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Quantitative Morphometric Analysis of Dzumah Watershed of Upper Dhansiri, Nagaland, India

Rizongba Kichu, Manoj Dutta*, R.C. Nayak and Lamneithem Hangshing[1]

Department of Soil and Water Conservation, School of Agricultural Sciences and Rural Development
Nagaland University, Medziphema-797 106, India
[1]Department of Agricultural Engineering, Palli-Siksha Bhavana (Institute of Agriculture) Visva- Bharati
Shantiniketan-731 235, India
**E-mail: manojdutta1997@yahoo.com*

Abstract: In the present study, an attempt was made to quantify the morphometric characteristics of Dzumah watershed located in Nagaland, India. The Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) of 30 m spatial resolution was used in ArcGIS environment for evaluating the morphometric parameters and generation of maps. The Dzumah watershed is a fifth order drainage basin with an area of 65.55 km^2 with 228 stream segments (total stream number) with a total stream length of 130.71 km. A low drainage density of 1.99 km/km^2 indicates coarse drainage texture revealing that the watershed has good infiltration/permeability and vegetation cover. The analysis of various aerial aspects such as form factor, circularity ratio and elongation ratio revealed that the watershed is elongated in shape. The analysis of relief aspects revealed that the lowest and highest elevation in the watershed was 328 m and 2345 m above mean sea level, respectively. The observed values for relief ratio and ruggedness number are 0.14 and 4.02, respectively, indicating that the watershed has rough, steep and uneven topography. The high permeability as inferred by low values of drainage density could be negated by high rainfall and steep uneven terrain characteristics of the watershed which would not only decrease the absorption time but also increase the velocity of accumulated surface run off. The overall results from the study showed that the watershed is characterized by rugged uneven terrain with steep slopes which would favour a considerable increase in flow velocity, thus increasing the risk of soil erosion.

Keywords: Morphometric analysis, DEM, Dzumah watershed, Soil erosion

Characterization based on analysis of morphometric aspects is a relatively simple procedure to understand the landform, hydrological response and erosion characteristics of a watershed. Quantitative morphometric analysis includes calculation of linear, aerial and relief aspects of a drainage basin. The advances in remote sensing and geospatial technologies has greatly simplified the process of computation and analysis of morphometric parameters and are capable of generating accurate and reliable results. A geospatial approach for morphometric analysis is desirable since manual on-site efforts for characterization is tedious, expensive and laborious (Harinath and Raghu 2013). Various researchers have consistently validated the use of geospatial approach for effective analysis of morphometric parameters of watersheds (Kulkarni 2015, Aparna et al 2015, Ayele et al 2017, Pande and Moharir 2017. Gizachew and Berhan 2018). For a state like Nagaland, which is characterized by steep, uneven and hilly terrain, the need for conservation of soil and water resources is of paramount importance as these are basic and critical resources where majority of the society and the overall economy rely on agricultural production and forest resources. Moreover, owing to its steep and rugged topography, the state acts as a runoff zone. Soil and water conservation projects require a comprehensive understanding of its hydrological and physical characteristics (Gutema et al 2017, Gezahegn et al 2018, Gizachew and Berhan 2018, Asfaw and Workineh 2019). Therefore, the present study was undertaken to quantify the morphometric characters of the Dzumah watershed using GIS techniques which can serve as decision-making and planning inputs for soil and water conservation and related activities.

MATERIAL AND METHODS

Study area: The Dzumah watershed selected for the study is located in Medziphema, under Dimapur district of Nagaland. The watershed is located between 93° 51' 33" to 94° 00' 16" E longitude and 25° 40' 45" to 25° 47' 01" N latitude occupying an area of 6555 ha (65.55 sq km). The elevation of the watershed is at a height of 328 m above mean sea level at the confluence and increases up to a height of 2345 m above mean sea level. The watershed area has a typical humid sub-tropical and associated agro-ecological setup. The watershed exhibits a dendritic drainage pattern (Fig. 1).

