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Delineation of Teesta river basin from remotely sensed digital elevation data

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ABSTRACT

Identification, classification, and monitoring of the earth resources along with detailed topographic information for use in hydrological analysis and modelling can be easily done by using remote sensing. Present study was conducted for selection of watershed outlet, developing the watershed boundary, clipping the watershed from the entire basin and the streamline generation for Teesta river watersheds from SRTM data. Using the ERDAS IMAGINE 8.6 and ArcGIS 9.2 software the delineation was done. A total number of 163959 sinks were found to be present in the DEM data, after sink filling the numbers of sinks were reduced to 6225 that gave continuous stream network. The Teesta river watersheds boundaries were generated from the filled DEM data. Watershed catchment was delineated by superimposing this clipped stream network over watershed boundary image. Satellite imageries, soil data, land use, land cover map etc. can be generated to develop a detailed database for quick reference of the hydrologists working in the region.

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Key words : SRTM data, ArcGIS 9.2, Watershed delineation

INTRODUCTION

Remote sensing is the science of obtaining information about an object, area, or phenomenon, through the analysis of data acquired by a sensor that is not in contact with the object. In this regard the significant areas of concern are accurate delineation of watershed and development of a hydrological database with the information like runoff, precipitation, soil, topography, stream network etc. (Gangodagamage, 2001). In remote areas collection of spatial topographic data by ground surveying can be a cumbersome process. Even with the use of very accurate modern surveying techniques like total station, it remains a challenging task to capture and create database for a large river basin. The commonly used topographic data is known as digital elevation model (DEM) where the elevations are recorded in digital format. Salient advantages of such DEM data are easy data acquisition over inaccessible area, data acquisition at different scales and resolutions, and analysis of the data in laboratory to reduce extensive field work.

A major portion of the floodplains of North Bengal is frequently affected by floods. Therefore, the area has a vast scope for the researchers to conduct hydrological studies. But the non-availability of relevant hydrological data for the area is a major constraint for conducting such investigations. There is an urgent need to develop a hydrologic database for the major river basins of the area as till now no such database is available with the hydrologist working in North Bengal. Keeping this in view, the present project work was undertaken to carry out raster based analysis for delineating watershed areas of Teesta river basins using ArcGIS software and generate stream network and extract DEM data for Teesta river basins of North Bengal.

MATERIALS AND METHODS

The Teesta River is a 'trans-Himalayan' river flowing through the entire state of Sikkim. This river forms the boundary between Sikkim and West Bengal before merging with the Brahmaputra in Bangladesh as a tributary. The river originates from the Cho Lhamu Lake at an average height of 5,330 metres (17,500 feet) above mean sea level in the majestic Himalayas. The total length of the river is about 315 km.

Remotely sensed elevation data :

Geographical information system (GIS) has emerged as a significant support tool for managing and analyzing land and water resource from digital elevation model (DEM) of land terrain. Remotely sensed digital elevation data have been used for the area for developing a database for the watershed. Since the Earth is three-dimensional, it would seem that all GIS application include some element of three-dimensional analysis. To, meet this

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demand, the digital terrain modeling or DEM techniques have emerged. A digital elevation model (DEM) is a grid or raster of square cell whose cell value is the average land surface elevation of the cell area.

DEM data :

The term digital elevation model or DEM is frequently used to refer to digital representation of a topographic surface. A DEM may be described by three elements, namely block, profile, and elevation point. According to U.S.G.S (United State Geological Survey) a block is used to describe the physical extent of DEM. Resolution of available DEM data:

- 1 km DEM of the Earth: Global Topographic Data (GTOPO).
- 100 m DEM from 1: 250,000 scale maps.
- 30 m DEM from 1:24,000 scale map
- 90 m Shuttle Radar Topography Mission Data (SRTM).

The SRTM data:

The Shuttle Radar Topography Mission (SRTM) was conducted in collaboration between the National Aeronautics and Space Administration (NASA) and National Geospatial Intelligence Agency (NGA). This mission was initiated on 11th February, 2000 with the help of the Space Shuttle Endeavour to collect over 224 hours of three dimensional radar images of Earth between latitudes 60º N and 54º S from and altitude of 233 km (145 miles) using C-band and X-band interoferometic aperture radars. The performance requirements for the SRTM data products are (a) linear vertical absolute height error shall be less than 16 m for 90% of the data (b) linear vertical relative height error shall be less than 10 m for 90% of the data (c) circular absolute geolocation error should be less than 20 m for 90% of data.

