AUTOMATED DRAINAGE NETWORK EXTRACTION USING DIGITAL ELEVATION MODEL IN GIS. A CASE STUDY.

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ABSTRACT

Although field mapping is acknowledged as the most accurate way to determine channel or drainage networks, it is often impractical and time consuming, especially for the large and remotely situated mountainous watersheds. Topographic maps, providing a useful surrogate for drainage networks, are the fundamental source for the drainage analysis. But, drainage analysis by manual delineation on topographic maps requires time and expertise, and subjectivity judgments. In this study for GIS based modeling, Digital Elevation Model (DEM) is used in presenting drainage networks, lineaments and geomorphic features. Drainage network delineation was performed using two methods: 1) Traditional method by hand delineation on 1/50,000 topographic map; and 2) Using TauDEM (Terrain Analysis Using Digital Elevation Models) model in ArcGIS 9.2 environment using SRTM DEM. The results revealing that the data extracted from the SRTM images are greatly equivalent to those obtained from the topographic maps 1:50.000 and providing more details in the lower stream orders, and morphotectonic parameters. The DEM suggests the tectonic influence on development of landscape.

Keywords: DEM, TauDEM , drainage network, basin delineation

1. INTRODUCTION:

Geomorphologists and hydrologists often view streams as being part of drainage basins. Drainage basins are divided from each other by topographic barriers called a drainage divides. Tectonics plays a very important role in the morphological evolution of any drainage basin and is well reflected by structural, fluvial and morphotectonic parameters. Analysis of active tectonics depends upon the use of morphometric parameters, which are sensitive to rock resistance, climatic change and tectonic processes resulting into landscape evolution. The information about tectonic history of an area can be retrieved by quantification of different morphometric parameters of drainage basins developed. Digital Terrain Modeling and Geographic Information System (GIS) have become essential tools for various surface and sub-surface studies in earth sciences. Concept of hydrological modeling is broadly applied nowadays to represent a digital simulation of drainage systems based primarily on terrain analysis and performing automation extraction of the drainage networks. The model executes as well stream orders, watershed, and quantifying the most important morphometric parameters of watershed. In GIS based hydrological modeling Digital Elevation Model (DEM) is used to delineate drainage networks and watersheds, morphometric parameters and hypsometric integrals to understand the tectonic setting of the study area. The physical surface determines characteristics of the flowing water across it gives reliable analysis of DEM. Direction of flow is determined by surface aspect that defines the maximum rate of changes in elevation and slope direction.

Shuttle Radar Topographic Mission (SRTM) 90 m were the primary data sources used in this study. DEM is the data files that contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the surface of the earth. The intervals between each of the grid points will always be referenced to some geographical coordinate system. This is usually either latitude-longitude or UTM (Universal Transverse Mercator) coordinate systems. The closer together the grid points are located, the more detailed the information will be in the file. The details of the peaks and valleys in the terrain will be better modeled with small grid spacing than when the grid intervals are very large.

1.1 Study Area:

Two watersheds of Kajali and Machkundi rivers were selected from the Konkan Coastal Belt (KCB) around Lanja, District Ratnagiri, in the State of Maharashtra has been studied. The study area exposes Poladpur and Ambenali formations. (68+0.6, 65+0.7 Ma respectively) Southwestern part of the Deccan Volcanic Province (DVP) is represented by massive and amygdaloidal basaltic flows. At some places these basaltic flows are overlain by laterite capping (duricrust). Morphotectnically the DVP has been divided into three regions viz. (1) the Konkan Coastal Belt, (2) the Western Ghats and (3) the Maharashtra plateau. The KCB is coastal low-land forming narrow and elongated strip of land whose average width is about 40 km. The KCB is bounded by coastline to its west and