Data source and analytical approach: The extraction of drainage, delineation of watershed and determination of elevation ranges was done using Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) of 30 m spatial resolution in ArcGIS environment. The automated method for generation of drainage network, delineating the watershed and deriving basic parameters followed a series of steps (Fig. 2). Thereafter, morphometric parameters for the watershed were computed based on this dataset (Table 1).

RESULTS AND DISCUSSION

Stream order (Su): The Dzumah watershed is a 5th order watershed (Fig. 3) consisting of 184, 36, 5, 2 and 1 stream segments of first, second, third, fourth and fifth order, respectively (Table 1). Wakode et al (2013) reported a higher stream order under humid mountain-plain settings than in a sub-humid plateau-plain environmental setting.

Stream number (Nu): The total number of stream segments in the basin was 228 (Table 1) and the number of stream segments decreased as the stream order increased to higher orders. The higher number of lower order streams could be due to the uneven, hilly and undulating terrain. A higher count of stream segments in higher elevations of the basin denotes a young topography indicating that the basin is at a youthful developmental stage (Mahala 2020). There was an abrupt decrease in the number of streams as the stream order increases. This sudden drop in stream number indicates major morphological change within the watershed.

Stream length (Lu): The total stream length of the watershed is 130.72 km, of which 66.20, 34.40, 19.84, 6.35 and 3.9 km are of first, second, third, fourth and fifth stream orders, respectively (Table 1). The total length of stream decreases as the stream order increases to higher orders. Similarly, the overall stream length was highest for first order stream and declined with further increase in stream order, indicating that there is no lithological inconsistency in the watershed. Several studies have reported the occurrence of higher stream length in mountain–plain regions as compared to plateau–plain regions (Chitra et al 2011, Magesh et al 2013, Mahala 2020, Babu et al 2016)

Mean stream length (Lsm): The mean stream length of the first, second, third, fourth and fifth order streams of the watershed were 0.36, 0.96, 3.97, 3.18 and 3.92 km, respectively (Table 1). The increase in mean stream length from 1st order to the 5th order denotes that the lower order streams are shorter in length but greater in number whereas the higher order streams are longer but lesser in number as described by Strahler (1964). This could be due to the

