CAPABILITY OF CARTOSAT-1 STEREO IMAGE DATA FOR INTEGRATED WATERSHED MANAGEMENT

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ABSTRACT
The high-resolution Cartosat-1 stereo image data is expected to have significant impact in topographic mapping and watershed applications. The objective of the present investigation is to make an assessment of the potential of the Cartosat-1 data in generation of DEMs and watershed delineation. The collection of GCPs presents a significant problem in many practical applications due to non availability of GCPs. A DEM generation method which requires no GCPs would therefore be of significant interest to users of stereo data. In this study, automatic DEM extraction of Cartosat-1 multi-View data without the use of GCPs has been evaluated. The assessment is based on the entropy analysis of the fore/aft images, geometric quality of the fore/aft images (2-D perspective), generation of high-resolution Digital Elevation Model (DEM), Quality evaluation in different elevation strata, generation of ortho-image and application potential of the photogrammetric products for natural resources applications. Watershed boundary, flow accumulation, flow direction, flow length, stream ordering have been prepared using ArcHydro Tool; and contour have been prepared using Surface Tool in ArcGIS-10 software, and DEM is generated using LPS software.

Key words: Cartosat-1, DEM, ArcHydro , Arc-GIS, LPS

1.1 INTRODUCTION

High resolution space-borne remote sensing image data show a high level of detail and provide many opportunities to be integrated into remote sensing applications. Precise digital maps generated from satellite imagery are assuming growing importance in the spatial information industry. For coverage at medium to small mapping scales, satellite line scanner imagery has a number of advantages over aerial photography for topographic mapping, the production of digital ortho-images and the generation of DTMs (Ono et al., 2000). The information contents and the geometric accuracy are important for the generation of qualified topographic maps with the required contents and geometry. The new generation of high-resolution satellite imagery will provide strong geometric capabilities that have not been available from existing satellite imaging systems. Specific geometric aspects of the imagery that are interesting to the mapping community include, for example, high-resolution, photogrammetric stereo capability, and revisit rate (Rongxing, 1997). Stereo image viewing has been the most common method of elevation modelling used by the mapping, photogrammetry, and remote sensing communities. Multi-view image contains radiometrically corrected images with rational polynomial coefficients. The advent of very high resolution optical satellites capable of producing stereo images led to a new era in extracting digital elevation model (DEM).

The definition of high resolution satellite imaging systems is not fixed, it depends upon the application. For meteorological satellites even 1km may belong to high resolution but here it is used in relation to topographic mapping purposes, means it starts approximately at a ground sampling distance (GSD) of 10m.

Ground sampling distance is the distance of the centre of neighboured pixels projected to the ground. This appears as pixel size on the ground even if the real ground pixel size is influenced by over- or under-sampling.

