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The Significance Impact Assessment of Morphological Parameters on Watershed: A Review

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ABSTRACT

Watershed morphological analysis is momentous for controlling floods risk, forethought and management of the watershed area, as well as it is foremost useful to perceive catchment hydrology. Remote sensing and geographic information system are used in recent times as a tool for watershed delineation and its planning. Many types of input parameters generally use for watershed delineation such as Toposheet, ALOS, SRTM DEM, ASTER DEM and CARTOSAT DEM. Based on analysis SRTM DEM gives meticulous and clear results compared to other DEM files. Morphometric based prioritization of watershed was given in many research papers but an appropriate result of priority range was not given and this type of study confusing to evaluate the rank of priority based on its erosional behaviour. In many papers results of morphometric parameters were not indicate how to retaliate these results of morphometric parameters to a watershed. This paper deals with the implication of different values of morphometric parameters with adequate contextual information. This review paper can give useful information for the morphometric analysis of watersheds.

Key words: Drainage density, Morphology, Prioritization, Runoff, Sediment production rate.

Watershed is an area of land in which raindrop rollover. It means an area of land where all rainwater drains from a single outlet point into lake, river, ocean. Watershed also is known as a catchment area and drainage basin. Land and water resources development is precisely planned based on a watershed (Balasubramanian *et al.,* 2017). Watershed management is endowed techniques for sustainable development of natural resources (Patel *et al*., 2012). Watershed is not only a hydrological unit but also provides life support service to peoples by socially, politically, ecologically. Watershed management concept recognizes the interrelationship among the linkages between upland, land use, slope and soil (Rahaman *et al.,* 2015).

In watershed prioritization process used different morphometric parameters such as stream length, bifurcation ratio, drainage density, drainage texture, stream frequency, elongation ratio, circularity ratio, length of overland flow, basin relief, relief ratio (Biswas *et al.,* 1999; Patel and Dholakia, 2011). Prioritization of watersheds will help in the efficient adoption and allocation of these resources on a priority basis (Aher *et al.,* 2014).

DEMs can be generated from topographic maps obtained with remote sensing technologies or aerial photography. The global elevation dataset will be the best freely available global digital elevation model (DEM) at a horizontal resolution of 1 arc second. We assess the quality of G DEM in comparison with 3 arc second SRTM DEM, the best current global elevation dataset (Hayakawa *et al.,* 2008).

In several papers, morphometric parameter resulted as a low and high value, but not gave any proper range of these parameters. In some papers also not indicated the implication of low and high value. This paper bargains with the implication of proper ranges of morphometric parameters and it will be very helpful in future research work.

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Required input data

In recent years, the rendition of remote sensing and geographic information system technology for providing information with sufficient truly ground information it makes to possible identify topographic features such as geological structures, geomorphic features and hydraulic characters (Ali and Ikbal, 2015). The use of DEM is a purely idealistic approach for studying and virtually visiting landscapes encompassing large areas where direct physical access may be limited due to hostile terrain and/or thick vegetation cover (Manoj *et al*., 2016). A DEM can be represented as a raster or vector based triangular irregular network (TIN) (Patel. 2012). However, the accuracy of satellite-based DEMs is varying from terrain to terrain, sensor to sensor and application to application. Input data is very useful for generating accurate results of research work. The main inputs for the watershed delineation process are toposheet, SRTM DEM, ASTER DEM, CARTOSAT DEM and ALOS files. For precise delineation of the watershed were manually digitized with the help of Topographic sheet and overly on DEMs. SRTM DEM gives more accuracy in the generation of drainage maps in all terrain as well as plain area. SRTM

DEM was generated DEMs with a vertical RMSE of 16 m. Area and perimeter generate from the SRTM DEM file is closer and less deviate from toposheet base manual generation. CARTOSAT DEM and ASTER DEM use only in plain terrain topography and rugged terrain respectively for obtaining accurate results (Bhanudas *et al.,* 2017).

This information can be used to define watershed boundaries and stream network with help of ArcHydro Tool in ArcGIS. ASTER could not produce a better result compare to other DEM imagines. ASTER derived watersheds boundaries are highly deviated from all other boundaries. All DEM derived watersheds boundaries have slightly higher perimeter values compared to toposheet because delineation from DEMs always produces more zig zag boundaries with help of ArcHydro Tool in ArcGIS.

