ISSN XXXX XXXX © 2018 IJESC

Research Article Volume 8 Issue No.3

Morphometric Analysis of Sub Watersheds in Nilgiri District, Tamilnadu using Remote Sensing and GIS

Er.Afreeda.V[1], Dr.Balaji Kannan[2]
Research Scholar[1], Assistant Professor (SWCE)[2]
Department of Soil and Water Engineering[1], Department Remote Sensing and Geographic Information System[2]
TNAU, Coimbatore, India

Abstract:
In the present study, an attempt has been made to determine areal morphological parameters of three sub watersheds falling in Nilgiris district of Tamil Nadu. Remote Sensing (RS) coupled with Geographical Information System (GIS) technique has proved to be an efficient tool in drainage delineation and their updation for morphometric analysis. For detailed study, we used four different DEM sources viz., Toposheet, ASTER, SRTM and Cartosat data for delineating watershed boundary and geographical information system (GIS) was used in evaluation of linear, areal and relief aspects of morphometric parameters. The three delineated sub watersheds were Devarshola, Pykara and Parsons Valley River. The comparison of morphological parameters of the watershed under consideration obtained using different sources viz., SRTM, ASTER and Cartosat DEM with the watershed derived from Survey of India topographical sheet, 1:25,000 scale was done. The use of geospatial technologies for this study, proved effective on comparison with the conservative approach in terms of time taken and output product.

Key words: ASTER, SRTM, CARTOSAT, Morphometry

I. INTRODUCTION

Watershed is a natural hydrological unit which allows surface run off to a defined channel drain, stream or river at particular point. It is the basic unit of water, which evolves over time. Chow (1964) defined watershed as the separating boundary of a drainage basin and termed it as a catchment. Watershed size varies from fractions of hectares to thousands of kilometers. The development of Geographic Information Systems (GIS), digital elevation models (DEM) have been generated throughout the world. DEMs provide good terrain representations and are applied routinely in watershed modeling. DEMs can be used to derive flow networks and then automatically generate watershed boundaries for given outlet points using GIS technology. Therefore, an essential component to watershed delineation is a hydrologically sound DEM of the land area of interest (Julia K. Pryde, 2007). Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Clarke, 1966). Drainage analysis based on morphometric parameters is very important for watershed planning since it gives an idea about the basin characteristics in terms of slope. Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds (Strahler, 1964). The Cartosat spacecraft launched by the Indian Space Research Organization in May 2005 is dedicated to stereo viewing for large-scale mapping and terrain modeling applications. ASTER (Advance Space borne Thermal Emission and Reflection Radiometer) is a high-spatial-resolution, multispectral imaging system flying aboard TERRA, a satellite launched in December 1999 as part of NASA's Earth Observing System (EOS). SRTM (Shuttle Radar Topography Mission) DEM is very similar to the DEM from the digitized contours from the 1: 50,000 topographic maps. In the present study, the spatial datasets namely, Topo DEM extracted from Survey of India Toposheet (1:25.000), Cartosat-30, ASTER-30, along with SRTM-90 have been used to determine the areal morphometric parameters with the help of ArcGIS software for the study area and also an effort has been made to compare morphological parameters of selected watershed delineated from DEM of Toposheet, Cartosat, SRTM and ASTER at the sub-catchment scale.

II. MATERIALS AND METHODS

Study Area

The present study lies in the Nilgiris district of Tamil Nadu state. Nilgiris is one of the important hilly areas in South India and lying in the junction of Eastern and Western Ghats of India. The geographical area of Nilgiris is 2549 Km^2. It is elongated in the east west direction and bounded by 11°30' and 11°15' North latitude and 76°45' and 77°00' East longitude. The elevation ranges from 300 m to 2700 m above mean sea level. Several rivers either flow through the Nilgiris or originate there are Pykara, Moyar, Bhavani, Chaliyar, Kodalundi, Bharathapuzha, Noyil, Kundah, Suvarnathi and Lakshmana tirtha.

Data Acquisition

The details of collection of DEM data required from different sources and the systems used for their collection are briefly discussed below.

DEM

A Digital Elevation Model (DEM) can be represented as a raster (a grid of squares, also known as a height map when representing elevation) or as a vector-based triangular irregular network (TIN). DEM provide good terrain representations and DEM can be used to derive flow networks and then automatically generate watershed boundaries for given outlet points using GIS technology. Therefore, an essential component to watershed delineation is a hydrologically sound DEM of the land area of interest. The DEM extracted from 1:25,000 scale Survey of India Toposheet and satellite derived DEM viz., ASTER, SRTM and Cartosat were used in this study (Table 1).