The Cartosat-1 satellite was launched by the PSLV on May 5, 2005 from the newly built second launch pad at Sriharikota, and is the eleventh satellite to be built in the Indian Remote Sensing (IRS) satellite series. CARTOSAT – 1 is the first Indian Remote Sensing Satellite capable of providing in-orbit stereo images. It is a unique satellite having along track stereo imaging capability with 2.5 m resolution with a dedicated stereo platform. The images are used for Cartographic applications meeting the global requirements. While it can be configured to collect imagery in a monoscopic mode, the sensor payload consists of a pair of 2.5 meter panchromatic camera assemblies mounted in a stereo viewing configuration much like the ASTER sensor onboard TERRA (Abrams et al., 2002). It has got two identical optical sensor, Fore and Aft operating in panchromatic band to operationally acquire along track stereo images, that take black-and-white stereoscopic pictures in the visible region of the electromagnetic spectrum. The spacecraft is configured with the Panchromatic cameras which are mounted such that one camera is looking at +26 degree with respect to nadir and the other at -5 degree with respect to nadir along the track. The images taken by CARTOSAT-1 cameras are compressed, encrypted, formatted and transmitted to the ground stations. CARTOSAT-1 also carries a Solid State Recorder with a capacity of 120 Giga Bits to store the images taken by its cameras. The stored images can be transmitted when the satellite comes within the visibility zone of a ground station. These two cameras combinedly provide stereoscopic image pairs in the same pass. Geometrically, the RPCs (rational polynomial coefficients), which provide the image-to-ground geometric relationship, for the images acquired from the Fore and Aft sensors, have been modified to rectify the anomaly of occasional zero crossovers in the denominators; as well as to modify the longitude convention used in the data products to -180 to +180 degrees instead of 0 to 360 degrees (Nandakumar et al., 2008). Cartosat-1 satellite is dedicated to stereo viewing for large scale mapping and terrain modeling applications. Stereo imaging from space-borne platforms offers information about terrain elevation besides supplying spectral reflectance of the scene. The spacecraft body is steerable to compensate the earth rotation effect and to force both fore and aft cameras to look at the same ground strip when operated in stereo mode. The stereo pairs have a swath of 26 km and a fixed B/H ratio of 0.62. Apart from the stereo mode, the satellite is also equipped to operate in the wide swath mode. When operated in this mode the satellite can be maneuvered such that image strips will fall side by side so that wider swath images of 55 km are obtained by the cameras.

During imaging, the spacecraft is maneuvered continuously so as to acquire either stereo or wide-swath images. This maneuvering could be done throughout the length of the pass for a given ground station or for any desired portion thereof (Nandakumar et al., 2008). The primary advantage of Cartosat-1 mission is it provides stereo pairs required for generating DEM, production of Orthoimage in an operational setup and Value added products for various applications of Geographical Information System (GIS). This also facilitates 3D terrain visualization for very large tracts of land. This greatly assists the analysis and interpretation of images in terms of identifying slopes, surface material, waterways, vegetation growth, etc. Generating DEMs from stereo data normally requires the use of a geometric model and ground control points (GCPs). The collection of GCPs presents a significant problem in many practical applications due to non availability of GCPs. A DEM generation method which requires no GCPs would therefore be of significant interest to users of stereo data. An automated image matching procedure is then used to produce the DEM. In this study, automatic DEM extraction of Cartosat-2 multi-View data without the use of GCPs has been evaluated, as well as the improvement of extracted DEM quality by applying horizontal shift on reference DEMs from the available Global DEMs or other source DEMs. High quality DEM has been generated at 2 m grid spacing which will be of immense use for producing digital city model (DCMs). The fig.1 and table.1 below shows the figure and the characteristics of Cartosat-1.

Fig. 1: Cartosat-1 Satellite

Table 1: Characteristics of Cartosat-1 Satellite

LAUNCH INFORMATION	Launch Date : May 05, 2005 Launch Vehicle : PSLV-C15 Launch Site : SHAR Centre Shriharikota India
SENSORS	Panchromatic
RESOLUTION	Panchromatic : 2.5m
SWATH WIDTH	9.6km
ORBIT	618km, Polar Sun-Synchronous
REVISIT	5 Days
MISSION LIFE	5 Years

DEM in Watershed management

The recent development of digital representation has stimulated the development of automatic actions to extract topographic and hydrologic information from Digital Elevation Model input, using GIS and hydrologic models that integrate multiple databases within a minimal time. Digital elevation model (DEM) data derived from Remote Sensing data have been widely used for the extraction of catchment and drainage network. Digital elevation model (DEM) is indispensable for many analyses such as topographic feature extraction, Runoff analysis, landslide susceptibility analysis and so on. The advents of Remote Sensing and Geographic Information Systems (GIS) have resulted in the availability of Digital Elevation Models (DEMs). DEMs are the digital representation of the natural topography as well as man-made features on the surface of the earth. This has improved the face of hydrological modelling and water resources management over the last few decades (Moore et al., 1991). Hydrological modelling is fast growing as a result of the growing technological advancement and excellent computer computation speed and reliability.

