper Karha watershed. Upper Karha watershed is basically 6th order watershed and mainly dendritic to sub dendritic drainage pattern. Drainage density and texture of the drainage basin is 3.15 km/km2, 17.84 respectively. The drainage frequency of Upper Karha watersheds is 4.37 whereas the mean bifurcation ratio is 3.87. Hence from the study it can be conclude that GIS technique proves to be competent tool in morphometric analysis.

Keywords: Morphometric analysis, ASTER DEM, Arc GIS, Drainage frequency, Drainage density, Surface Development.

I. INTRODUCTION

The water scarcity and soil erosion are the global issues arising due to rapid urbanization and increasing population, changing land cover and changing climate conditions. The available surface and ground water resources are inadequate to meet the growing water demands which unable to fulfil demand and supply ratio all over the world. The demand for water has increased over the years, due to which the assessment of quantity and quality of water for its optimal utilization is necessary. Identification and outlining of various ground features such as geological structures, geomorphic features and their hydraulic characteristics may serve as direct or indirect indicators of the presence of ground and surface water (Zende et al., 2011). The geomorphic conditions are essential pre-requisites in understanding the water bearing characteristics of hard rocks. The role of rock types and geologic structure in the development of stream networks can be better understood by studying the nature and type of drainage pattern and by a quantitative morphometric analysis. The morphometric parameters of a watershed are reflective of its hydrological response to a considerable extent and can be helpful in synthesizing its hydrological behaviour (Zende et al., 2011). The relationship between the different aspect and characteristics of drainage basin can be understand by the drainage morphology which proves most satisfactory method that helps in appropriate planning of watershed management. Also to make a comparative evaluation of different drainage basins developed in various geologic and climatic regimes.

The term morphometry is the measurement and mathematical analysis of configuration of earth's surface, shape and dimension of its landform (Clark 1966). In the present study, Geographic Information System technique has been used to assessing various terrain and morphometric parameter of drainage basins and watershed. Linear, relief and aerial morphometric parameters are evaluated for development planning of sub watershed in upper Karha watershed.

Linear parameters

Linear aspect of drainage basin includes stream order, stream length, Mean stream length, stream length ratio bifurcation ratio and mean bifurcation ratio are the most common attribute.

The number of stream in various order is countered and total number of segment (N_u) in each order (u) was computed on basis of Horton (1945) method as modified by Strahler A.N. Stream order in this drainage basin are numbered upto 6th order (Figure No. 2).

Stream length is indicative of chronological development of stream segments including tectonic disturbances if any. Generally, higher the order, longer the length of stream, in nature. The equation used for calculation of stream length is same as the perimeter calculation.

Stream length ratio (Rl) is the ratio between the lengths of streams of a given order to the total length of streams in the next order (Horton 1945). Rl tends to be constant throughout the successive stream orders of the basin.

Bifurcation ratio is the ratio between the number of stream segments of a given order and the number of stream segments of next higher order. Bifurcation ratios characteristically range between 3.0 and 5.0 for watersheds in which the geologic structures distort the drainage pattern. The lower values of Rb are characteristic of less structural disturbances (Strahler 1964) and the drainage pattern has not been distorted because of the structural disturbances (Nag 1998).

Areal parameters

Drainage density (Dd) is defined as total length of streams in a catchment per unit area. High drainage density of a drainage basin indicates high run-off and consequently low infiltration rate whereas, low drainage density of an area implies low run-off and high infiltration.

Drainage texture (T) is an expression of the relative channel spacing in a fluvial dissected terrain. T is the product of Dd and Fs. It depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development of a basin (Smith 1950).

Stream frequency (Fs) is the ratio of total number of streams (Nu) in a basin to the basin area (Horton 1945). It is a measure of closeness of drainage. High drainage frequency means more surface run-off and low drainage frequency means more percolation and hence more groundwater potential (Sreedevi et al. 2009).

Elongation ratio (Re) is defined by Schumm (1956) as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. The values of Re generally vary from 0.6 to 1.0. Values close to 1.0 are typical of regions of very low relief, whereas values in the range 0.6–0.8 are usually associated with high relief and steep ground slope (Strahler 1964).