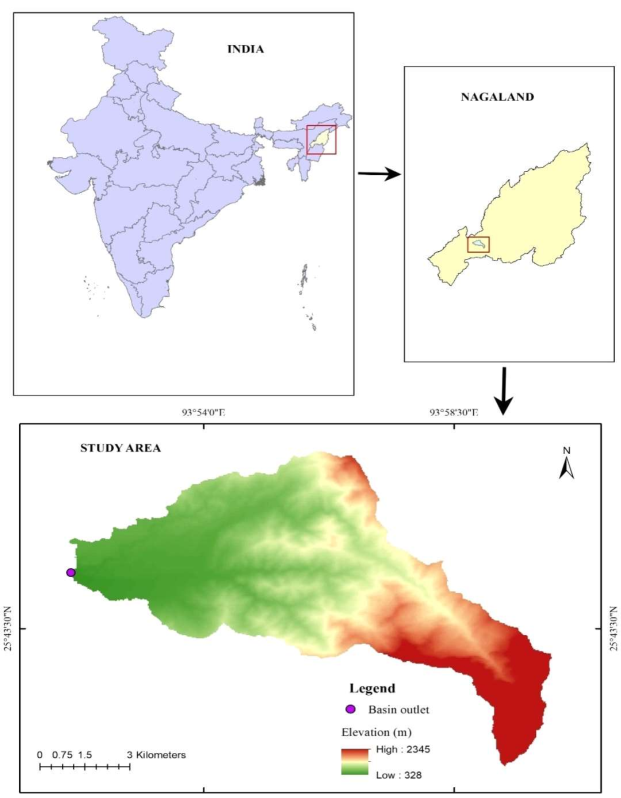

Fig. 1. Location and DEM representation of **s**tudy area

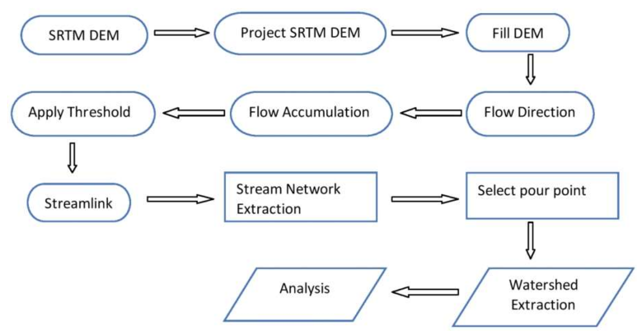

Fig. 2. Flow chart of methodology

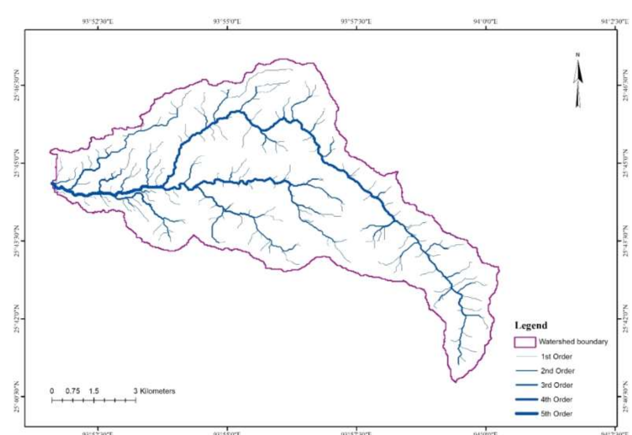

Fig. 3. Stream order map of Dzumah watershed

decrease in slope from the edges of the divide line to the confluence of the basin, which further suggests that the watershed is at a youthful stage (Gizachew and Berhan 2018). Short stream lengths suggest the presence of sharp and steep gradients whereas longer stream lengths are indicative of flat or gentle slopes (Withanage et al 2014).

Length of overland flow (Lg): It is categorized into three classes *i.e.,* low, moderate and high with value range of < 0.2, 0.2-0.3 and >0.3, respectively (Chandrashekar et al 2015). Low value of Lg denotes high relief, short flow paths, more runoff, less infiltration and vice versa. The length of overland flow calculated for the Dzumah watershed is 0.25 (Table 1) and thus, falls under the moderate class indicating that the watershed is prone to moderate risks of runoff and erosion.

Stream length ratio (Rl): The observed stream length ratio for the Dzumah watershed was 0.52 for first to second order

