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Extraction of Drainage Pattern from ASTER and SRTM Data for a River Basin using GIS Tools

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Abstract. River drainage pattern is extracted from digital elevation data using D8 algorithm available within ArcGIS, hydrology toolbox. The extensive use of the tool box is described step by step. Study area is the Cauvery basin spanning across three states of Southern India viz., Tamilnadu, Karnataka and Kerala. Watershed is delineated by using ArcGIS 10 by the normal delineation procedure which is described in detail and plugins like ArcSWAT and Hydrotools are used to get the best results. Google earth is used as a reference to visually inspect the ridges and boundaries. The basis for assuming the limiting threshold value is discussed. All the aforementioned work is done for ASTER and SRTM data separately and the results are compared. The number of sub watersheds resulting for limiting threshold value obtained by trial and error method is shown.

Keywords: ASTER, SRTM, GIS, hydrology, river drainage pattern, watershed delineation.

1. Introduction

We use a Geographic Information System (GIS) and Remote Sensing Data for extracting the river drainage pattern. The areas of basins studied using GIS and Remote Sensing Techniques in similar studies are of the range of a few hundreds to a little over thousand sq.km, whereas the study area considered here is 81,155 km^2. Accuracy of the morphometric properties (based on shape of the basin) depends on the accuracy in delineation of the watershed which is governed by the resolution of the satellite imagery available. Morphometric properties like Horton's ratio, Elongation ratio, etc., depend on the accuracy of the data and the effectiveness of the method used in deriving the drainage pattern. Traditional techniques for determining channel width, depth, and cross-section area are time consuming and may not be truly representative of the spatial variability within a watershed (Miller, 2002).

The *D8* algorithm is being used here in this study. It is scripted into ArcGIS 10, ESRI. The entire delineation procedure is described in detail.

2. River Drainage Pattern

2.1. Extraction of River Drainage Pattern; Algorithm and Parameters that can be Studied using the Extracted River

2.1.1. D8 Model of Flow Routing

The D8 algorithm (Jenson and Domingue, 1988) has been the most commonly used method of approximating flow direction on a topographic surface. This method of flow routing was introduced by

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O'Callaghan and Mark in 1984. This model has been incorporated into ArcGIS by ESRI. Flow line computations using the D8 algorithm can also be done using GRASS (open source GIS platform) and *Mathematica* (Boonklong, Jaroensutasinee, & Jaroensutasinee, 2007)

A new approach was developed by Li, Wang, & Hao (2008), in which the river system in digital maps was considered as the correct river network (CRN) while that extracted from DEM was called the digital river network (DRN).

2.1.2. Morphometric Parameters

Morphometric parameters of a watershed can be studied from the digital network extracted from using GIS. The importance of morphometric analysis was demonstrated by Thakkar & Dhiman, (2007). Morphometric parameters like stream order, stream length, bifurcation ratio, basin length, drainage density, stream frequency, texture ratio, form factor, circularity ratio, elongation ratio, compactness constant, shape factor, etc., were shown by Thakkar & Dhiman (2007) and Kumar & Raju (2011) in their respective studies of watershed prioritization and classification using GIS techniques. Many works on morphometric parameters was followed by prioritization of sub watersheds based on weightage given to ratios (Horton's ratio, texture ratio, etc.,) and their influence on watershed behavior (Thakkar & Dhiman, 2007Vittala, Govindaiah, & Gowda, 2008, Mishra & Nagarajan, 2010).

2.2. Extraction Procedure

2.2.1. Filling of Voids

Since the raw data is not pre-processed and is of research grade, the grids of no data (voids) and erroneous data are to be corrected. *Fill* function of the ArcGIS toolbox in hydrology toolset is employed for this purpose. The method (Tarboton & Rodriguez-Iturbe, 1989) is used to remove all sinks in the data.

2.2.2. Creation of Flow Direction Raster

Flow direction raster shows the direction of the steepest downslope neighbor for each cell by colour coded direction.

Maximum drop = (Difference in elevation between cells / Distance between cell centers) x 100

2.2.3. Creation of Flow Accumulation Raster

Flow accumulation raster shows for each cell in the grid, the number of cells contributing to flow. Each cell carries a contributing weight of one.

2.2.4. Flow Limitation

A limiting threshold value is to be given to limit the flow accumulation raster to required limit of drainage density. This is done by trial and error method. It was found by (Li, Wang, & Hao, 2008) that the spatial distribution of watershed changes approximately with power function of upslope gradient in areas with the same vegetation. It would be of benefit to take into account its spatial variation during extracting catchment properties and simulating hydrological processes.