OBJECTIVE OF STUDY

- To generate Digital elevation model (DEM) from high resolution stereo data (Cartosat-1).
- To extract a watershed and drainage network from the Cartosat-1 DEM.

1.2 STUDY AREA

The area under investigation is a sub watershed in Kuttiyadi River Basin. Kuttiyadi River Basin falls in the Kozhikode district, Northern Kerala which lies between latitudes 11^0 30'N and11^0 44'N and longitudes 75^0 34 'E and 75^0 58'E is an important water source of Kozhikode district of Kerala. The fig.2 given below shows the study area.

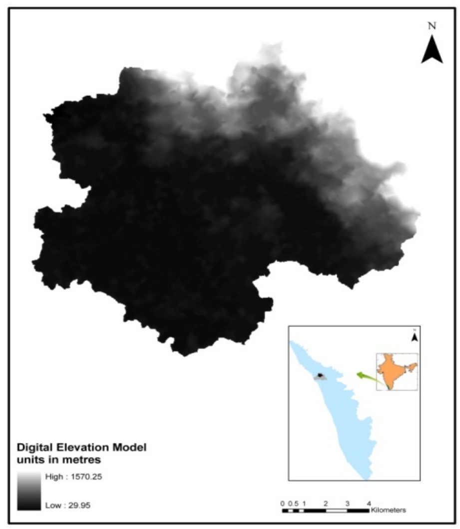

Fig.2 : Sub-watershed of Kuttiyadi River Basin

It is a west flowing river, rising from the Narikota Ranges on the western slopes of the Wayanad Hills a part of Western Ghats, at an elevation of 1220m above mean sea level (amsl) and drains into the Arabian Sea at Kottakal. The river is 74km long and along with its tributaries it drains an area of 676 km^2 in Kozhikode district of Kerala.

1.3 LITERATURE REVIEW

Suganthi and Srinivasan (2010), in this study author investigate and demonstrate the state of Remote sensing techniques for detailed landslide hazard assessment in the Ooty, Tamil

Nadu. The most common methods of landslide susceptibility assessment using weighted overlay are heavily dependent on 3-dimentional terrain visualization and analysis stereo satellite image. Comparison of Digital elevation model generated from high resolution satellite data (CARTOSAT-1) and aerial photograph scale 1:8000 is been incorporated in this particular study. This project gave the perfect DEM which can give slope information for landslide hazard assessment. Kuldeep and Upasana (2008), an attempt has been made to study the quantitative geomorphological analysis of a watershed of Ravi river basin in Himachal Pradesh, India. Authors have evaluated the morphometric characteristics on the basis of Survey of India toposheets at 1:50,000 scale, and Cartosat-1 DEM data with 2.5m spatial resolutions. For this detailed study, Cartosat-1 based DEM, and GIS were used in evaluation of linear, areal and relief aspects of morphometric parameters. Watershed boundary, flow accumulation, flow direction, flow length, stream ordering have been prepared using ArcHydro Tool; and contour, slope-aspect, hillshade have been prepared using Surface Tool in ArcGIS-10 software using the DEM dataset from Cartosat-1. Based on all morphometric parameters analysis; that the erosional development of the area by the streams has progressed well beyond maturity and that lithology has had an influence in the drainage development**.** Gopala et al., 2008**,** In this paper authors are worked on DEM generation from high resolution multi-view data product. A comparison of DEM from Cartosat 2 and SRTM 90 m resolution is performed in this study. This study proves that it is possible to extract DEMs from Cartosat-2 multi-view images without GCPs. Only tie points have been used for the generation of DEMs. Automatic DEM extraction of Cartosat-2 multi-view data without the use of GCPs has been evaluated, as well as a study in the improvement of extracted DEMs quality by applying horizontal shift on reference DEMs from the available Global DEMs or other source DEMs. High quality DEM has been generated at 2 m grid spacing which will be of immense use for producing digital city model (DCMs).