Table 1. Methods of calculation of morphometric parameters and observed values

Morphometric parameters	Formula	Description	References	Observed values
A. Linear aspects				
Stream order (u)	-	Hierarchical rank	Strahler (1964)	5
Stream length (Lu)	-	Length of the major stream	Horton (1945)	1st = 66.20 km 2nd= 34.40 km 3rd= 19.84 km 4th= 6.35 km 5th= 3.92 km Total =130.71 km
Stream number (Nu)	-	Total number of stream segments of order 'u'	Horton (1945)	1st = 184 2nd= 36 3rd= 5 4th= 5 5th= 1 Total = 228
Mean stream length (Lsm)	Lsm = Lu/Nu	Lu = Total stream length of order 'u' Nu=Total number of stream segments of order 'u'	Strahler (1964)	1st = 0.36 km 2nd= 0.96 km 3rd= 3.97 km 4th= 3.18 km 5th= 3.92 km
Stream length ratio (Rl)	Rl = Lu/Lu-1	Lu = Total stream length of order 'u' Lu-1 = Total stream length of its next lower order	Horton (1945)	1:2=0.52 2:3=0.58 3:4=0.32 4:5=0.62
Length of overland flow (Lg)	Lg = 1/(2xDd)	Dd = Stream density	Horton (1945)	0.25 km
Bifurcation ratio (Rb)	Rb=Nu/Nu+1	Nu = Total number of stream segments of order 'u' Nu+1 = Number of stream segments of the next higher order	Schumm (1956)	1:2=5.1 2:3=7.2 3:4=2.5 4:5=2.0
Mean bifurcation ratio (Rbm)	-	Average of bifurcation ratios of all orders	Strahler (1957)	4.2
Basin length (Lb)	-	-	Schumm (1956)	14.74 km
B. Aerial Aspects.				
Watershed area (A)	-	-	Schumm (1956)	65.55 km^2
Watershed perimeter (P)	-	-	Schumm (1956)	59.58 km
Form factor (Ff)	$Ff = A/Lb^2$	A = Area of watershed Lb = Basin length	Horton (1932)	0.30
Elongation ratio (Re)	$Re = (2/Lb)[(A/\pi)^{0.5}]$	A = Area of watershed Lb = Basin length	Schumm (1956)	0.62
Circulatory ratio (Rc)	$Rc = (4\pi A)/P^2$	A = Area of watershed P = Perimeter	Strahler (1964)	0.23
Drainage density (Dd)	Dd = Lu /A	Ratio of total stream length and area	Horton (1945)	1.99
C. Relief aspects				
Basin relief (Bh)	Bh = H-h	Vertical distance between the lowest and highest points	Strahler (1952)	2016 m
Relief ratio (Rr)	Rr = Bh/Lb	Ratio of basin relief and length	Schumm (1956)	0.14
Ruggedness number (Rn)	Rn = Bh x Dd	Bh = Basin relief Dd = Drainage density	Strahler (1958)	4.02

streams, 0.58 for second to third order, 0.32 for third to fourth order and 0.62 for fourth to fifth order (Table 1). The tendency of increasing Rl from lower order to higher order denotes their mature geomorphic stage of a basin (Vinutha and Janardhana 2014). Therefore, there is no classification for Rl (Sukristiyanti et al 2018). An increasing trend in the stream length ratio was observed up to the third order. However, a drop in the ratio trend was noticed between the third and fourth order stream and subsequently increases between the fourth and fifth order. The variation in Rl ratio could be attributed to the diverse topographic conditions and varying slopes (Qadir et al 2019). Such changes in Rl suggest an early stage of geomorphic development in the watershed, indicating that the watershed is subjected to changes and transformations in future (Mahala 2020).

Bifurcation ratio (Rb): Bifurcation ratio denotes the extent of integration among streams segments of different orders in the watershed (Gutema et al 2017). The observed Rb values between fifth to fourth order, fourth to third order, third to second order and second to first order streams are 2.0, 2.5, 7.2 and 5.1, respectively. The mean Rb of the watershed is 4.2 (Table 1). The bifurcation ratio among the lower order streams are much higher compared to those among the higher order streams. This could be due to a greater influence of geologic structures on the drainage pattern of lower order streams in the higher reaches of the watershed as compared to the higher order streams occupying flatter and plain locations of the watershed.

Watershed area (A) and perimeter (P): The Dzumah watershed falls under the Dhansiri river catchment and has an area of 65.55 km^2. The perimeter of the watershed was 59.58 km.

Form factor (Rf): Elongated basins tend to have lower values of Rf. Higher Rf values indicates a basin that is more circular in shape and having higher peak flows in shorter time periods whereas an elongated basin tends to have lower Rf values with relatively lower peak flows over a longer period of time (Bali et al 2011). The observed form factor for the Dzumah watershed is 0.30 indicating that the watershed is elongated (Table 1). This finding suggests that the discharge from the watershed will have flatter peak flows for longer period.