The contributing area of all grids can be obtained after sink filling and flow direction calculation during the period of extracting the river network from DEM. Grids with a larger contributing area more possibly belong to channels. Based on this concept, a common approach of extracting drainage networks from a DEM is to consider a grid cell as being part of a channel if its contributing area is larger than a defined contributing area threshold (O'Callaghan & Mark, 1984). The threshold is also called a *critical contributing area.* It is considered as a parameter of digital river network extraction and distinguishes stream processes from flow concentration of hill slopes.

2.2.5. Creation of Stream Network

For this step, the *data conversion* toolbar is used. Stream raster is converted into a vector file.

2.2.6. Picking Pour Points

This is done with the help of *data management* toolbox. The point of confluence of streams is assumed to be the pour point of each sub watershed.

2.2.7. Watershed Delineation

This step requires pour point data and flow direction raster data as inputs.

Hydrology toolbar of the "*spatial analyst*" toolset was used for the entire work. The same was carried out with ArcSWAT and ArcHydro plugins. The boundary of watershed delineated was found to be more accurate with ArcSWAT. Accuracy was judged by visually inspecting the ridges using Google Map.

2.3. SRTM and ASTER comparison

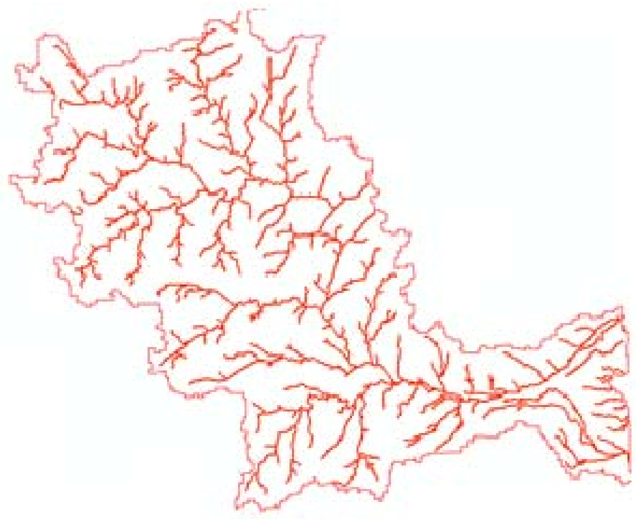

Fig. 1: Digital River Network from SRTM Data

Fig. 2: Digital River Network from ASTER Data

The threshold value for deciding on the required drainage density is arrived at by trial and error method where the watershed boundary derived from digital network matches the digitized boundary most accurately. Threshold value for flow limitation in ASTER (30 meter resolution) is higher than SRTM (90 meter resolution) due to the difference in resolution. Correspondingly, drainage density is notably higher in ASTER for scarcely distinguishable watershed boundary obtained as a result.