Ghat escarpment to its east. The E-W offsets have become the site of confluence of major rivers flowing down from the Western Ghats. (Fig. 1) The KCB exhibits different drainage characteristics and landforms as a result of episodic cymatogenic uplift particularly during the quaternary. [1] Drainage pattern is dendritic, angular, trellis and barbed type suggesting structural control. The area is traversed by several east-west trending ridges and west flowing rivers and their tributaries with steep to moderate gradients. The most common geomorphic features recognized are raised beaches, stabilized dunes, mud flats, drowned valleys, estuaries, laterite platforms, weathered hills, hilly interfluves, cliffs, etc. Studies also indicate the presence of submergent and emergent coast formed due to sea level changes and tectonic movements. [2] Summer and rainy are two major seasons and hence whether is hot and humid. It receives 2000 to 3000 mm rainfall per year. Most of this belt is under forest and soil cover of varying density and thickness respectively. The study area is enclosed between long $73^0$15'E and $73^0$50'E and lat $16^0$40'N and $17^0$00'N

1.2 Data Used:

The Space Shuttle Radar Topography Mission (SRTM) gap filled data of the world at 90m horizontal resolution and made available through the Consortium for Spatial Information (CSI) web portal (http://srtm.csi.cgiar.org/).

The Survey of India (SOI) toposheets (Nos. 17H/5, 6, 9 and 10) of 1:50,000 scale were also used for digitization to check accuracy of extracted drainage network from DEMs.

Ground Control Points (GCPs) are mapped with the help of GPS points taken in the field and used for preprocessing of DEM. Extensive fieldwork was carried out to selective localities showing morphologic signatures of tectonic activities.

2. METHODOLOGY:

The SRTM DEM (Version 2.1) was downloaded through the Seamless Data Distribution System (SDDS) at 90m resolutions for the study areas. Version 2.1 is a recalculation of the SRTM3 (nominal 90m sample spacing) version made by 3x3 averaging of the full resolution edited data. Occasional artifacts, spikes and voids were eliminated in Version 2.1.

2.1 DEM preprocessing:

The downloaded SRTM DEMs was mosaiced in the ARC GIS 9.2 environment.

During the data finishing process **[3]** the following tasks were implemented:

1. Spikes and wells in the data were detected and voided out if they exceeded 100 meters compared to surrounding elevations.
2. Small voids (16 contiguous posts or less) were filled by interpolation of surrounding elevations. Large voids were left in the data.
3. Water bodies were edited. The ocean elevation was set to 0 meter and were flattened and set to a constant height.

The original data set of 90m resolution was then converted into 30m resolution using bicubic polynomial interpolation technique.[4] The resolution conversion was achieved by using ARC GIS 9.2. The higher resolution SRTM DEM helped to delineate micro topographic features and to extract lowest order streams correctly. The SRTM DEM was further orthorectified with the help of resampling technique using ERDAS imagine. The GPS points plotted in the field were mapped and overlayed on SRTM DEM in ARC GIS software. The mapped GPS points were used as GCP (Ground Control Points) for resampling. The orthorectification of the DEM was achieved by using polynomial method in ERDAS software. This process improves correctness in spatial correlation of each pixel in DEM.

2.2 Drainage extraction:

Digital data (SRTM DEM) and non-digital data (1:50,0000 topographic maps) were used to extract channel networks. An extraction of channel network from digital data was carried out in the ArcGIS 9.2 environment using TauDEM (Terrain Analysis Using Digital Elevation Model) software. TauDEM incorporates the DEM analysis tools and functions developed by David G Tarboton at Utah State University for hydrologic digital model analysis and drainage basin delineation. (http://www.engineering.usu.edu/dtarb/taudem/). An automated delineation using TauDEM is more sophisticated, convenient, and can circumvent the efforts on digitizing to incorporate with other GIS data. It extracts the highest resolution channel network statistically consistent with geomorphological laws by using the smallest weighted support area threshold calculated from the constant drop analysis.**[5]** In the TauDEM, grid digital elevation model data is used. Grid DEM is distinct from other DEM representations such as triangular irregular network (TIN) and contour-based data storage structures **[6]** Figure 2 represents the flow chart of the processing of DEM and automated extraction of drainage network. Figure 3 shows the processed DEM of the Lanja region and overlayed extracted drainage network. The extracted drainage network and watersheds of Kajali River and Machkundi River were overlayed on geocoded and orthorectified scanned toposheets for comparison. The drainage network derived using TauDEM shows good agreement with the drainage network and basins in toposheets. (Figure 4)