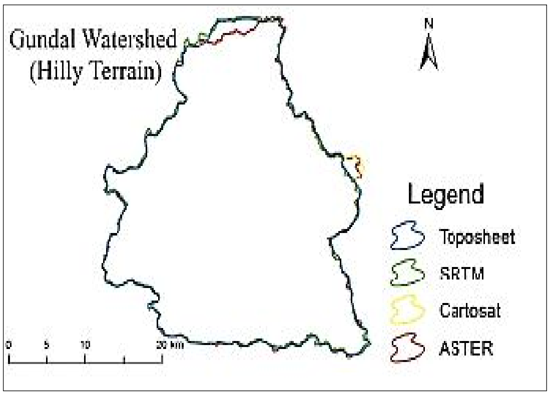

Fig 1: Gundal watershed area.

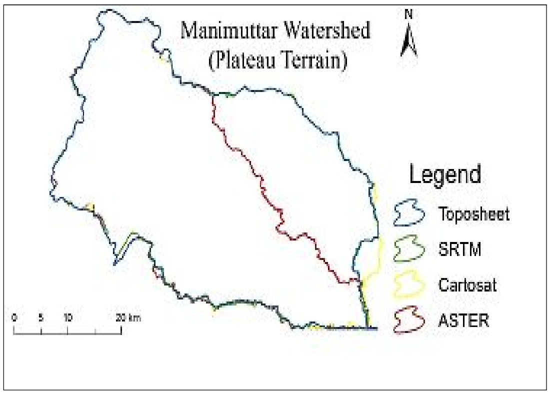

Fig 2: Manimuttar watershed area.

Morphometric parameters

The first extensive hydrologic applications of quantitative measurement of drainage basin morphology were illustrated by Horton (1945) and Langbein *et al.* (1947). The morphometric parameters depend on the watershed characteristics; the characteristics vary as per the behaviour of hydrological and geological processes, such that it requires an integrated approach to data analysis and modelling. These morphometric parameters can also illustrate the hydro geomorphological characteristics of the watershed area. A total number of 85 morphometric parameters are available but this study only considers erosion risk assessment morphometric parameters and classifying its range for appropriate research work. Stream frequency, drainage density, drainage texture ratio and bifurcation ratio are directly proportional to land and water degradation factors. Quantitative morphometric analysis using RS and GIS approach is time and cost-effective in providing essential information for characterizing basin hydrologically, physio-graphically and geologically. However, such morphometric analysis should be linked with the geophysical, hydrogeological and hydro-metrological studies to use the information for decision makings.

Stream length

The total length of the stream network was maximum in 1st order and it decreased with an increase in stream order. The length of the stream of any giver order was greater than its lower order (Horton, 1945). Longer the stream length means a high amount of runoff and soil detachability also high.

Bifurcation ratio (R_b)

The bifurcation ratio is defined as the ratio of a number of stream segments of a given order to the next higher order stream (Schumn, 1956). Mainly R_b indicates two different things. The higher value of bifurcation ratio indicates sloppy terrain and impermeable rock. Lower value of R_b indicates plain terrain, permeable and soft bedrock. R_b value varies between 3 to 5 based on some research work (Suresh 2007; Strahler 1964).

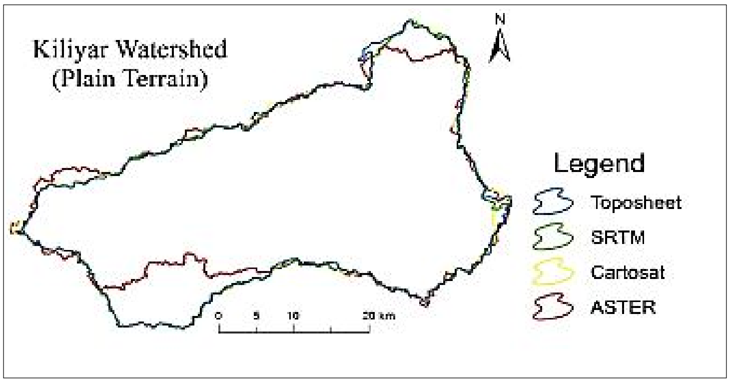

Fig 3: Kiliyar watershed area.