Circularity ratio (Rc) is the ratio of the area of the basin to the area of a circle having the same circumference as perimeter of the basin (Miller 1953). The basin having circulatory value more than 0.5 is having more circular area that characterized by high to moderate relief and drainage system is structurally controlled.

Form factor (F_f) of a drainage basin is expressed as a ratio between the area of the basin and the square of the basin length (Horton 1945). The basin with high Ff has high peak flows of shorter duration, whereas elongated watershed with low form factor has lower peak flow of longer duration (Chopra et al. 2005).

Drainage density (Dd) is one of important indicator of land form. It provides a numerical measurement of landscape dissection and runoff potential. It also indicates closeness of spacing of streams. Low Df, value indicates low relief and high infiltration capacity of the bed rock.

Texture ratio (T) is dependent on the underlying lithology, infiltration capacity and relief aspect of the terrain.

Drainage texture (Rt) is the total number of stream segments of all orders per perimeter of that area (Horton, 1945). The Rt value depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development (Smith, 1950).

Stream frequency (Fs) is the ratio of the total number of stream segments of all the orders in the watershed to the total area of the watershed (Horton, 1932). The Fs value exhibit positive correlation with the drainage density and related to permeability, infiltration capacity and relief of sub-watershed.

Infiltration number (IF) of a drainage basin is the product of drainage density and stream frequency. It is a parameter that gives an idea of the infiltration characteristics of the basin. The higher value indicates low infiltration and high runoff whereas its lower value indicate higher infiltration and low run off with shallow depth to water table (Das and Mukherjee, 2005).

Constant of channel maintenance (C) is a measure of texture similar to the drainage density. It is equal to the reciprocal of drainage density and is a measure of the minimum area required for the development of a drainage channel (Schumn, 1956). Constant of channel maintenance depends on basin relative relief, lithology and climate. It decreases with increasing erodibility.

Length of overland flow Horton (1945) defined the term length of overland flow (Lg) as the length of flow of water over the ground before it becomes concentrated in definite stream channels. The average length of overland flow is equal to half the reciprocal of the average drainage density (1/2 Dd). The Lg averages the down slope flow paths, from the drainage divide to the nearest channel and also points to the efficiency of the drainage in the basin.

Relief parameters

Basin relief (R) is an important factor in understanding the elevation characteristics of a basin. The difference in elevation between highest and lowest points on the basin is called basin relief. It is a parameter that determines the stream gradient and influences flood pattern and volume of sediment that can be transported (Hadley and Schumm 1961).

Relief ratio (Rh) is the ratio between total relief (R) of the basin and its longest dimension parallel to the principal drainage line (Lb). It measures the overall steepness of the drainage basin and is an indicator of the ntensity of erosion processes operating on the slopes of the basin.

Ruggedness number (Rn) is expressed as the product of basin relief and drainage density (Strahler 1952). The basins having high Rn values are highly susceptible to erosion.

II. STUDY AREA

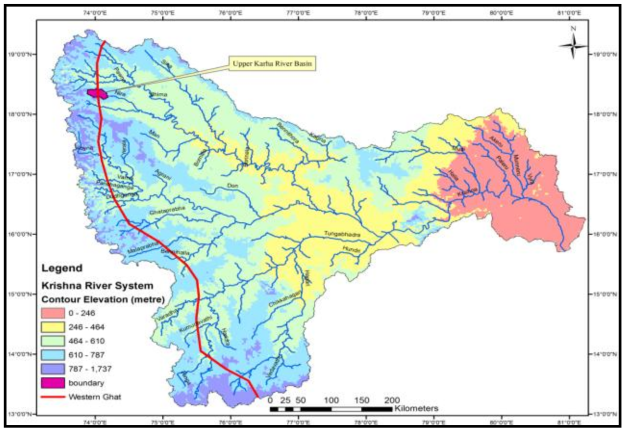

Figure 1 Location Map of Upper Karha Watershed

The study area lies in Western Maharashtra state bounded by Latitude 18^0 14' 24" to 18^0 25'58" N and Longitude 73^0 52'9" to 74^0 11' 51"E falling in part survey of India topographical sheet no 47 F/15, 47J/-3, 4 and 7on the scale 1:50,000 (Figure 1) The study area is a part of Pune and Baramati districts encompassing an area of 400 km2. The study area comes under the semiarid region of the agro-climatic zone IV-A of the state of Maharashtra. According to latest classification by CGWB, this watershed area is declared as semi critical area. The Upper Karha watershed does not have any perennial source of water. The study area is largely dependent on rainfall for water supply. The average annual rainfall ranges 350 mm to 650mm and more than 80% occurs mainly during the monsoon season, i.e. from June to September. The Karha river originates near Garade Village in Saswad Tehsil and gets unite in the main stream of the Neera river near the village Songaon in Baramati Tehsil.