3. DISCUSSIONS:

The processed DEM generated of the study area and extracted drainage basins show various features as general slope, relative relief, and change in relief, topographic breaks, ridges and valleys with their trends, linear and curved valleys controlled by lineaments, drainage networks, density pattern of drainage network, bends and sinuosity along the streams, planar surfaces and landforms. It helps in understanding tectonic setting and distribution of major geomorphic features in the study area. The length and spatial data of the lineaments can be determined. The geomorphic features associated with lineaments can be recognized and hence it is possible to characterize the lineaments and weak planes. Thus DEM can be used as a tool for the quantitative and qualitative studies of morphotectonics and neotectonics.

Figure 5 is the drainage map generated from the DEM with the help of ARC GIS and shows good agreement with the drainage network in toposheets. (Figure 4) The morphometric analysis with respect to basin area can be determined. Thus by integration of both DEM and extracted drainage network it is possible to undertake quantitative geomorphic analysis such as linear aspects, areal aspects, relief aspects, geomorphic indices like hypsometric integrals, stream length gradients etc.

Figure 6 represents the digital profile across the DEM in east-west direction showing the change in relief and morphological cross section. Such cross sections illustrate the perspective view of the study area.

4. CONCLUSION

Thus, the use of DEM and drainage basin generation provide strong tool for the morphotectonic studies as it represents instantaneous relationship between various tectonic features, geomorphic features associated with them.

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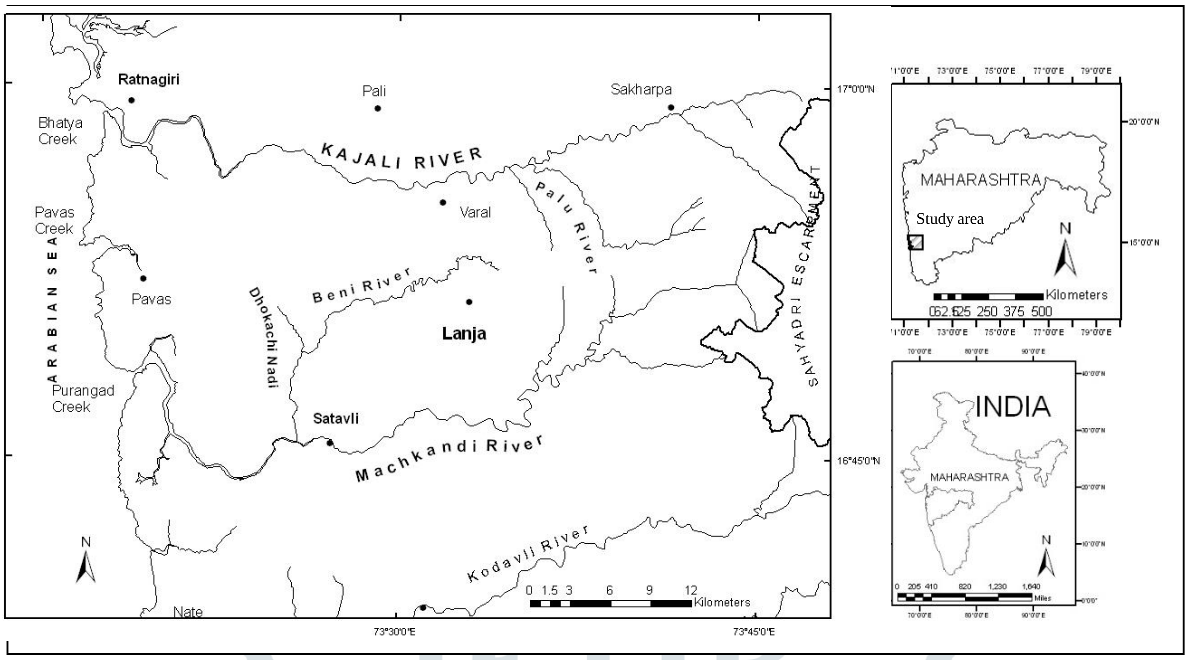

Figure 1: Location map of the study area.