Elongation ratio (Re): The Re values are categorized into four classes *i.e.,* elongated, less elongated, oval and circular with value ranges of < 0.7, 0.7 to 0.8, 0.8 to 0.9 and > 0.9, respectively (Sukristiyanti et al 2018). The observed *R*e value of the Dzumah watershed is 0.62, which denotes the elongated and elliptical characteristics of the basin (Table 1). This finding further highlights the steep slopes and uneven terrain characteristics in the higher reaches of the study area.

Circularity ratio (Rc): Rc values of 0.4 and below indicates an elongated basin, Rc values ranging between 0.4-0.75 indicate intermediate shape of basin and values greater than 0.75 indicate circular basin (Miller 1953). Lower values of Rc indicate a higher vulnerability to soil erosion (Kadam et al 2019). The observed Rc value of the Dzumah watershed is 0.23 (Table 1), indicating that the watershed is elongated in shape. The drainage density pattern is coarse if Dd is less than 5 km/km^2, medium if Dd is between 5-10 km/km^2 and fine if Dd is more than 10 km/km^2 (Yousuf et al 2020). Several studies indicated that high values of drainage density occur in locations with impermeable surface materials, sparse vegetation and high relief, whereas, low values of drainage density are observed in places with relatively better vegetation cover, permeable soil and low relief (Asfaw and Workineh 2019, Babu et al 2016, Gizachew and Berhan 2018). The observed value of drainage density of Dzumah watershed is 1.99 km/km^2 (Table 1), indicating that it has a coarse drainage texture. Given the relationship of drainage density with other basin characteristics, it can be inferred that on account of low drainage density, the Dzumah watershed is expected to have good infiltration capacity/permeability and excellent vegetation cover.

Basin relief (Bh): Outlet of the Dzumah watershed is located at an elevation of 328 m above mean sea level whereas the highest elevation recorded in the watershed is at an elevation of 2345 m above mean sea level (Fig. 4). This results in a basin relief of 2017 m for the watershed.

Relief ratio (Rr): It is the ratio between the basin relief and basin length. In general, low Rr values imply low relief, whereas high Rr values suggest steep slopes and considerable relief. Considering the findings of other researchers, observed that the Rr values ranged from as low as 0.0028 (Mahala 2020) to as high as 0.19 (Adhikari 2020), with the latter indicating high relief and high slope. The observed relief ratio of the Dzumah watershed is 0.14 (Table

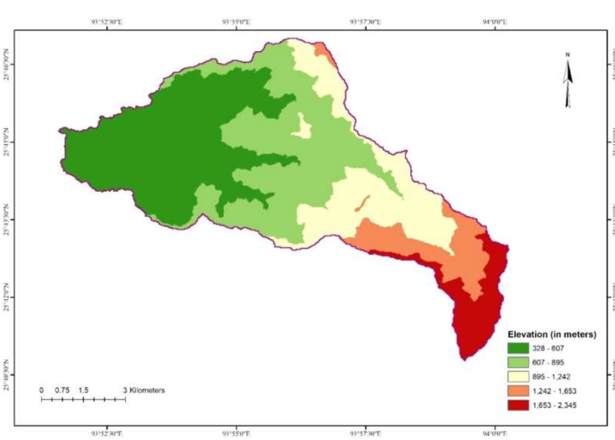

Fig. 4. Elevation map of Dzumah watershed

1). Based on relative assessment and comparison, it can be inferred that the study area has a high relief ratio indicating strong relief and steep slopes.

Ruggedness number (Rn): Rn is a combination of slope length and steepness suggestive of the degree of vulnerability of the land surface. Areas with low Rn values are less susceptible to erosion hazards (Pareta and Pareta 2011) and vice- versa. The ruggedness value of the Dzumah watershed is 4.02 (Table 1), which is high and indicates that the watershed has a rough and uneven topography vulnerable to soil erosion.