Table.1. Data collected for the study:-

Sl. No	Ancillary Data	Source
1.	Topo DEM	58A11 (NE), 58A11 (NW), 58A11 (SE) and 58 A11 (SW).
2	ASTER DEM	http://www.gdem.aster.ersdac.or.jp
3	SRTM DEM	http://srtm.csi.cgiar.org.
4	CARTOSAT DEM	http://bhuvan.nrsc.gov.in

Methods

Attempts were made to delineate watershed by using ArcGIS 10.2 and calculate morphological parameters with the aid of materials collected. Methods adopted with a view to fulfill the objectives of this investigation are enumerated. Watershed boundaries were derived from different DEMs using automated procedures with the Watershed Delineator (written by ESRI and the Texas Natural Resource Conservation Commission), an ArcGIS extension that requires the Spatial Analyst extension to be installed as well.

Delineation of streams

The streams were delineated using different DEMs. This process required flow accumulation raster. The basic conceptual process is to reclassify all cells that meet a certain accumulated flow threshold to be 1, and all other cells to be no data. In the present study, threshold value for flow accumulation was taken as 100. A conditional statement was created using raster calculator which showed a threshold value for streams as 100. The streams for the area covered by flow Accumulation grid were obtained.

Quantitative Morphometry

Morphometric analyses of three selected watersheds were done. The linear, areal and relief aspects of the watersheds extracted from ASTER DEM have been carried out using the standard mathematical formulae and the details are given in the Table 2, 3 and 4 Systematic description of the geometry of a drainage basin and its stream channel requires measurement of linear, areal and relief (gradient) aspects of the channel network and contributing ground slopes.

Table.2. Description of Areal morphological parameters of a watershed

S. No.	Morphological parameters	Formula	References
1	Area (A)	Area from which water drains to a common stream and boundary determined by opposite ridges	Strahler (1964)
2	Perimeter (P)	Outer boundary of drainage basin measured	Schumn (1956)
3	Drainage density (D)	D = Lu/A Lu = Total stream length of all orders; A =Area of the basin	Horton (1945)
4	Stream frequency (Fs)	Fs = Nu/A Nu = Total no. of streams of all orders; A = Area of the basin	Horton (1945)
5	Form factor (Rf)	$Rf = A/Lb^2$ A = Area of the basin Lb^2 = Square of basin length	Horton (1945)
6	Circularity ratio (Rc)	$Rc = 4\pi A/P^2$ π = "*Pi*" A = Area of the basin P = Perimeter	Miller (1953)
7	Elongation ratio (Re)	Re = (2/Lb) sqrt (A/π) A = Area of the basin π = "*Pi*" value that is 3.14; Lb = Basin length	Schumn (1956)
8	Drainage texture (Rt)	Rt = Nu/P Nu = Total no. of streams of all orders P = Perimeter	Horton (1945)
9	Constant channel maintenance (C)	C = 1/D; D = Drainage density	Schumn(1956)
10	Texture ratio (T)	$T = N_1/P$ N_1 = Total number of streams in 1st order P = Perimeter of basin	Horton (1945)
11	Compactness coefficient (Cc)	$Cc = 0.2821\ P/A^{0.5}$	Horton (1945)
12	Drainage intensity (Di)	Di = Fs/Dd; Fs = Stream frequency Dd = Drainage density	Faniran (1968)
13	Shape index (Sw)	$Sw = Lb^2/A$; Lb = Basin length A = Area	Horton (1945)
14	Drainage frequency	Fs = Nμ/A Fs = Drainage frequency. Nμ = Total no. of streams of all orders and A = Area of the basin	Singh (1997)
15	Infiltration number	If = Dd × Fs Dd = Drainage density Fs = Drainage frequency.	Zavoiance (1985)

III. RESULTS AND DISCUSSION

To achieve the goal of the present research, DEM from the Shuttle Radar Topographic Mission (SRTM), Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER), Cartosat and DEM extracted from Survey of India Toposheet was exported to a Geographic Information System (GIS) environment to extract all possible morphological parameters of the catchment in the area. Further, comparison of morphological parameters of sub watersheds in the study area was done.