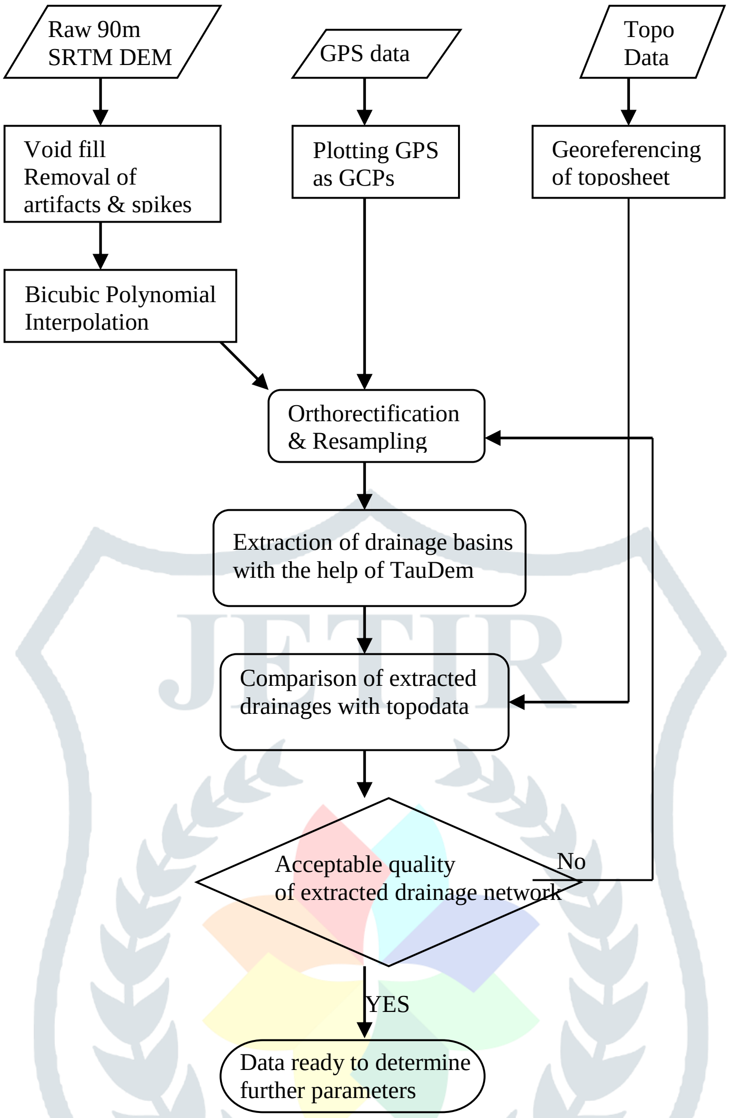

Figure 2: Flow chart of DEM quality improvement and automated drainage extraction