SRTM data downloading and processing:

The SRTM data for the study area were downloaded from the website http://srtm.csi.cgiar.org/. To cover the entire region of interest four scenes of data were downloaded. The data were in the form of compressed image file (*.img* file extension). The image files were uncompressed to get the actual image files. After that systematic step by step approaches were followed for further processing and analysis of the SRTM data.

Software used :

For the analysis and processing of the SRTM data ERDAS IMAGINE 8.6 and Arc-GIS 9.2 softwares were used. For initial operations like masaicing and sub-setting the image processing software ERDAS IMAGINE 8.6 was used. The grid based analyses were conducted using the GIS package Arc-GIS 9.2.

Mosaicing :

The extracted SRTM image files were joined together using the mosaic option available in ERDAS IMAGINE 8.6. The four image files to be joined were added to the list one by one and an output file name was specified. Then the mosaic command was run and a new file containing all the four scenes was created.

Subsetting :

After mosaicing the final image becomes a large file and grid based operations to be carried out with such large files may be time consuming. Therefore, wherever possible a smaller frame containing the area of interest can be clipped out for analysis. This process is known as subsetting. ERDAS IMAGINE 8.6 software was used to do the subsetting. The area of interest (AOI) was defined by a rectangular selection and the selected area was subsetted using the subset option of the software. The subset file created is also in *.img* format.

Preprocessing :

The grid based operations of DEM were done with ARC-GIS 9.2 software. For this the DEM data is to be converted from image format to grid format. The conversion tool is available in command tools of arc toolbox. The image file to be converted was selected and an output file name was specified.

Computation of flow direction :

The first operation to be conducted with the DEM file is the computation of flow direction. To generate the flow direction grid the following grid command was used.

flow_dir = flowdirection (elevation)

where, *flowdirection* is the grid command, *flow_dir* is the output flow direction grid file name, and *elevation* is the input DEM grid file.

Computation of flow accumulation :

The flow accumulation function calculates accumulated flow as the accumulated weight of all cells flowing into each down slope cells in the output grid. The flow direction grid can be used as input file to compute the flow accumulation. The grid command used is

flow_acc = flowaccumulation (flow_dir)

where *flowaccumulation* is the grid command, *flow_dir* is the input flow direction grid, and *flow_acc* is the output flow accumulation grid.

Streamline generation :

Streamline is a vectorization program designed primarily for vectorization of stream networks or any other grid representing raster linear network for which directionality is known. Streamline is optimized to use a direction grid to aid vectorizing intersecting and adjacent cells. To generate a streamline the following grid command is used

streamnet = con (flow_acc* > 5, 1*)

where *streamnet* is the output grid file of stream network, *flow_acc* is the flow accumulation file name, and 5 is the threshold value of accumulated flow to assign it as a streamline.

Watershed deliniation :

With the help of flow accumulation grid a suitable outlet can be specified from the viewer or by its coordinates. To specify outlet from flow accumulation grid the following grid command can be used.

wshed= watershed(flowdirection(elevation), selectpoint (elevation, *))

where *wshed* is the output grid file of watershed boundary. The command for clipping streamlines for an watershed is

CLIP *strmcov wshedcov wshedstrm* LINE

where *strmcov* is the generated stream network, *wshedcov* is the polygon coverage of watershed boundary, *wshedstrm* is the clipped stream coverage for the watershed.

Sink filling :

Sink filling is the process of filling the uneven depression in the streamlines and making the streamlines continuous. For the subset DEM file used in this study it was detected that there were total 163959 sinks. Now the filling of sinks is done interactively slowly increasing the fill depth till we get continuous streamlines. The grid command used for filling is

FILL *elevation filled* SINK 5

where *filled* is the DEM file after doing 5 units of sink filling of the DEM file *elevation*.

RESULTS AND DISCUSSION

The selection of watershed outlet, developing the watershed boundary, clipping the watershed from the entire basin and the streamline generation were done for both Teesta and Torsa watersheds from SRTM data following the methodologies was described.