2.1 MATERIALS AND METHODS

MATERIALS / DATA USED

The main data source used is CARTOSAT-1 imagery (Path 537 and Row 341) consist of band A and band F which is associated with meta data file and RPC file. Orthokit Stereo Products contain a pair of radiometrically corrected 10-bit image files corresponding to the Fore and Aft sensors in GeoTIFF format, two (encrypted and decrypted) ASCII files containing the rational polynomial coefficients (RPCs) respectively for each image, and metadata files in ASCII format. These products enable further processing to generate an ortho image by way of improving the ground-to-image relationships as provided in the RPC files using ground control points (GCPs).

Orthokit products are geometrically uncorrected except for the tagging of centre and corner coordinates with system corrected geographic latitude-longitude values. However detailed ground to- image relationship is explicitly provided in the RPC file. Watershed is delineated by using ArcGIS 10 by the onscreen digitization procedure which is described in detail and plugins like Hydrotools are used to get the best results. Arc hydro tools (version 2.0) an application extension for ArcGIS 10 recently released by ESRI was used to extract drainage network.

2.1.2 METHODS

DEM GENERATION

The automated DEM extraction and modelling has been done using the software Leica Photogrammetry Suite 2011. The flow chart below shows the procedure involved in the extraction of DEM.

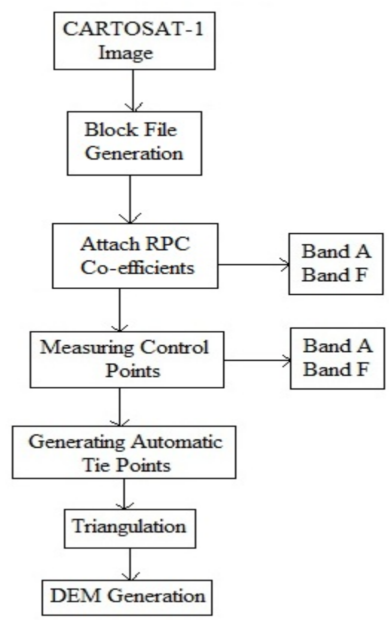

Fig.3 : flow chart showing the automated extraction of DEM from Cartosat-1

For the generation of the DEM the main data source required is the Cartosat-1 product, that contains one tiff file, one meta data file and RPC files for each band A and band F. Band A and band F are the stereo pairs used for generating DEM in LPS module. The software supports reading of data, manual or automatic GCP/tie points (TP) collection and geometric modeling of different satellites including RPC model. It is also capable of automatic DEM generation, DEM editing, ortho rectification and mosaicking. This RPC method of the software is based on the block adjustment method developed by Grodecki and Dial. LPS software supports zero order, a first order and second order RPC polynomial adjustments. To generate DEM a project has been created inside the software. Since no ground control point was used a zero order polynomial adjustment has been considered. The triangulation function is carried out to check the RMS error. Then digital terrain model is extracted to generate the automatic digital elevation model.

2.2.2 DRAINAGE NETWORK EXTRACTION

DIGITAL ELEVATION MODELS (DEMs) can be used to derive a wealth of information about the morphology of a land surface (U.S. Geological Survey, 1987). The figure (Fig.4) below shows the flow chart for automatic extraction of drainage network from the DEM generated Cartosat-1.