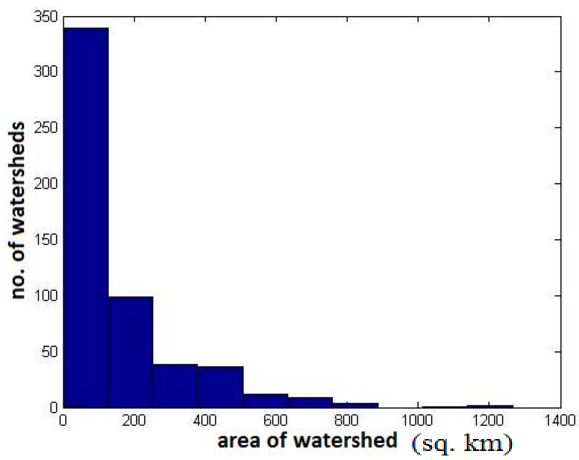

Fig. 3: SRTM: No. of watersheds vs area of watershed

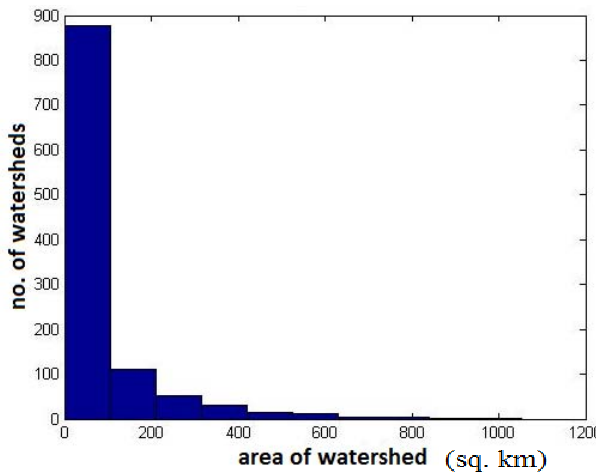

Fig. 4: ASTER: No. of watersheds vs area of watershed

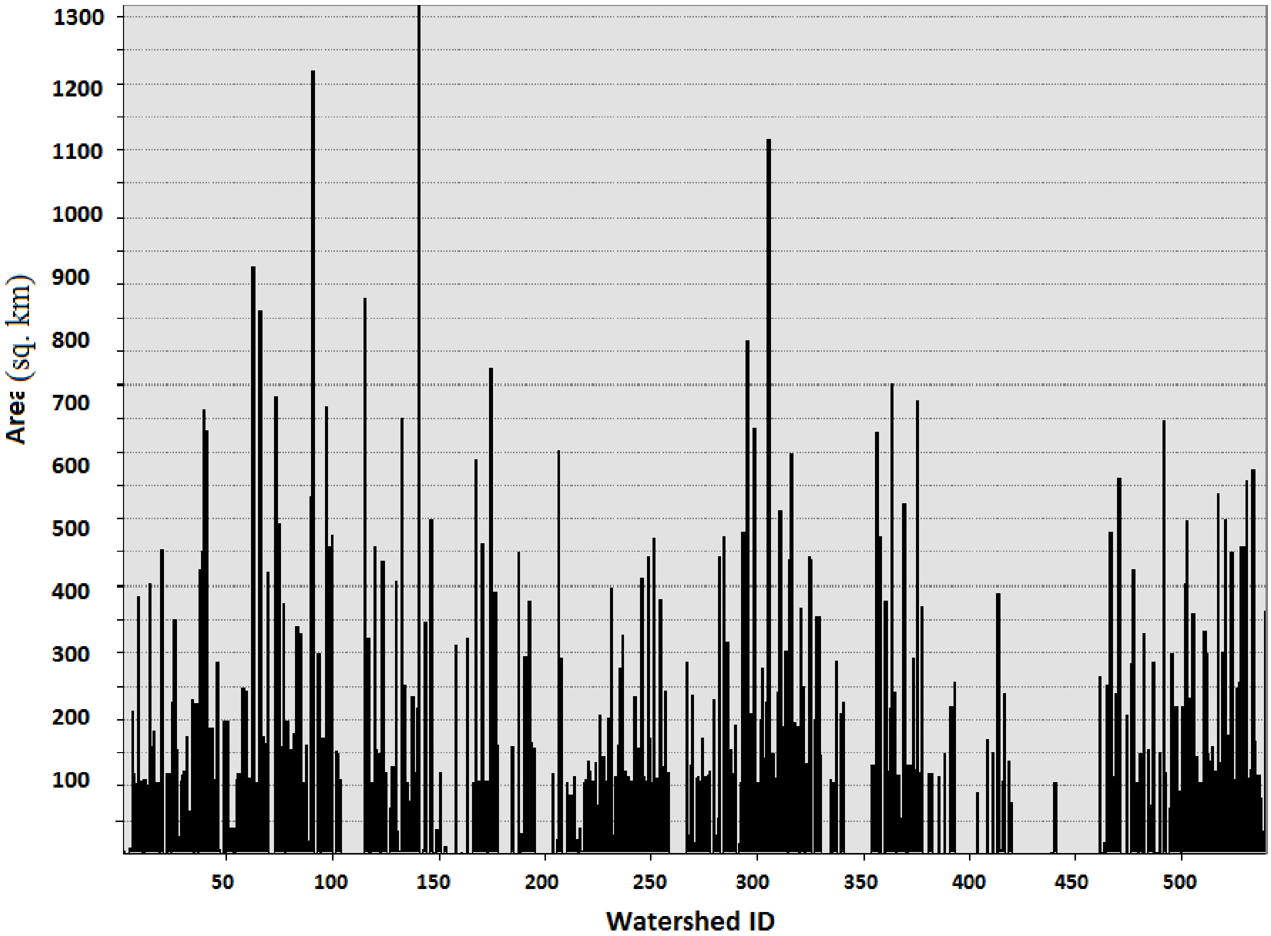

Fig. 5: SRTM: Area of watershed vs. Identification number