Creation of mosaiced image :

Using the ERDAS IMAGINE 8.6 mosaicing and subsetting of the data were done. The output image is displayed in Fig. 1 in grayscale composition.

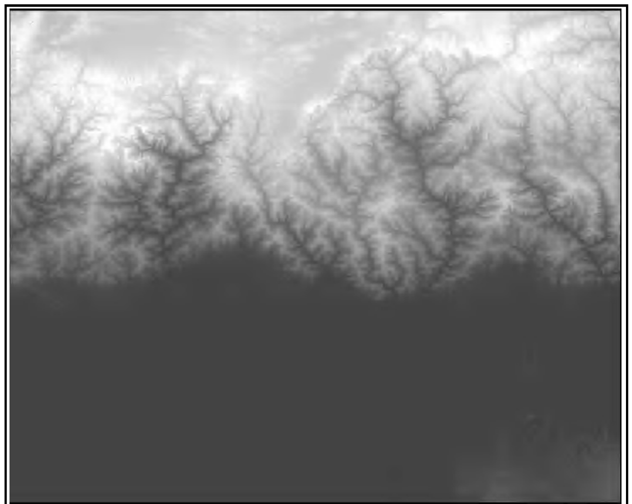

Fig. 1 : Mosaiced and subsetted image in grey colour composition

Conversion from image to grid :

The subset image was converted from image to grid format using ArcGIS 9.2. The grid format DEM data is shown in pseudo colour composition in Fig. 2

Computing flow direction :

Using grid command the flow direction grid was generated. Fig. 3 shows the flow direction grid generated from the raw DEM data

Determining flow accumulation :

From the flow direction grid the flow accumulation grid was generated. The generated flow accumulation grid is shown in Fig. 4. From A threshold value of 1400 was taken to assign an accumulation grid cell as a part of streamline