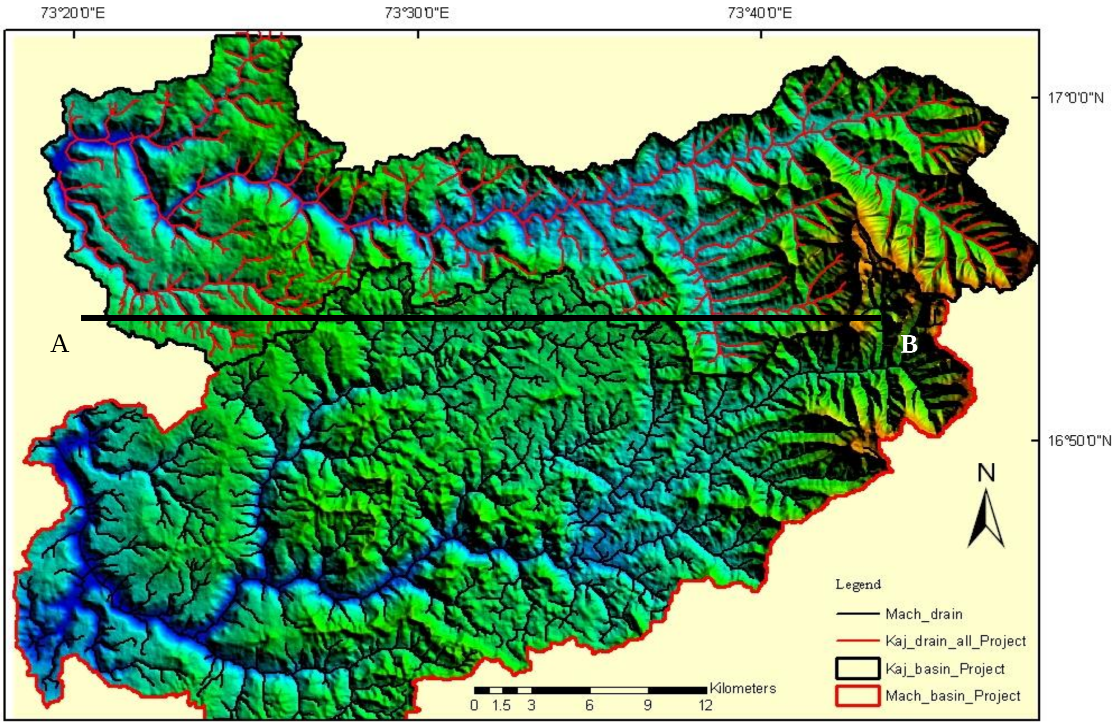

Figure 3: Drainage network and basins draped over the pre-processed DEM (30m resolution)
A profile taken along line A-B (figure 6)

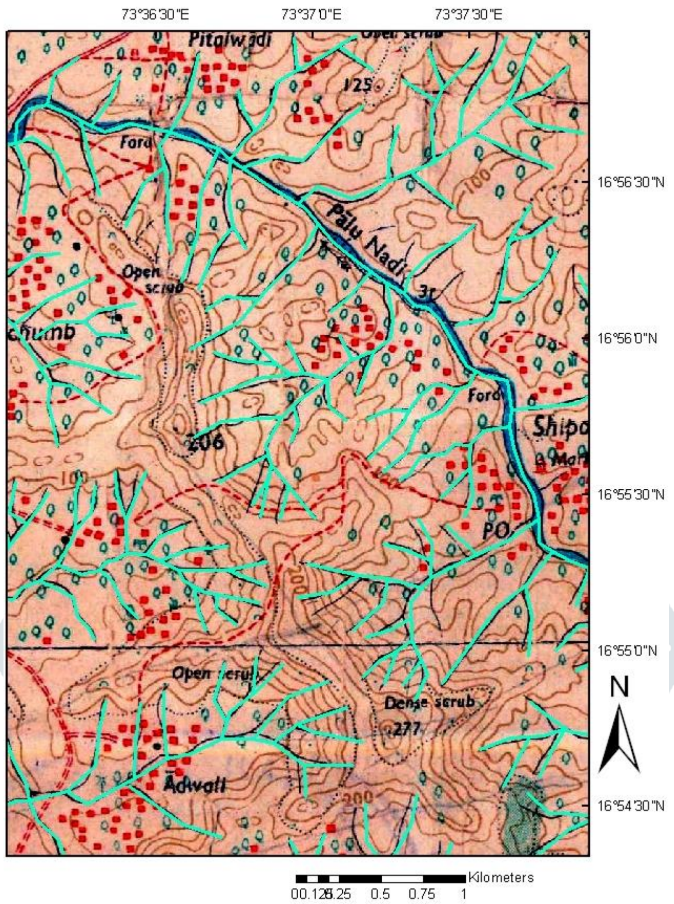

Figure 4: Extracted drainage network overlayed to check its accuracy.