III. METHODOLOGY

Entire study area is delineated from rectified; mosaiced SOI topographic maps no. 47 K –7, 10, 11 on the scale 1:50,000 on polyconic projection system with the help of Arc-GIS software. Drainage network was digitized (Figure No. 2) and stream order was calculated using method proposed by (Stahler 1964). Arc-GIS 9.3 software was used for computing all morphometric parameter (Table - 1)

IV. HYPOTHESIS

Different segments of upper Karha network exhibit different morphometric and hydrologic characteristics and relationship. These will analyses by ordering scheme. This scheme is applied to prepare different morphometric tables and it helps for deriving idea for suggesting drainage capacity and discharge form the segment which helps to develops Decision Support System (DSS) for water and soil conservation.

V. RESULTS AND DISCUSSION

Stream number (Nu)

The number of stream in various order is countered and total number of segment (N_u) in each order (u) was computed on basis of Horton (1945) method as modified by Strahler. Stream order in this drainage basin are numbered up to 6th order (Figure No. 2).

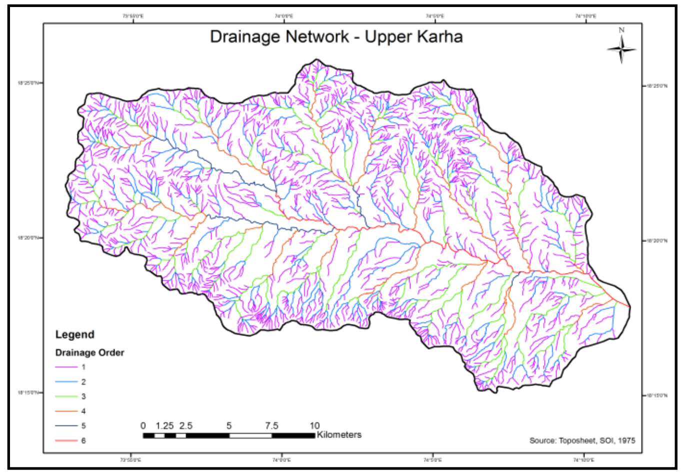

Figure 2 Drainage Network

Soil erosion is more for the number of streams in particular order means the first and second order having more number of streams are more prone to erosion. The details of stream characteristics confirm Horton's first law (1945).

Stream length (L_u)

Stream length (L_u) has been computed based on the law proposed by Horton (1945). 1st order (1296) and 2nd order (399) streams are mostly in highly elevated with moderate slope while higher order stream occurred in low elevation with deep dissects. Generally higher the order longer the length of stream is noticed in the nature. Longer length of stream is advantages over the shorter length as the entire water collects from wider area and greater option for construction a bund along the length.

Mean Stream length (Lsm)

It is observed form Table 4 that L_{sm} value is 0.72. Stream length ratio and analysis is given in Table 3. In general, mean length of channel segments of a given order is more than that of the next lower order, but less than the next higher order. It indicates that the watershed evolution follows erosion laws acting on geologic material with homogeneous weathering erosion characteristics (Nag and Chakraborty 2003).

Bifurcation ratio (Rb)

The Bifurcation ratio is an indicative tool for the shape of basin. Elongated basins have low R_b value while circular basins have high R_b value (Morisawa 1985). The low R_b value of Upper Karha watershed is 3.87 which indicate systematic branching pattern of streams with elongated shape of watershed.

Basin area

The basin area is calculated with the help of Arc GIS 9.3 tool. It is calculated as 400 sq.km.

Drainage density (D_d)

It is one of important indicator of land form. It provides a numerical measurement of landscape dissection and runoff potential. In present study drainage density (D_d) is 3.15. High D_f, value indicates high relief and low infiltration capacity of the bed rock.

