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Morphological Parameter Estimation Derived From DEM Using GIS and Remote Sensing Techniques

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Abstract:
In the present study, an attempt has been made to determine relief 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 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 scales 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 relief 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 Relief morphological parameters of a watershed

S. No.	Morphological parameters	Formula	References
1	Total relief (H)	H= Z-z Z=Maximum elevation Z=Minimum elevation	Rudraiah (2008)
2	Relief ratio (Rh)	Rh = H/Lb; H = Total relief of the basin Lb = Basin length	Schumn (1956)
3	Slope (S)	S=Z-z/L Z=Highest elevation ; z=lowest elevation L=Horizontal distance between both points	Miller (1953)
4	Relative relief (R_R)	Rr =H/Lp H= maximum watershed relief Lp= perimeter of watershed	Melton (1957)
5	Ruggedness number (Rn)	Rn = H X Dd; H= maximum watershed relief	Melton (1957)
6	Geometric number (Nr)	Nr=HXDd/Sg Sg = length of overland flow	Schumn (1956)
7	Time of concentration (Tc)	$Tc=0.001947L^{0.77}S^{-0.385}$ L=length of watershed;S=Slope	Kirpich (1940)

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 relief 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.

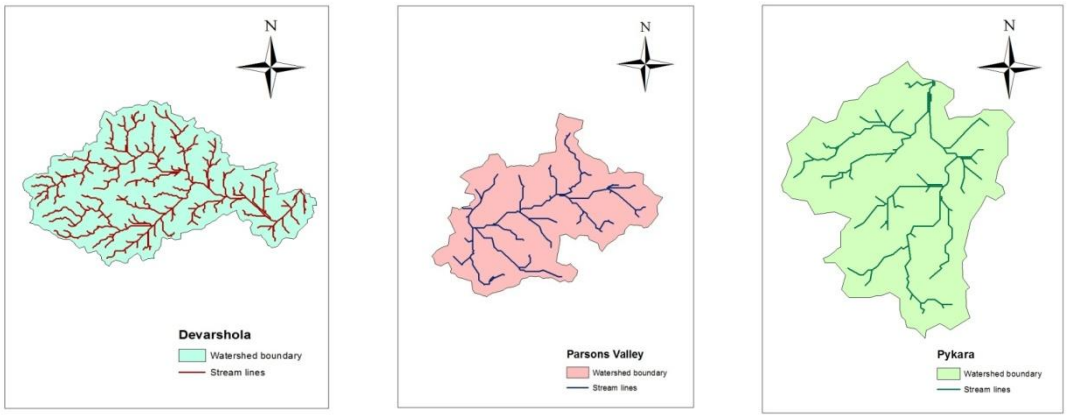

Figure.3. the streams delineated from ASTER DEM

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 measurement of linear, areal and relief (gradient) aspects of the channel network and contributing ground slopes.

Relief aspects

Relief is defined as the difference in elevation between the lowest and the highest point of a basin. Basin relief is an important factor in understanding the denudational characteristics of the basin. It plays a significant role in landforms development, drainage development, surface and subsurface water flow, permeability and erosional properties of the terrain. The total reliefs of the Devarshola, Pykara and Parsons Valley watersheds are 0.555, 0.392 and 0.256 km, respectively. The high relief value indicates the gravity of water flow, low infiltration and high runoff conditions. The present study Devarshola and Pykara have high relief.

Relief ratio (Rh)

Relief ratio, Rh, is defined as the horizontal distance along the longest dimension of the basin parallel to the principal drainage line (Schumm 1956). According to him, there is direct relationship between the relief and channel gradient. There is also a correlation between hydrological characteristics and the relief ratio of a drainage basin. The Rh normally increases with decreasing drainage area and size of sub of a given drainage basin (Gottschalk, 1964). The values of Rh are given in Table 7 and ranges from 0.042 to 0.075, which indicates moderate relief and steep to moderate slope. While the lower values may indicate the presence of basement rocks that are exposed in the form of small ridges and mounds with lower degree of slope (GSI, 1981).

Relative relief (R_R)

The observed relative reliefs Devarshola, Pykara and Parsons Valley are 0.0128, 0.023 and 0.0125 respectively. Observation of the present investigation coincides with the results obtained Pareta (2010).

Ruggedness number (Rn)

Strahler's (1968) ruggedness number is the product of the basin relief and the drainage density. It indicates the structural complexity of the terrain in association with the relief and drainage density. It also implies that the area is susceptible to soil erosion (Romshoo, 2011; Zaz, 2012). Calculated accordingly, the Devarshola, Pykara and Parsons Valley watersheds have a ruggedness number 1.282, 0.929 and 0.535. The low ruggedness value of watershed implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density.

Geometric number (Nr)

The observed geometric numbers of Devarshola, Pykara and Parsons Valley are 5.922, 4.404 and 2.237 respectively (Table 7).

Slope

Slope (S) enables the assessment of runoff generation, direction and volume. The Slope of Devarshola, Pykara, and Parsons are 0.031, 0.063 and 0.042 respectively. That reflects the relatively mountainous and plateau nature of the terrain. The above results are agreement with Hajam (2013).

Time of concentration

Time of concentration the Devarshola, Pykara and Parsons Valley watersheds are 39.8, 13.79 and 15.69 min (Table 7) respectively, which in turn gives an idea of delayed peak flow from the watershed (Suresh, 1997). The low value of time of concentration was found due to higher stream slope and lower basin length.

Table .3. Comparison of relief morphometric parameters of the watersheds under study

S. No	Morphological parameters	Watersheds		
		Devarshola	Pykara	Parsons Valley
1	Total relief (km)	0.55	0.39	0.25
2	Relief ratio	0.04	0.07	0.04
3	Relative relief	0.01	0.02	0.01
4	Slope	0.03	0.06	0.04
5	Ruggedness number	1.28	0.92	0.53
6	Geometric number	5.92	4.40	2.23
7	Time of concentration(min)	39.8	13.78	15.94

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 The Slope of Devarshola, Pykara, and Parsons Valley are reflects the relatively mountainous and plateau nature of the terrain

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