Delineation of streams

Stream lines were delineated for Devarshola, Pykara and Parsons Valley from all the four DEM sources viz., Topo, ASTER, SRTM and Cartosat. The streams delineated from ASTER DEM are shown in Fig. 3.

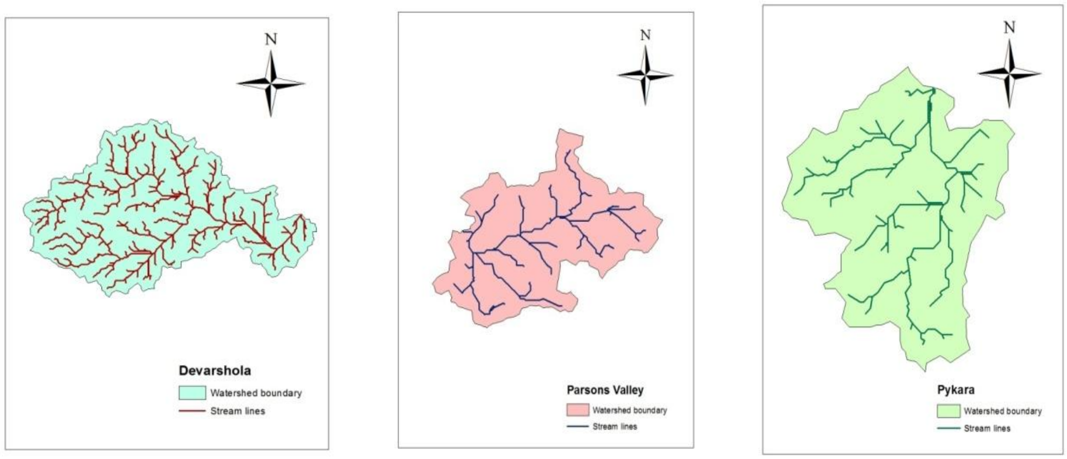

Figure.3. The streams delineated from ASTER DEM

Morphological parameters of watershed

The study of basin morphometry relates basin and stream network geometries to the transmission of water and sediment through the basin. Systematic description of the geometry of a drainage basin and its stream channel requires measurements of areal aspects of the channel network.

Areal aspects:

Area (A) and perimeter (P) are the important parameters in quantitative geo-morphology. Basin area directly affects the size of the storm hydrograph, the magnitudes of peak and mean runoff. The maximum flood discharge per unit area is inversely related to size (Smart and Surkan, 1967). The total area of the Devarshola, Pykara and Parsons Valley watersheds are 57.01, 11.17 and 11.5 km^2 respectively, as shown in Table 6. The observed perimeter of Devarshola, Pykara and Parsons Valley are 43.23, 17.04 and 20.40 km respectively.

Drainage density (D):

Drainage density is defined as the closeness of spacing of channels. It is a measure of the total length of the stream segment of all orders per unit area. Slope gradient and relative relief are the main morphological factors controlling drainage density. Strahler (1964) noted that low drainage density occurs where basin relief is low, while high drainage density is favored where basin relief is high. According to Nag (1998), low drainage density generally results in the areas of highly resistant or permeable subsoil material, dense vegetation and low relief. High drainage density is the resultant of weak or impermeable subsurface material sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture. The drainage density varies between 2.09 and 2.3 km/km^2 (Table 6) indicates clearly that the basin has permeable subsurface material, good vegetation cover and medium relief, causing more infiltration of water and recharging groundwater aquifers. This trends followed by the findings of Kowsalya (2013).

Stream frequency (Fs)

Horton (1932) introduced stream frequency (Fs) or channel frequency which is the total number of stream segments of all orders per unit area. It mainly depends on the lithology of the basin and reflects the texture of the drainage network. It is an index of the various stages of landscape evolution. The Stream frequency depends on the rock structure, infiltration capacity, vegetation cover, relief, nature and amount of rainfall and subsurface material permeability. Table 6 shows stream frequency for all sub-watersheds of the study area. The calculated results of Devarshola, Pykara and Parsons Valley watersheds are 12.29, 15.03 and 8.11 respectively. Pykara is having rocky terrain and very low infiltration capacity out of all the 3 sub watersheds. Similar results have been reported by Althaf (2013).