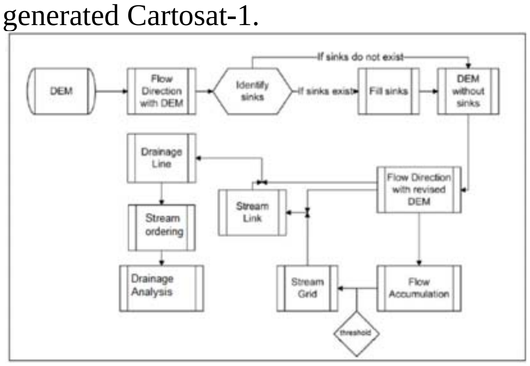

Fig 4: Flow chart for automatic drainage extraction

Horton provided the theoretical background for quantitative analysis of geomorphologic features for drainage network extraction. According to him the Drainage network should be analyzed in two main aspects of hill slope and channel system for representation surface runoff mechanism in any drainage basin. On the basis of Horton's drainage network hierarchy theory several important analytical tools evolved. With the help of DEM and Geospatial tools the extraction of drainage network has been carried out. Several algorithms have been proposed by scholars and geomorphologists to investigate river basin structure for network tracing based on flow direction algorithms. These algorithms applied on raster data to initiate the channel (CI) or Valley recognition (VR) methods, or in hybrid manner. Channel initiation is strongly influenced on the local morphology. Generally, the Deterministic (D8) a popular single direction algorithm has been used and existing software's are confined to it. In slope subsystem it is not successful to perform successful mapping on the other hand multiple path algorithms give non natural result (Carol and Sudhanshu, 2009). For better result both the algorithms could be used in conjunctive approach. Terrain Preprocessing uses DEM to identify the surface drainage pattern. Once preprocessed, the DEM and its derivatives can be used for efficient watershed delineation and stream network generation. All the steps in the Arc Hydro Terrain Preprocessing menu should be performed in sequential order, from top to bottom. All of the preprocessing must be completed before Watershed Processing functions can be used. DEM reconditioning and filling sinks might not be required depending on the quality of the initial DEM. DEM reconditioning involves modifying the elevation data to be more consistent with the input vector stream network. This implies an assumption that the stream network data are more reliable than the DEM data, so you need to use knowledge of the accuracy and reliability of the data sources when deciding whether to do DEM reconditioning. By doing the DEM reconditioning you can increase the degree of agreement between stream networks delineated from the DEM and the input vector stream networks. All ArcGIS raster operations involved in watershed delineation are derived from the premise that water flows downhill. In DEM grid structure, there exist at most eight cells adjacent to each individual grid cell. The first important grid derived from the digital elevation model grid is the flow direction grid. Water will flow in the direction of steepest descent, where slope defined by elevation decrease per unit travel distance. The process is repeated for each cell in the DEM grid, thereby creating the flow direction grid whose cell values are the flow direction defined by the eight direction pourpoint model. The below figure illustrates the mechanism in D8 algorithm for flow direction.

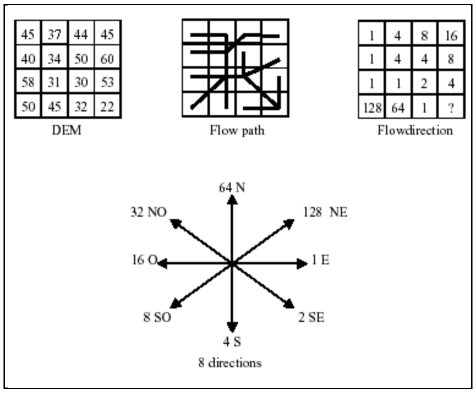

Fig.5: Mechanism involved in the generation of Flow direction grid from depressionless DEM

Flow accumulation is calculated from the flow direction grid. The flow direction grid records the number of cells that drains in to an individual cell in the grid. The flow accumulation grid is the drainage area measured in unit grid cells. The fig.6 showing the mechanism involved in generating flow accumulation grid from flow direction grid.