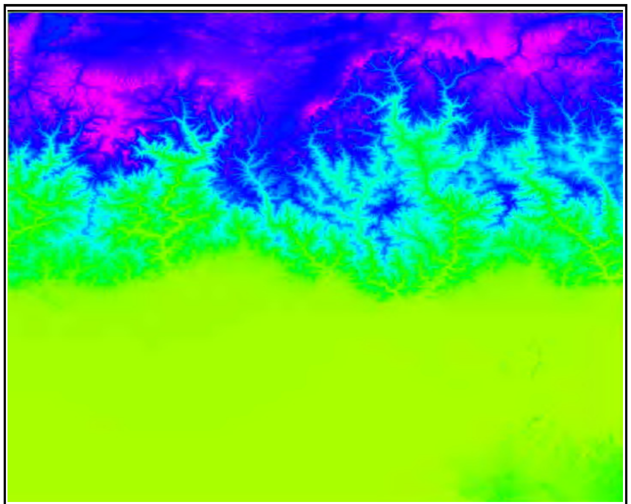

Fig. 2 : Grid format DEM Image in pseudo colour composition

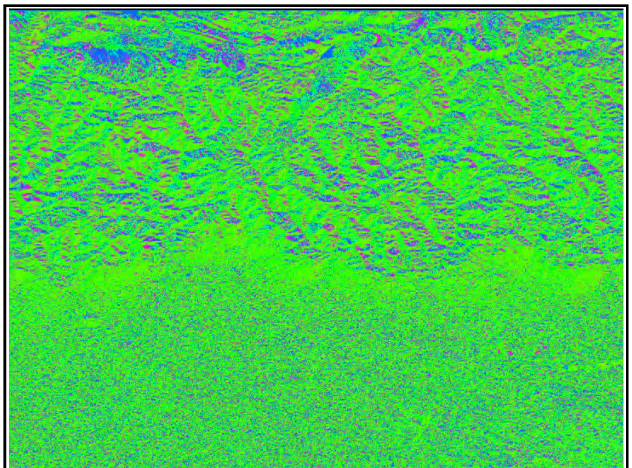

Fig. 3 : Flow direction grid from raw DEM data

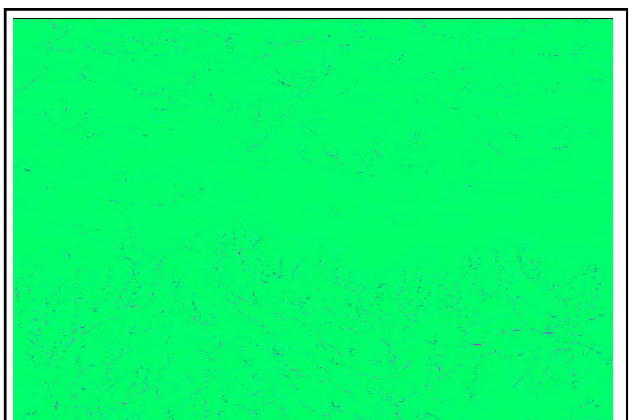

Fig. 4 : Flow accumulation grid with discontinuous stream lines

Generation of continuous stream lines :

The stream lines visible in Fig. 5 are not continuous. This is because of the presence of sinks. A total number of 163959 sinks were found to be present in the DEM data. Using the process of sink filling the numbers of sinks were reduced to 6225. At this stage with the filled DEM the generated flow accumulation showed continuous stream network. This grid file was converted to arc coverage to get the stream network coverage.

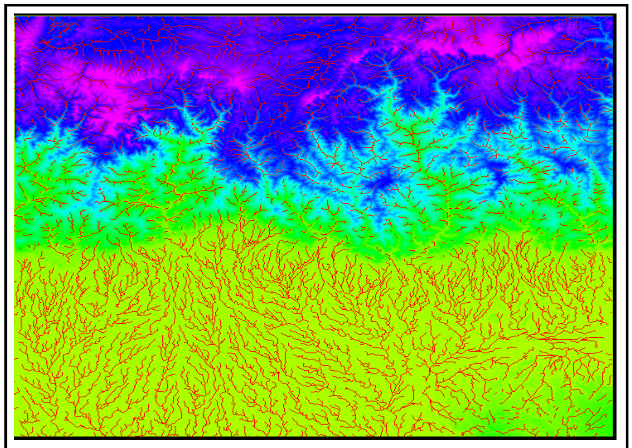

Fig. 5 : Continuous streamlines superimposed over DEM

Watershed delineation and data layer generation:

The Teesta watersheds boundary was generated from the filled DEM data. Fig. 6 shows the Teesta river basins. Now using the watershed boundary polygon coverage the stream network for Teesta watersheds was clipped out (Fig. 7-10). Similarly, different layers of data can be generated for these watersheds. Similarly, satellite