Circulatory ratio (R_c)

It is the ratio between the area of a watershed to the area of a circle having same circumference as the perimeter of the watershed (Miller, 1953). Its value varies between 0 to 1. A minimum value of R_c indicates less circular watershed and discharge may also slow. The maximum value of R_c indicates circular watershed and runoff/discharge is high (Choudhari *et al.,* 2018, Patel *et al.,* 2012).

Drainage density (D_d)

Drainage density is the ratio between the total length of all stream order to drainage area and is generally expressed as a km/km^2 (Horton, 1945). Horton (1932, 1945) suggested that, in addition to area, stream slope and drainage density should be highly correlated with maximum flood discharge. Drainage density, the length of the channel per unit of drainage area, is controlled by numerous variables, including the relief, rainfall, infiltration capacity of the terrain and resistance of the land to erosion (Horton, 1945).

In many papers proper range of D_d not give but indicate as a high and low value. A high value of D_d indicates impermeable subsurface material, sparse vegetation and mountainous relief. A lower value indicates a highly permeable subsurface and dense vegetative cover (Vittala *et al.,* 2004, Waikar *et al.,* 2014, Nautiyal *et al.,* 1994).

Drainage texture (T)

It is the ratio of the total number of stream segments of all orders to the perimeter of the basin (Horton, 1945). It is also known as texture ratio. This ratio reflects the soil erosion risk. In different papers, drainage texture is classified into 5 classes based on its value range. Value of T less than 2 indicated very coarse, between 2 to 4 related to coarse, between 4 to 6 is moderate, ranging from 6 to 8 indicated fine and more than 8 indicated as is very fine drainage texture (Smith, 1950; Vittala *et al.,* 2004; Pandey *et al.,* 2011).

Elongation ratio (R_e)

Elongation ratio, being the ratio of the diameter of a circle of the same area as the basin to the maximum basin length (Smith, 1950). R_e indicates how the shape of watershed deviates from the circle and also indicate erosion risk of watershed. In some papers, the value gives as high and low. The high value of R_e indicates high infiltration capacity and a low amount of runoff. A low value indicates high erosion and sedimentation load (Sreedevi *et al.,* 2009). There are many classifications of R_e in many papers. Mainly R_e classify into three groups base on its range, R_e > 0.9 indicates the circular shape, varies between 0.9-0.8 indicates oval shape and R_e < 0.7 means elongate shape.

Form factor (R_f)

The form factor is another ratio of watershed area to the square of the length of the watershed (Horton, 1945). The perfect range of form factor was not get in any paper but it indicates R_f > 0.7854 means perfect circular in shape. The small value of R_f indicates an elongated shape of the watershed and higher value means circular shape. In circular shape watershed peak flow is of shorter duration and small value of R_f means flatter peak flow for a longer duration (Aher *et al.,* 2014; Javed *et al.,* 2009; Pandey *et al.,* 2011; Patel *et al.,* 2012; Waikar *et al.,* 2014).

Stream frequency (F_s)

It is a dimensionless number as a total number of channel segments of all stream orders per unit area of the watershed (Horton, 1945). Stream frequency is a direct relation with drainage density and increases stream population with increasing drainage density (Waikar *et al.,* 2004; Javed *et al.,* 2009). Stream frequency is generally classified into low and high based on its range value. A high value means rocky terrain and very low infiltration capacity (Kadam *et al.,* 2019). A low value of F_s indicates plain land surface with high infiltration rate and low runoff (Balasubramanian *et al.,* 2017).

Length of overland flow (L_g)

The length of overland flow defined as water runs over the land surface before getting concentrated into a certain defined stream channel (Horton, 1945). L_g directly affects soil erosion. L_g relates inversely to the channel slope (Patel *et al.,* 2012; Balasubramanian *et al.,* 2017). L_g of the sub watersheds varies between 0 km to 1 km. Lower value of L_g indicates high relief for shorter duration and low infiltration rate of the soil. Higher values of L_g mean less slope, low relief for longer duration and high infiltration rate.