Form factor (Ff)

Form factor (Ff) is defined as the ratio of the basin area to the square of the basin length. This factor indicates the flow intensity of a basin of a defined area (Horton 1945). The form factor value should be always less than 0.7(the value corresponding to a perfectly circular basin). The smaller the value of the form factor, the more elongated will be the basin (Singh S, 1998). Basins with high-form factors experience larger peak flows of shorter duration, whereas elongated watersheds with low-form factors experience lower peak flows of longer duration. The form factor values (Table 6) of Devarshola, Pykara and Parsons Valley 0.335, 0.418 and 0.416 respectively, indicating all the watersheds comprise elongated basin with lower peak flows of longer duration. Observation of the present investigation coincides with the results obtained by Hajam (2013).

Circularity ratio (Rc):
Circularity ratio (Rc) is defined as the area of the basin to the area of a circle having the same circumference as the perimeter of the basin (Miller 1953). It is influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. Rc is a significant ratio that indicates the dendritic stage of a watershed. Low, medium and high values of Rc indicate the young, mature, and old stages of the life cycle of the tributary watershed. The Rc (Table 6) values of Devarshola, Pykara and Parsons Valley watersheds are 0.383, 0.483 and 0.349 respectively which indicates all the three watersheds are at an early stage of topographical maturity. The above results are agreement with the findings of Pankaj and Kumar (2009).

Elongation ratio (Re)
Elongation ratio (Re) is defined as the ratio between the diameter of a circle of the same area as the basin and the maximum basin length (Schumm 1956). Values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Re values close to unity correspond typically to regions of low relief, whereas values in the range 0.6–0.8 are usually associated with high relief and steep ground slope (Strahler 1964). These values can be grouped into three categories namely—Circular (0.9), Oval (0.9–0.8), Less elongated (0.7). The Re values (Table 6) of the Devarshola, Pykara and Parsons Valley reservoir 0.653, 0.7 and 0.728 respectively. This reveals that the area has high relief and that the watersheds are elongated. Magesh (2011) also reported the similar results.

Drainage texture (Rt)
Drainage texture (Rt) is one of the important concepts of geomorphology which means that the relative spacing of drainage lines. Drainage lines are numerous over impermeable areas than permeable areas. According to Horton (1945), Rt is the total number of stream segments of all orders per perimeter of that area. He recognized infiltration capacity as the single important factor which influences Rt and considered drainage texture which includes drainage density and stream frequency. Smith (1950) has classified drainage density into five different textures. The drainage density less than 2 indicates very coarse, between 2 and 4 is related to coarse, between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 is very fine drainage texture. In the present study, the drainage density (Table 6) of Devarshola, Pykara 16.213, 9.8 respectively which indicate very fine drainage texture. Parsons Valley watershed has a drainage density of 4.6, that indicating moderate drainage texture. Similar work has done by Sreedevi (2009) and reported the similar results.

Constant channel maintenance (C)
In the present study, constant channel maintenance varies from 0.47 to 0.43 as is shown in Table 6. The reciprocal of the drainage density (D) is constant of channel maintenance and signifies how much drainage area is required to maintain a unit length of channel. Low values of constant channel maintenance in all the three watersheds indicates that the magnitude of surface area of watershed needed to sustain unit length of stream segment and the watersheds are under the influence of high structural disturbance, low permeability, steep to very steep slopes and high surface runoff. Observation of the present investigation coincides with the results obtained by Althaf (2013).

Texture ratio (T)
Texture ratio is one of the most important factors in the drainage morphometric analysis, which depends on the underlying lithology infiltration capacity, and relief aspect of the terrain is the texture ratio (Demoulin, 2011; Altin, 2011). As shown in Table 6, T values for the Devarshola, Pykara and Parsons Valley watersheds are 8.349, 4.6 and 2.2. Hydrologically, it can be said that Parsons Valley in terms of T alone will have the longest basin lag times and Devarshola will have the shortest. The results are accordance with the findings of Altaf (2013).

Compactness coefficient (Cc)
Compactness coefficient expresses the relationship of a basin with that of a circular basin having the same area. A circular basin yields the shortest time of concentration before peak flow occurs in the basin. Cc = 1 indicates that the basin completely behaves as a circular basin. Cc> 1 indicates more deviation from the circular nature of the basin. The values for all the sub watersheds range from 1.4 to 1.6 as seen in Table 6, which indicates all watersheds has the deviation from the circular nature (Potter and Faulkner, 1987).