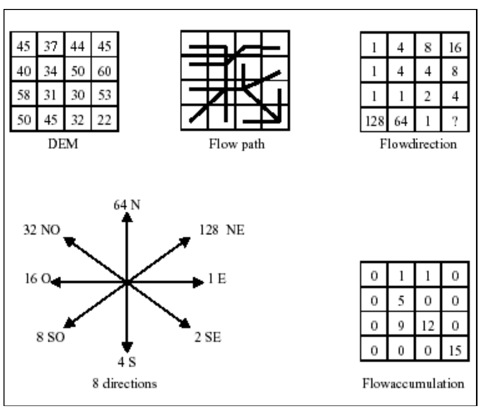

Fig.6: Flow Accumulation grid generated from flow direction grid

With a Flow Accumulation grid, streams may be defined through the use of a threshold drainage area or flow accumulation area value. To define the catchments for each stream link, the zone of cells has to be defined with the flow direction grid. In the Arc Hydro terrain preprocessing functions, the catchment grid is defined to link the land surface to the water flow system. The catchment grid can be converted into a set of catchment polygons using standard ArcGIS raster to vector conversion functions. This process generate spurious polygons which are isolated single cells or small groups of cells or small group of cells connected along a diagonal flow direction with the rest of the catchment. The Arc Hydro toolset is contains an automated procedure to detect the existence of such polygons and eliminate them by dissolving them into correct parent catchment polygon. The stream links are also vectorized to form drainage line and the outlet cells are vectorized to form drainage points. The catchment drainage point and drainage line feature classes in arc hydro store the vector products resulting from terrain analysis using a digital elevation model.

CHAPTER – 3

3.1 RESULTS AND DISCUSSIONS

The DEM derived from the high resolution stereo pairs are shown in the fig.6. The Fill Sinks function modifies the elevation value to eliminate these problems. This function fills the sinks in a grid. If cells with higher elevation surround a cell, the water is trapped in that cell and cannot flow.

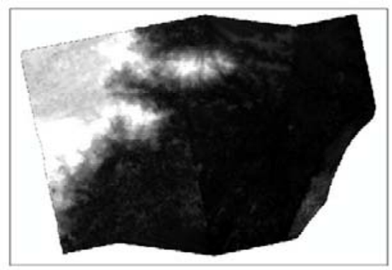

Fig.6: DEM generated from Cartosat-1

The fig.7 is showing the range of elevation for the study area in a depressionless DEM. The elevation is varying from 29.95m to 1570.5m. Physiographically, the major portion of the study area lies in high land (elevation >75 m)

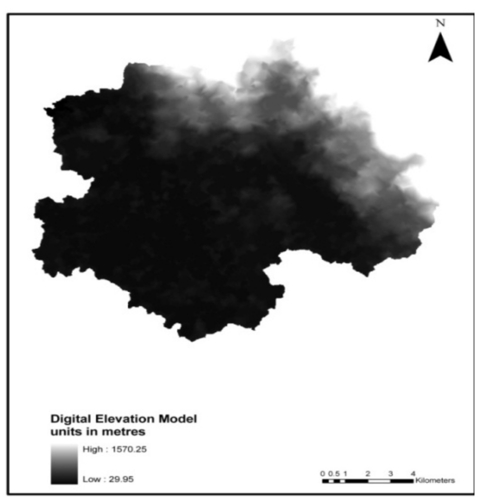

Fig.7: Digital Elevation Model of the sub-watershed in Kuttiyady River Basin

The drainage network and the watershed were delineated following the methodology as described in the flow chart (fig.4). The initial input for the drainage network generation is the creation of flow direction grid. The flow direction grid generated from the depressionless DEM is shown in the fig.8.