Implications for soil and water conservation: The present reconnaissance analysis of relief aspects indicates that the Dzumah watershed is characterized by rugged uneven terrain with steep slopes which would favour a considerable increase in flow velocity, thus increasing the risk of soil erosion. The results of aerial parameters such as form factor, elongation ratio and circularity ratio suggest that the watershed has an elongated configuration indicating flatter peak flows and less flooding hazards. The stream number and length of overland flow indicate that the watershed could have less infiltration and prone to moderate risk of soil erosion, whereas drainage density values suggest that the watershed has coarse drainage texture with permeable material, good infiltration, and adequate vegetation cover. The high permeability as inferred by low values of drainage density could be negated by high rainfall and steep uneven terrain characteristics of the watershed which not only decreases the absorption time but also increases the velocity of accumulated surface run off.

CONCLUSION

The study corroborates the practical application of remote sensing and GIS techniques in morphometric characterization of watershed and determination of its hydrological behavior. Dzumah watershed is a fifth order drainage basin with a low drainage density value of 1.99 km/km^2 indicating that the watershed has good infiltration/permeability and vegetation cover. The observed values for form factor, circularity ratio and elongation ratio indicate that the watershed is elongated in shape. The observed values for relief ratio and ruggedness number indicate that the watershed has a rough, steep and uneven topography. The overall results from the study showed that the watershed is characterized by rugged uneven terrain with steep slopes which would favour a considerable increase in flow velocity, thus increasing the risk of soil erosion. It is therefore imperative to undertake adequate soil and water conservation measures to minimize sediment transport and increase ground water recharge in the watershed. Furthermore, the hydrological behaviour of the watershed exert profound influence on the siltation and water quality affairs in the downstream areas of the Dhansiri River, of which the Dzumah watershed forms an important tributary. The findings of this study can serve as a planning and decision-making guide for erosion risk mitigation and efforts for surface water conservation in the watershed.

REFERENCES

Adhikari S 2020. Morphometric analysis of a drainage basin: A study of Ghatganga river, Bajhang district, Nepal. *The Geographic Base* **7**: 127-144.

Aparna P, Nigee K, Shimna P and Drissia TK 2015. Quantitative analysis of geomorphology and flow pattern analysis of Muvattupuzha River Basin using Geographic Information system. *Journal Aquatic Procedia* **4**: 609-616.

Asfaw D and Workineh G 2019. Quantitative analysis of morphometry on Ribb and Gumara watersheds: Implications for soil and water conservation. *International Soil and Water Conservation Research* **7**: 150-157.

Ayele A, Yasuda H, Shimizu K, Nigussie H and Kifle W 2017. Quantitative analysis and implications of drainage morphometry of the Agula watershed in the semi-arid northern Ethiopia. *Applied Water Science* **7**: 3825-3840.

Babu KJ, Sreekumar S and Aslam A 2016. Implication of drainage basin parameters of a tropical river basin of South India. *Applied Water Science* **6**: 67-75.

Bali R, Agarwal KK, Ali SN, Rastogi SK and Krishna K 2011. Drainage morphometry of Himalayan glacio-fluvial basin, India: Hydrologic and neotectonic implications. *Environmental Earth Sci*ence **66**(4): 1163-1174.

Chandrashekar H, Lokesh KV, Sameena M, Roopa J and Ranganna G 2015. GIS-based morphometric analysis of two reservoir catchments of Arkavati river, Ramanagaram district, Karnataka. International Conference on Water Resources, Coastal and Ocean Engineering (Mangalore), *Elsevier Procedia* **4:** 1345-1353.

Chitra C, Alaguraja P, Ganeshkumari K, Yuvaraj D, and Manivel M. 2011. Watershed characteristics of Kundah subbasin using remote sensing and GIS techniques. *International Journal of Geomatics and Geosciences* **2**(1): 311-335.

Gezahegn W, Anteneh D, Solomon T and Reddy RU 2018. Spatial modeling of soil erosion risk and its implication for conservation planning: The case of the Gobele watershed, East Hararghe Zone, Ethiopia. *Land* **7**(1): 25.