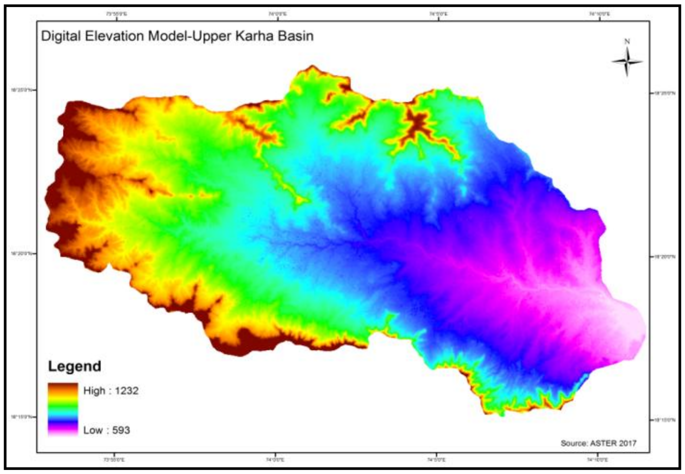

Figure 3 DEM of Study Area

Stream frequency (Fs)

It is 4.37 of Upper Karha watershed reflects moderate ground slope associated with moderately permeable rocks.

Texture ratio (T)

In the present study area, texture ratio (T) of Upper Karha watershed is 13.72 and categorized as moderate to fine texture in nature which reflects less infiltration.

Form factor (R_f)

The value of Form factor (R_f) has direct relation to stream flow and shape of watershed. Upper Karha watershed has high R_f value 0.34. This shows drainage basin is very elongated in nature with less side flow for shorter duration and high main flow for longer duration.

The circulatory ratio (R_C)

The circulatory ratio (R_C) is influenced by the length and frequency of stream, geological structure, land use / land cover, climate, relief and slope of the basin. The R_c value is 0.52 it indicates that watershed is elongated in nature.

Length of over land

The shorter length of overland flow, the quicker surface runoff will enter the stream in the present study the length of overland flow is 0.16. It indicates that the runoff is more due to short length of over land flow.

Constant Channel Maintenance (C)

The constant chanel Maintenance (C) of upper Karha watershed is 0.32, it indicates of high structural disturbance, steep to very steep slope with high surface runoff.

Elongation ratio (Re)

Elongation ratio (Re) of the upper Karha watershed is 0.66. According to Strahler (1964), Re values close to 1.0 are typical of regions of very low relief, whereas values in the range of 0.6–0.8 are usually associated with high relief and moderate to steep ground slope.

Infiltration number (IF)

It is a parameter that gives an idea of the infiltration characteristics of the basin. The higher value of 13.72 indicates low infiltration and high runoff .

Basin relief

Basin relief of the upper Karha watershed is 639m. High relief areas are mainly found at the western part of the watershed. High relief values indicate low infiltration and high run-off conditions.

Relief Ratio (Rh)

The relief ratio value 1.87 indicates that the watershed have steep to moderate slope having high flow velocity.

Ruggedness Number (Rn)

The higher value 4.93 shows the peak discharge rates are likely to be higher and indicated the watershed is susceptible to erosion (Chitra et al., 2011).

VI. CONCLUSION

Areal, Linear and Relief properties for the quantitative analysis of morphometric parameter, using GIS software is found to be immense utility in drainage basin, elevation, watershed prioritization for soil and water conservation, flood prediction and natural resources management. Application of Morphometric approach revealed that there are total 1748 streams grooved with each other from order 1^{st} to 6^{th} sprawled over 400 km^2 area of the catchment. Detailed study of upper Karha watershed gives a useful direction for surface runoff and helps for natural resource development. Bifurcation ratio indicates that the drainage has covered by impermeable sub surface and high mountainous relief. Circulatory ratio, elongation ratio shows watershed have high slope and high peak flow. Texture ratio gives an idea about infiltration capacity and relief aspect of terrain. The higher ruggedness number indicates higher soil erosion susceptibility The study area exhibits dendritic to sub dendritic drainage pattern and is classified as moderately sloping and high runoff zone which give rise to high drainage discharge. Thus study shows that the morphometric analysis using GIS helps to understand terrain parameters which lead to finalize watershed development planning and management with respect to water and soil conservation.

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