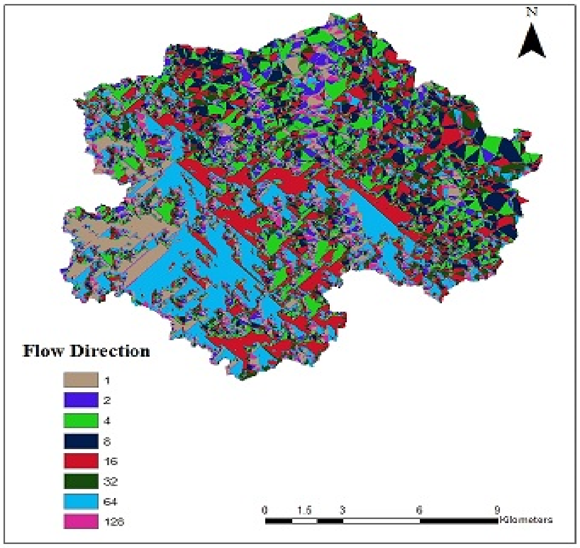

Fig.8: Flow Direction grid

The Flow Accumulation function input flow direction grid as the input and it computes the associated flow accumulation grid that contains the accumulated number of cells upstream of a cell, for each cell in the input grid. Flow accumulation processing is the most time consuming task in the terrain preprocessing and can take a lot of time to complete. It requires significant computer memory and a significant amount of hard disk space (about 5 times the size of the final flow accumulation GRID. The flow accumulation grid is shown in the fig.9.

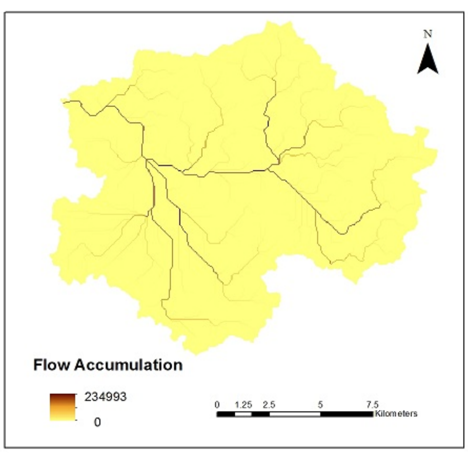

Fig.9: Flow Accumulation grid

The Stream Definition function takes a flow accumulation grid as input and creates a Stream Grid for a user-defined threshold. This threshold is defined either as a number of cells (default 1%) or as a drainage area in square kilometers. In general, the recommended size for stream threshold definition (which in turn defines the sub basin delineation during preprocessing) is 1% of the overall area. For increased performance on large DEMs (over 20,000,000 cells), the size of the threshold may be increased to reduce the stream network and the number of catchment polygons. This function computes a stream grid which contains a value of "1" for all the cells in the input flow accumulation grid that have a value greater than the given threshold. All other cells in the Stream Grid contain no data. The fig.10 shows the stream threshold

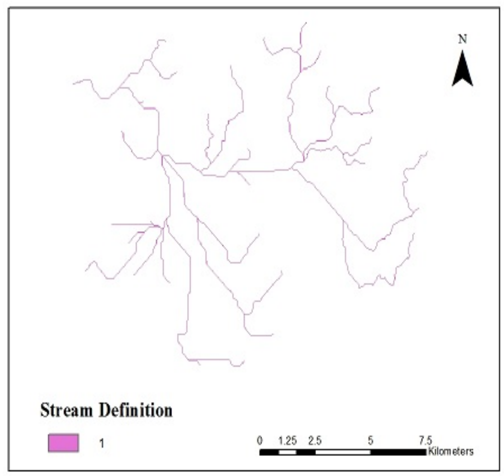

Fig.10: Stream definition

The Stream Segmentation function creates a grid of stream segments that have a unique identification. Either a segment may be a head segment, or it may be defined as a segment between two segment junctions. All the cells in a particular segment have the same grid code that is specific to that segment. The output is in link grid format. The Drainage Line Processing function converts the input Stream Link grid into a Drainage Line. Each line in the feature class carries the identifier of the catchment in which it resides. The fig.11 shows the drainage line generated after drainage line processing.

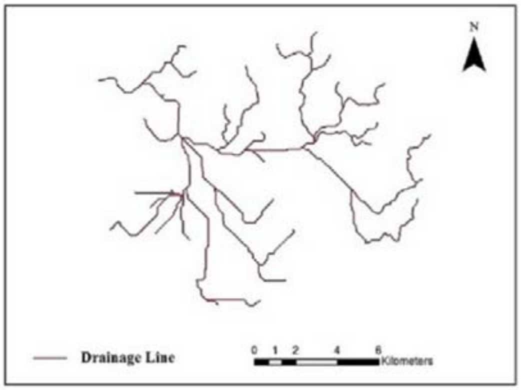

Fig.11: Drainage line generated after linking the streams

The stream order is given to the drainage line using the hydrology (spatial analyst tool) in ArcGIS 10. The drainage network is in the raster format assigned with stream order. The drainage with stream order is shown in the fig.12.