Gizachew K and Berhan G 2018. Hydro-geomorphological characterization of Dhidhessa river basin, Ethiopia. *International Soil and Water Conservation Research* **6**: 175-183.

Gutema D, Kassa T and Koriche SA 2017. Morphometric analysis to identify erosion prone areas on the upper blue Nile using GIS: case study of Didessa and Jema sub-basin, Ethiopia. *International Research Journal of Engineering and Technology* **4**(8): 1773-1784.

Harinath V and Raghu V 2013. Morphometric analysis using ArcGIS techniques: A case study of Dharurvagu, South Eastern part of Kurnool district, Andhra Pradesh, India. *International Journal of Science and Research* **2**(1): 2319-7064.

Kulkarni MD 2015. The basic concept to study morphometric analysis of river drainage basin: A review. *International Journal of Science and Research* **4**(7): 2277-2280.

Magesh NS, Jitheshlal KV and Chandrasekar N 2013. Geographical information system-based morphometric analysis of Bharathapuzha river basin, Kerala, India. *Applied Water Science* **3**: 467-477.

Mahala A 2020. The significance of morphometric analysis to understand the hydrological and morphological characteristics in two different morpho-climatic settings. *Applied Water Science* **10**: 33.

Miller VC 1953. A quantitative geomorphic study of drainage basin characteristics on the Clinch Mountain area, Virgina and Tennessee, Columbia University, *Department of Geology, Technical Report*, Number 3, pp 389-402, ONR, New York.

Pande CB and Moharir K 2017. GIS based quantitative morphometric analysis and its consequences: A case study from Shanur River Basin, Maharashtra India. *Applied Water Science* **7**: 861-871.

Pareta K and Pareta U 2011. Quantitative morphometric analysis of a watershed of Yamuna Basin, India using ASTER (DEM) data and GIS. *International Journal of Geomatics and Geosciences* **2**(1): 248-269.

Qadir A, Mallick TM, Abir IA, Aman MA, Akhtar N, Anees MT, Hossain K and Ahmad A 2019. Morphometric Analysis of Song Watershed: A GIS Approach. *Indian Journal of Ecology* **46**(3): 475-480

Strahler AN 1964. Quantitative geomorphology of basins and channel networks. In: Chow VT (ed) *Handbook of applied hydrology*. McGraw Hill Book Company, New York.

Sukristiyanti S, Maria R and Lestiana H 2018. Watershed-based morphometric analysis: A review. *Global Colloquium on GeoSciences and Engineering- IOP Conf. Series: Earth and Environmental Science*. doi :10.1088/1755-1315/118/1/012028

Vinutha DN and Janardhana MR 2014. Morphometry of the Payaswini Watershed, Coorg District, Karnataka, India, Using Remote Sensing and GIS Techniques. *International Journal of Innovative Research in Science, Engineering and Technology* **5**: 516-524.

Vittala SS, Govindaiah S and Gowda HH 2004. Morphometric analysis of sub-watersheds in the Pavagada area of Tumkur District, South India using remote sensing and GIS techniques. *Journal of the Indian Society of Remote Sensing* **32**(4): 351-362.

Wakode HB, Dutta D, Desai VR, Baier K and Azzam R 2013 Morphometric analysis of the upper catchment of Kosi River using GIS techniques. *Arabian Journal of Geosci*ences **6**(6): 395-408.

Withanage SN, Dayawansa KDN and De Silva PR 2014. Morphometric analysis of the Gal Oya River Basin using spatial data derived from GIS. *Tropical Agricultural Research* **26**(1): 175-188.

Yousuf A, Ara S, Ahmed S, Prasad R and Thakur BR 2020. *Remote sensing and GIS based morphometric analysis of a micro watershed. Urban Environment: Issues and Challenges.* Publisher: RK Books New Delhi.

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