Drainage intensity (Di)
Faniran (1968) defines the drainage intensity, as the ratio of the stream frequency to the drainage density. This study shows a low drainage intensity of 6.3 and 3.88 for the watersheds Pykara and Parsons Valley, Table 6. This low value of drainage intensity implies that drainage density and stream frequency have little effect on the extent to which the surface has been lowered by agents of denudation. With these low values of drainage density, stream frequency and drainage intensity, surface runoff is not quickly removed from the watershed, making it highly susceptible to flooding, gully erosion and landslides. For Devarshola having 28.4 which indicates surface runoff will quickly remove from the watershed (Kowsalya, 2013).

Shape index (Sw)
Rate of water and sediment yield along the length and relief of the drainage basin is largely affected by the shape. The index is close to 1 for a watershed with a circular shape and is greater than 1 for a watershed that is elongated in shape .The shape index values for sub watersheds of the study area range from 2.4 to 2.983 as shown in Table 6. In terms of Sw only, all the sub watersheds will have the longer basin lag time. Althaf (2013) has reported the similar results.

Drainage frequency (Fs)
It mainly depends on the lithology of the basin and reflects the texture of the drainage network. It is an index of the various stages of landscape evolution. The Stream frequency depends on the rock structure, infiltration capacity, vegetation cover, relief, nature and amount of rainfall and subsurface material permeability. The stream frequency shows positive correlation with the drainage density. Lesser the drainage density and stream frequency in a basin, the runoff is slower, and therefore, flooding is less likely in basins with a low to moderate drainage density and stream frequency (Carlston, 1963). The stream frequency of

Devarshola, Pykara and Parsons Valley are 12.29, 15.03 and 8.11 respectively. Results are moderate, so the probability for flooding is less (Aravinda, 2013).

Infiltration number (If): Infiltration number plays a significant role in observing the infiltration characteristics of the basin. It is inversely proportional to the infiltration capacity of the basin. The infiltration numbers of the Devar shola, Pykara and Parsons Valley are 28.4, 35.64 and 16.96 (Table 6). It indicates that high runoff and low infiltration capacity as mentioned by Pareta (2012).

Table .6. Comparison of Areal Morphometric Parameters of the watersheds under study

S.No	Morphological parameters	Watersheds		
		Devarshola	Pykara	Parsons Valley
1	Area(km^2)	57.01	11.17	11.58
2	Perimeter(km)	43.23	17.04	20.40
3	Drainage density(km/km^2)	2.30	2.37	2.09
4	Stream frequency	12.29	15.03	8.11
5	Form factor	0.33	0.41	0.41
6	Circularity ratio	0.38	0.48	0.34
7	Elongation ratio	0.65	0.73	0.72
8	Drainage texture	16.21	9.85	4.60
9	Constant channel maintenance	0.43	0.42	0.47
10	Texture ratio	8.34	4.69	2.20
11	Compactness coefficient	1.61	1.43	1.69
12	Drainage intensity	28.40	6.34	3.88
13	Drainage frequency	12.29	15.03	8.11
14	Shape index	2.98	2.98	2.40
15	Infiltration number	28.40	35.64	16.96

IV. CONCLUSION

The purpose of the present study is collecting, comparing, processing and analysing the DEM data in a GIS environment for delineation of watershed boundary and determination of morphological parameters of selected sub watersheds in Nilgiris district, Tamil Nadu. For the analysis, the DEM extracted from 1:25,000 scale Survey of India (SOI) toposheet and satellite derived DEM viz., ASTER, SRTM and CARTOSAT were used. ASTER, SRTM and Cartosat are collected from http://www.gdem.aster.ersdac.or.jp. Basin area directly affects the size of the storm hydrograph, the magnitudes of peak and mean runoff. The maximum flood discharge per unit area is inversely related to size. While comparing other two watersheds Devarshola having more area and perimeter. The drainage density of three sub watersheds indicates clearly that the basin has permeable subsurface material, good vegetation cover and medium relief, causing more infiltration of water and recharging groundwater aquifers. The circularity ratio value indicates that all the three watersheds are at an early stage of topographical maturity. This low value of sub watersheds, drainage intensity implies that drainage density and stream frequency have little effect on the extent to which the surface has been lowered by agents of denudation. In terms of shape index, all the selected sub watersheds will have the longer basin lag time.