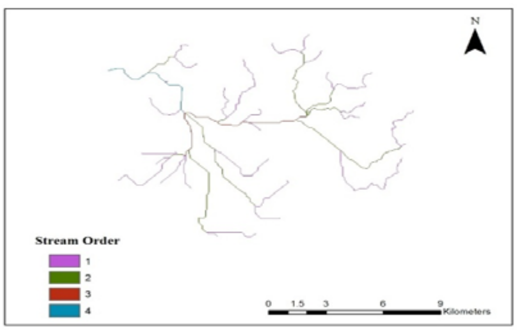

Fig.12: Drainage line stream order

To extract the watershed from the drainage line, Catchment Grid Delineation function creates a grid in which each cell carries a value in grid code indicating to which catchment the cell belongs. The value corresponds to the value carried by the stream segment that drains that area, defined in the stream segment link grid. The catchment grid generated is shown in the fig.13.

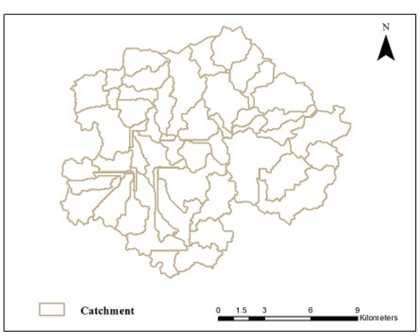

Fig:13: Catchment grid

The Catchment Polygon Processing function takes as input a catchment grid and converts it into a catchment polygon feature class. The adjacent cells in the grid that have the same grid code are combined into a single area, whose boundary is vectorized. The single cell polygons and the "orphan" polygons generated as the artifacts of the vectorization process are dissolved automatically, so that at the end of the process there is just one polygon per catchment. The fig.14 shows the catchment polygons in the watershed. Merging of polygons lying over the drainage network is the watershed for the particular sub watershed.

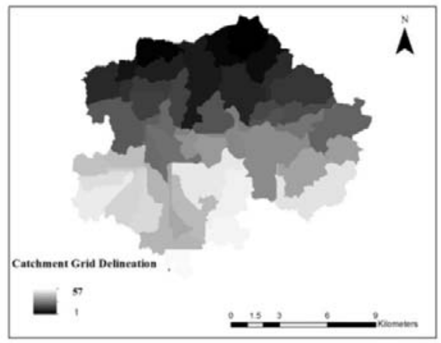

Fig: 14: Catchment polygons

The advantage of this Arc hydro tool is that it would help a novice with little GIS knowledge to run the model to obtain watershed and drainage network.

CONCLUSIONS

This study proves that, it is possible to extract DEMs from Cartosat-1 multi-view images without GCPs. Only tie points have been used for the generation of DEMs. In this study, automatic DEM extraction of Cartosat-1 multi-view data without the use of GCPs has been evaluated. Use of digital elevation models (DEMs) enable production of appropriate maps addressing elevation, drainage lines, catchments and counters. Integration of digital elevation models with geographic information systems results in generating maps on a scale not practical to be merely achieved manually. The methodology of using ArcHydro extension tools reduced time needed to delineate catchments as compared to manual use of contour lines in determining watershed boundaries. This methodology also would help engineers, scientists, planners, and regulators to understand morphology and topographic characteristics of the study area. The accuracy of the DEM generated from multi-view images can be further improved with the use of high quality GCPs for modelling. Assessment of generated DEM with a reference including GCP modelling is the future scope of this study.

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