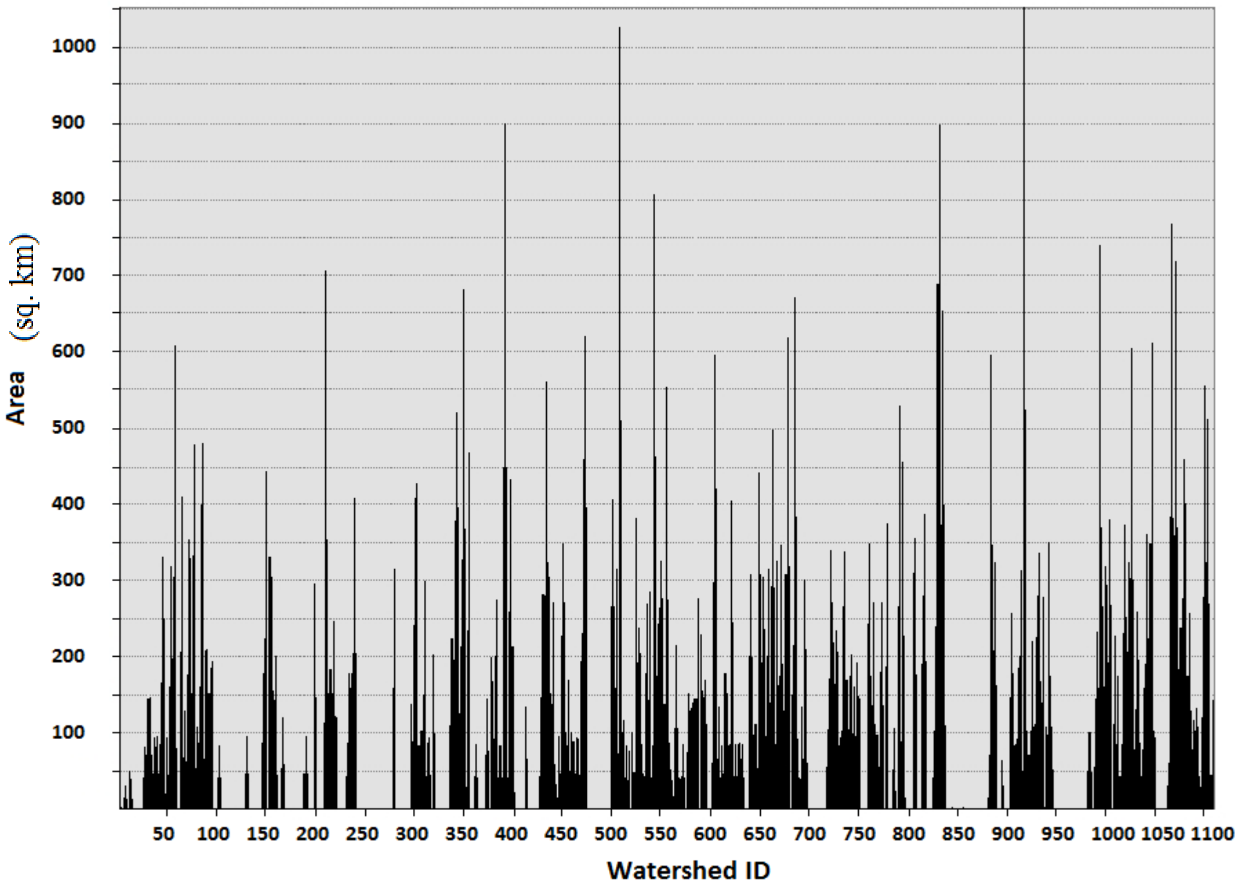

Fig. 6: ASTER: Area of watershed vs. Identification number

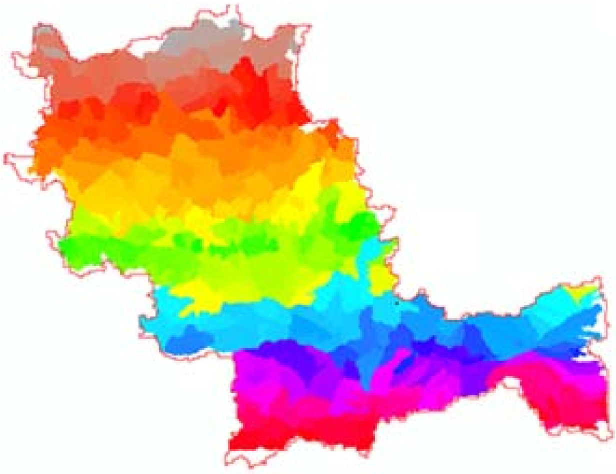

Fig. 7: Watersheds from SRTM Data

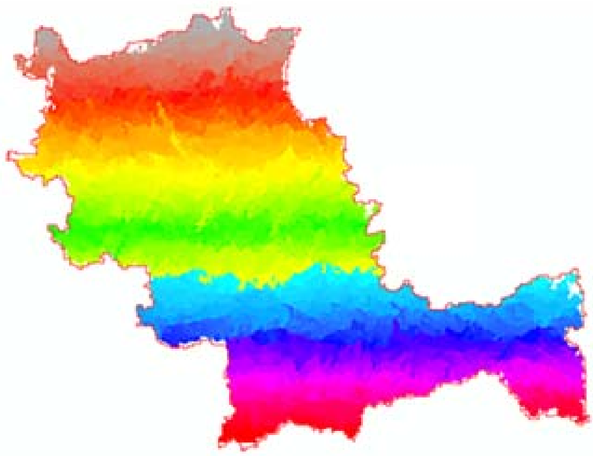

Fig. 8: Watersheds from ASTER Data

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