V. REFERENCES

[1]. Altaf, F., Gowhar Meraj, and Shakil A. Romshoo. 2013. Morphometric analysis to infer hydrological behaviour of Lidder watershed, western Himalaya, India. *Geography Journal* 13: 5-12

[2]. Aravinda, P. T. and Balakrishna, H. B. 2013.Morphometric analysis of Vrishabhavathi Watershed using remote sensing and GIS. *International Journal of Research in Engineering and Technology*. 2(13): 514-522.

[3]. Carlston, C. W. 1963. Drainage density and streamflow, U.S. Geological Survey Professional Paper. 422:1-8,

[4]. Clark. 1966. Morphometry from Map, Essay in geomorphology. *Elsevier* , 235- 274.

[5]. Demoulin and Alain. 2007. An automated method to extract fluvial terraces from digital elevation models: The Vesdre valley, a case study in eastern Belgium. *Geomorphology*. 91(1): 51-64.

[6]. Faniran, A. 1968. The index of drainage intensity—a provisional new drainage factor, *Australian Journal of Science*, 31: 328–330,

[7]. Gottschalk, L.C. 1964. *Reservoir Sedimentation*. In: V. T. Chow (ed), *Handbook of Applied Hydrology*. McGraw Hill Book Company, New York, Section 7-I.

[8]. GSI. 1981. Geological and Mineralogical Map of Karnataka & Goa, Geological Survey of India.

[9]. Hajam, R.A., Hamid, A., Bhat, S. 2013. Application of Morphometric Analysis for Geo- Hydrological Studies Using Geo-Spatial Technology –A Case Study of Vishav Drainage Basin. *Hydrol Current Res* 4: 157.

[10]. Horton, R. E. 1932. Drainage basin characteristics. *Transactions American Geophysical Union*, 13: 350–361,

[11]. Horton, R. E. 1945. Erosional development of streams and their drainage basins; hydrophysical approach to quantitative

morphology. *Geological Society of American Bulletin* 56: 275-370.

[12]. Julia, K. P., Osorio, J., Wolfe, M.L., Heatwole, C., Benham, B. andCardenas, A. 2007. Comparison of watershed boundaries derived from SRTM and ASTER digital elevation datasets and from a digitized topographic map. *An ASABE Meeting Presentation Paper Number: 072093*.

[13]. Kanth, T. A. and Hassan, Z. 2012. Morphometric analysis and prioritization of watersheds for soil and water resource management in Wular Catchment using geo-spatial tools. *International Journal of Geological Earth Environmental Science 2*(1), 30-41.

[14]. Kirpich, Z. P. (1940). Time of concentration of small agricultural watersheds.*Civil Engineering*, *10*(6), 362.

[15]. Kowsalya, M. and Suresh, B. S. 2013 Quantitative geomorphological analysis of micro watersheds of Ghataprabha river sub basin. *International Journal of Geomatics and Geosciences.13*

[16]. Magesh, N. S. 2012. GIS based morphometric evaluation of Chimmini and Mupily watersheds, parts of Western Ghats, Thrissur District, Kerala, India. *Earth Science Informatics*. 5(2): 111-121.

[17]. Magesh, N. S. and Chandrasekar, N. 2013. Evaluation of spatial variations in groundwater quality by WQI and GIS technique: a case study of Virudunagar District, Tamil Nadu, India. *Arabian journal of Geosciences*. 6(6): 1883-1898.

[18]. Martz, Lawrence, W. and Jurgen, G. 1992. Numerical definition of drainage network and subcatchment areas from digital elevation models. *Computers & Geosciences.* 18(6): 747-761.

[19]. Melton, M. A. 1957. *An analysis of the relations among elements of climate, surface properties, and geomorphology* (No. CU-TR-11). Columbia Univ. New York.

[20]. Miller, Jerry, R. and Kochel, R. C. 2010.Assessment of channel dynamics, in-stream structures and post-project channel adjustments in North Carolina and its implications to effective stream restoration. *Environmental Earth Sciences.* 59(8): 1681-1692.

[21]. Nag, S. K. 1998. Morphometric analysis using remote sensing techniques in the Chaka sub-basin, Purulia district, West Bengal. *Journal of Indian Society of Remote Sensing*. 26(l&2): 69-76.