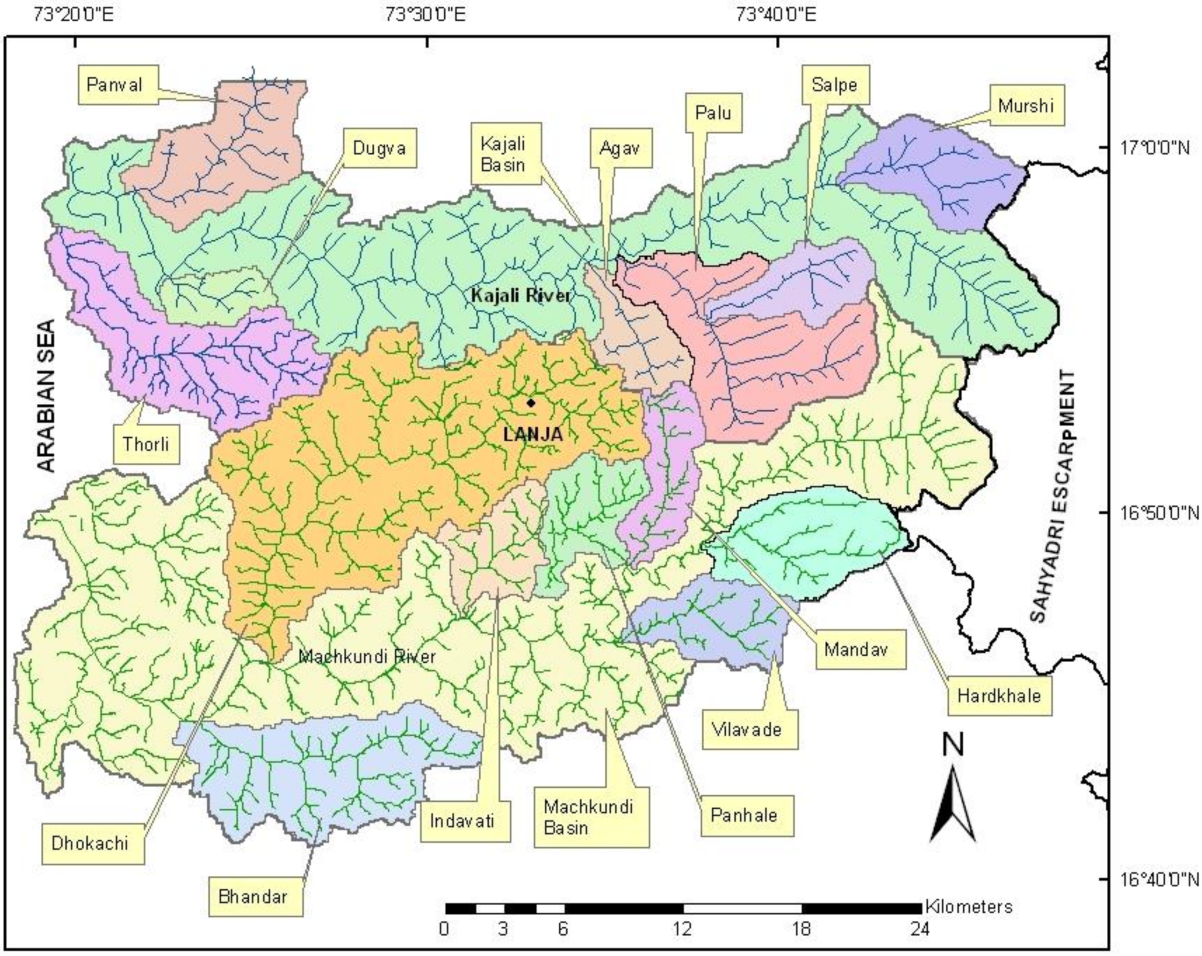

Figure 5: Drainage basins and sub-basins around Lanja.

Figure 6: A profile along A-B line as shown in Figure 2