Fig. 6 : Watershed boundary of the Teesta river

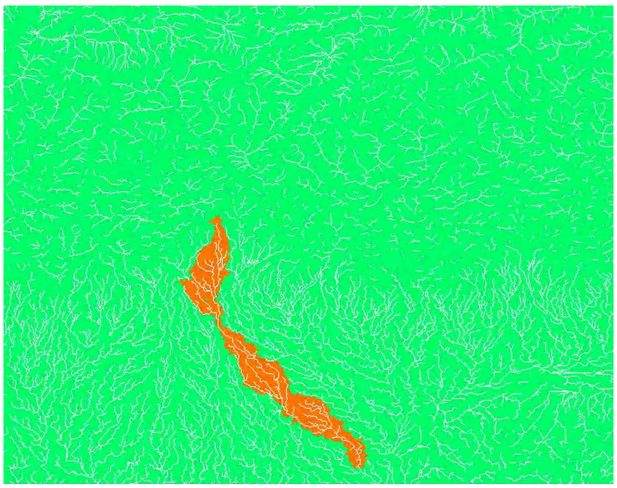

Fig. 7 : Clipping of stream network for the Teesta watershed

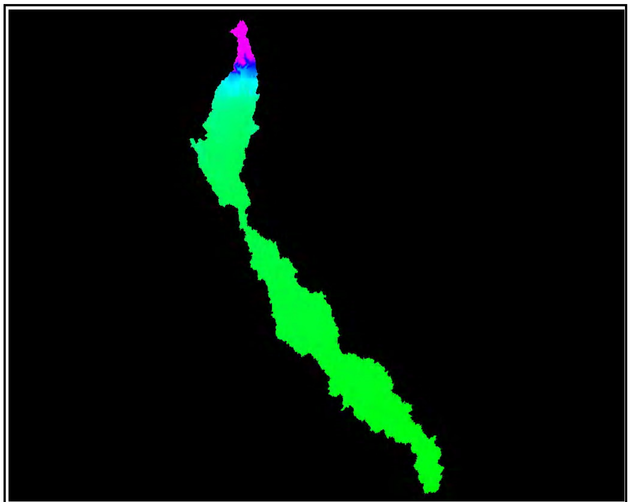

Fig. 9 : Actual DEM data of the Teesta watershed

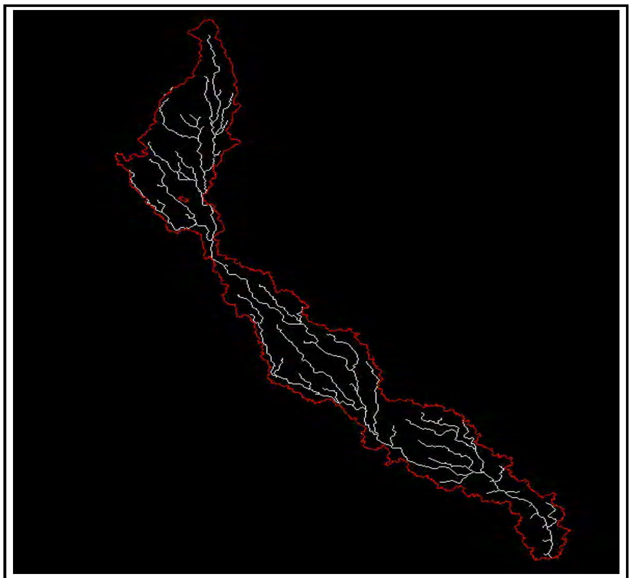

Fig. 8 : Streamlines and the boundary of the Teesta watershed

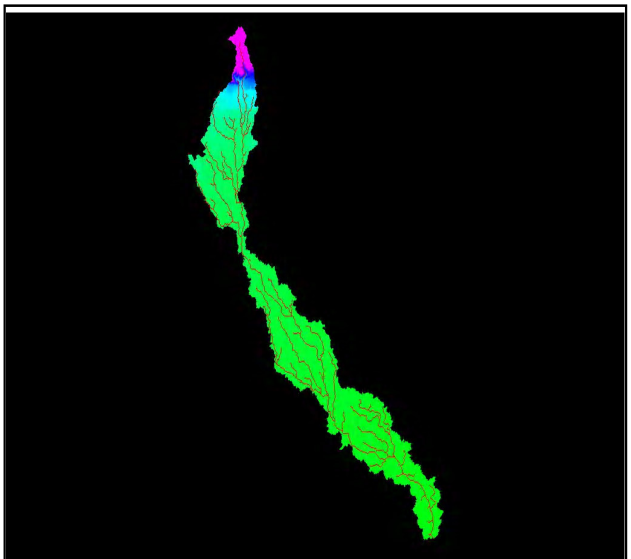

Fig. 10 : Stream network layer over the DEM data of the Teesta watershed

imageries, soil data, land use, land cover map etc. can be generated to develop a detailed database for quick reference of the hydrologists working in the region. The use and aplication of remote sensing and satellite data have been errphasized by Mustafa *et al.* (1997) and Tripathi *et al.* (2002).

Conclusion :

The Teesta river basins were delineated successfully from the freely available 90 m resolution SRTM data. The stream networks of the major river of North Bengal was also generated. In future the satellite data of land use and land cover (ETM, TM, LISS etc.), soil map etc., can easily be generated for the watersheds. Therefore, the use of remotely sensed digital elevation data can serve the purpose of GIS database generation for the remote but important river basin. The created database can be efficiently implemented for any hydrological analysis. The database can provide .

– Any necessary information to the hydrologist for their research

– Land use classification, soil map, runoff estimation etc.

– Slope map generation of the watersheds

– Valuable information as input to physical based hydrological models.

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Tripathi, M.P., Panda, R.K., Pradhan, S. and Sudhakar, S. (2002). Runoff modelling of a small watershed using satellite data and GIS, *J. Indian Soc. Remote Sensing*, **30** (1 & 2) : 39-52.

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