[22]. Nookaratnam, K., Srinivastava, Y. K.,Venkateswara, W., Amminedu, E. and Murthy, K. S. R. 2005. Check dam positioning by prioritization of micro watershed using SYI model and morphometric analysis remote sensing and GIS perspective. *Journal Indian Society of Remote Sensing*. 33(1): 25-28.

[23]. Pankaj, A., & Kumar, P. 2009. GIS-based morphometric analysis of five major sub-watersheds of Song River, Dehradun District, Uttarakhand with special reference to landslide incidences. *Journal of the Indian Society of Remote Sensing*, *37*(1), 157-166.

[24]. Pareta, K. 2004. Hydro-geomorphology of Sagar District (M.P.): a study through remote sensing technique, *in the proceeding of XIX M. P. young scientist congress*, Madhya Pradesh Council of Science & Technology (MAPCOST), Bhopal.

[25]. Pareta, K. and Pareta, U. 2012. Quantitative geomorphological analysis of a watershed of Ravi River Basin, H.P. India. *International Journal of RS and GIS.* 1(1): 41-56

[26]. Pareta, Kuldeep and Upasana, P. 2012. Quantitative geomorphological analysis of a watershed of Ravi River Basin, HP, India. *International Journal of Remote Sensing and GIS.* 1(1): 47-62.

[27]. Potter, K. W. and Faulkner, E. B. 1987. Catchment response time as a predictor of flood quantiles1. . *Journal of Earth System Science, 140,450-127*

[28]. Romshoo, S. A., Bhat, S. A., and Rashid, I. 2012. Geoinformatics for assessing the morphometric control on hydrological response at watershed scale in the Upper Indus Basin. *Journal of Earth System Science*, *121*(3), 659-686.

[29]. Rudraiah, M., Govindaiah, S. and Srinivas, V. S. 2008. Morphometry using remote sensing and GIS techniques in the sub- basins of Kagna river basin, Gulburga district, Karnataka, India. *Journal of the Indian Society of Remote Sensing*. 36: 351–360.

[30]. Schmid B. H., 1997, Critical rainfall duration for overland flow an infiltrating plane surface. *Journal of Hydrology*, 193, pp. 45-60.

[31]. Schumm, S. A. 1956. Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geol. Soc. Am. Bull.*, 67: 597-646.

[32]. Singh, Omvir, A., Sarangi and Milap, C. S. 2008. Hypsometric integral estimation methods and its relevance on erosion status of North-Western Lesser Himalayan Watersheds. *Water Resources Management*. 22(11): 1545-1560.

[33]. Singh, S. and Singh, M. C. 1997. Morphometric analysis of Kanhar river basin. *Nat. Geogr. J. of India*. 43(1):31–43.

[34]. Singh, S. R. 2006. A drainage morphological approach for water resources development of the sub-catchment, "Vidarbha Region". *Journal of Indian Society of Remote Sensing*. 34(1): 79-88.

[35]. Smart, J. S., and Surkan, A.J. 1967. The relation between mainstream length and area in drainage basins, *Water Resources Research*, 3(4), 963-974.

[36]. Sreedevi, P. D., S Owais, HH Khan, S Ahmed. 2009. "Morphometric analysis of a watershed of South India using SRTM data and GIS." *Journal of the Geological Society of India*, 73(4):543-552.

[37]. Sreedevi, P. D., Sreekanth, P. D., Khan, H. H. and Ahmed, S. 2012. Drainage morphometry and its influence on hydrology in an semi arid region: using SRTM data and GIS. *Environmental Earth Science (Spingers).*

[38]. Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. *Transverse American Geophysical Union*. 38: 913-920.

[39]. Strahler, A. N. 1964. Quantitative geomorphology of drainage basins and channel networks. In: V. T. Chow (ed), *Handbook of Applied Hydrology*. McGraw Hill Book Company, New York, section 4-1I.

[40]. Suresh, M., Sudhakar, S., Tiwari, K. N. and Chowdary, V. M. 2004.Prioritization of watersheds using morphometric parameters and assessment of surface water potential using remote sensing. *Journal of the Indian Society of Remote Sensing*. 32(3): 249-259.

[41]. Zavoiance I., 1985. Morphometry of drainage basins developments in water science, Publisher: Elsevier Science 20, pp 104-105.

[42]. Zaz, S., Romshoo S.A .2012. Assessing the geoindicators of land degradation in the Kashmir Himalayan region, India. *Nat Hazards* 64:1219–1245