Time of concentration (T_c)

The Time of concentration of any watershed is the time required to travel water from most hydraulically distant point to the outlet point of the watershed (Kirpich 1940; Bell and Kar 1969; McCuen *et al*., 1984; Garg 2001). Various empirical equations are given by different scientists for calculating the time of concentration such as Williams (1922), Kirpich (1940), Johnstone and Cross (1949), Haktanir and Sezen (1990) and Simas, (1996). Tc is the time parameter and it is widely used for estimate peak discharge in hydrologic designs for watershed management plans (Fang *et al.,* 2008). Time of concentration generally indicates as hours. Tc has direct relation with the soil erosivity factor. Higher the Tc is indicating higher the runoff and peak flow in the watershed, it means soil erosion potential of the watershed is high. In this parameter no any particular range of Tc, but high the Tc it means high erosion and low value means lower soil erosion.

Relief ratio (Relief diversity)

Relief ratio reflects an actual difference in the elevation of the highest and lowest point in a watershed. It is useful for calculating the steepness of watershed. In many papers, it is classified as very low (11.26-21.01), low (21.01-30.81), moderate (30.81-38.11), high (38.11-47.66) and very high (47.66-68.51). A high value means steep slope and a high amount of relief for a shorter duration. A low value of relief ratio indicates low relief for a longer duration (Schumm, 1956, Vittala *et al.,* 2004, Basu and Pal, 2019).

Soil erosion potential and its intensity in a basin could be obtained from relief aspect (Tejpal, 2013), which includes basin relief, relief ratio, channel gradients, ruggedness number, basin length and ruggedness number. The values of those parameters indicate that the basin is characterized by steeper slope or flattened slope and which allows difficult /easy to sediment production and transportation that dominated by bed loads (Wilford *et al*., 2004). The type study, showed basin is susceptible to sever soil erosion or week erosion, which is higher in the Anger and the Upper catchment.

Ground water recharge of a basin is influenced by stream frequency, infiltration number, drainage density, drainage texture, length of overland flow, basin configuration and basin length. Those parameters depict information about infiltration capacity of the area and runoff generation (Singh *et al*., 2014; Soni, 2016).

Prioritization of watersheds

Many studies show that the aerial and relief morphometric parameters have positive relationships with soil erosion. While shape parameters have a negative relationship with soil erosion (Singh *et al*., 2005; Hlaing *et al.,* 2008; Londhe *et al.,* 2010; Patel and Dholakia, 2011). Earlier priority of watersheds based on this kind of approach and this approach has associated with some biasness. This prioritization method tends to leads the priority to erroneous. It also observed that annexation of geospatial technology and statistical methods for giving appropriate priority to the watersheds has less subjected to a biasness. For the estimation of relative significance, priority uses statistical correlation with each variable and assigning the weight to each parameter with respect to its importance. This method for assigning priority of watershed is called "Weighted Sum Analysis (WSA)". With the help of this method remove individual biasness of morphometric parameters. This method will be helpful for soil and water conservation planning and its management (Aher *et. al.,* 2014; Prasad and Pani, 2017; Malik *et. al.,* 2019; Puno and Puno, 2019).

Conclusion

GIS-based drainage morphometric quantification and analysis is found to be a cost-and time-effective approach to characterize poorly gauged basins as an alternative and complementary source of information. In this paper, we concluded that the SRTM DEM file is very useful for generation watershed boundary maps, contour maps, slope maps and drainage maps. This DEM file gives more accurate results compared to ASTER, CARTOSAT, ALOS. Many parameters calculated for morphometric analysis and it is very confusing for giving a proper result. In this paper, we give an appropriate range of these erosive assessment parameters for accurate and improving results. Basically, the watershed is classified according to its shape such as elongated and circular. Stream length directly affects the erosion process. It means stream length is high than the runoff rate also high and it causes soil erosion problem. The bifurcation ratio indicates the topography of the watershed area. Circulatory ratio, elongation ratio and form factor all are the shape parameters and it indicates the shape of the watershed is elongated or circular. These all-erosion assessment parameters are very useful for the determination of watershed geological and hydrological response. Morphometric analysis-based prioritization of watersheds/ sub watersheds is useful for site selection of appropriate soil and water conservation measures. Soil and water conservation measures are constructed on 3rd, 4th and 5th order streams only because 1st and 2nd order stream generally placed at in high elevation so at that site that type of measure not suitable. Generally, this study shows that quantitative morphometric analysis using the-state-of-the-art approach is time- and cost-effective in providing baseline information for characterizing basin hydrologically, physio-graphically and geologically. However, such morphometric analysis should be supported by detailed geophysical, hydrogeological and hydro-metrological studies to use the information for decision-making.

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