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Contour Mapping and Terrain Analysis Using SRTM Data: Case Study of Dibang Multipurpose Project, Arunachal Pradesh, India

Alok Kumar Rahut, Devojit Bezbaruah and Sanjit Kumar Pal

Abstract

The study deals with the problem of generation of contour map from Shuttle Radar Topography Mission (SRTM) data. Further, SRTM data have also been utilized for terrain analysis over the study area. In steep rugged terrain/ deep narrow valley/ deep river some small data patches are not fully depicted. To supersede this problem a needful correction has been carried out on the SRTM data using ENVi 3.6 (Environment for Visualizing Images 3.6) by creating prediction surface from available 3 arc second (90 meter spatial resolution SRTM-DEM). The corrected 3arc second SRTM DEM data has been resampled to 10 meter spatial resolution DEM. Various interpolation methods, viz., Inverse Distance Weighted (IDW), Spline and Ordinary Kriging method have been carried out for resampling to higher resolution DEM. However, the results of Ordinary Kriging method have been found to be most suitable in the present study. Comparative analysis and accuracy assessment of SRTM DEM data and the DEM generated from Topographic contour plan (1:250,000) have been carried out. The result shows that SRTM data is more useful for terrain analysis (lineament, thrust etc.) and generation of contour map.

Introduction

Integrated remote sensing and GIS technology has open a new era in geological studies *viz.*, topographic structural mapping, lithological mapping etc. (Pal et al., 2006a; 2006b; 2007a and 2007b) and cartographic application viz., contour mapping, civil engineering planning, terrain analysis, land and water resource management, natural resource management, rural and urban planning, natural hazard assessment and mitigation with very time and cost effective. In general, any terrain could be represented based on the digital elevation model (DEM) of the area. DEM are one of the essential quantitative terrain related parameter which plays a vital role in almost all the remote sensing related studies. Visualization of the Earth surface is essential for the production of the most topographical or thematic maps in different scales and used for different purposes. The surface presentation is mainly employed for map backgrounds. The adequate digital elevation model (DEM) of inaccessible and remote steep rugged terrain comprising deep narrow gorge, valley, deep river etc. is an important source for detailed (Anderson, and Brooks, 1996; Philip and Sah, 1999; Mizukoshi and Aniya, 2002; Jordan, 2003; Jordan et al., 2005; Badura, and Przybylski, 2005) cartography, terrain analysis, geological feature analysis (neotectonic study/ structural analysis). In the present study, the DEM estimated using SRTM data has been compared with the DEM estimated using digitized topographic contour. Further, an attempt has been made towards the generation of contour map for construction of civil engineering planning of hydroelectric project and also for terrain analysis using the estimated DEMs.

In geological and geomorphological studies, the required density of spatial data and grids are dependent on scale and expected resolution. For regional study, the elevation data base easily available from Internet could

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NHPC Ltd., Subansiri Lower HE Project, Gerukamukh, Assam, Dhemaji-787035
*Corresponding author (E. Mail: sanjit_iitkgp@yahoo.co.in)

be used. For example, the GTOPO data base (http://edcdaac.usgs.gov/gtopo30/gtopo30.asp) provides elevation data for all continents in the DEM format at a density of 30", i.e., one point per sq. km. These data enable continent-scale analysis. Another Internet-accessible data base, Digital Terrain Elevation Data (DTED level 0 and 1), acquired from the space shuttle Endeavor (SRTM — Shuttle Radar Topography Mission) mission, makes it possible to construct Earth's surface models that are compatible with 1: 250,000 maps, at grid density 90 m (ftp://e0mss21u.ecs.nasa.gov/srtm/; http://netgis.geo.uw.edu.pl). These data are perfectly suitable for analysis of mountain ranges of high elevation differences. Digital models can also be used in analysis and verification of the existing geological and geomorphological maps, provided their scanned, raster images are available. Proper software enables such raster images to be calibrated according to the coordinates of a digital elevation model, and then be superimposed on 3D shaded relief map (3D digital terrain model). The obtained image can be verified with the strike of structures and map units confronted with the topography. This is an excellent method of verification of cross-cutting relationships shown on a geological map.

In Mountainous areas, disasters caused by mass movements such as landslides and debris flow, are common, and in winter, snow avalanches are serious threat. These phenomena are influenced by the pull of gravity, once they are set into motion and their movements path is generally controlled by topography, i.e., slope gradient, aspect and morphology (convexity). In order to analyze, understand, and predict such phenomena, it is essential to make terrain classification map using topographic features such as elevation, slope (gradient, aspect and morphology) and breakage of slope. Such map have been traditionally been produced manually using topographic (contour) maps as a base map.

A Digital Elevation Model (DEM) is a digital cartographic/geographic dataset of elevations in x, y and z coordinates. The terrain elevations for the ground location are sampled at regularly spaced horizontal intervals, and normally presented in raster/grid form. DEMs are widely used to support civil structure planning, assessment and analysis of Climate, Hydrology, Agriculture, Forestry and Biodiversity, as well as for use in simulations, telecommunications and image processing.

Study area

The dam site of Dibang Multipurpose Project is located at Munli having latitude 28°20'7"N and longitude 95°46'38"E in Lower Dibang Valley district of Arunachal Pradesh. There is no direct communication to project site or even near by area, except for a foot track which is very strenuous and risky, as it is pass through various precarious terrain. For this kind of tedious site there is a growing need of fast paced advanced technology that can boost up the preparation of Preliminary Feasibility Report (PFR), Feasibility Report (FR) and Detailed Project Report (DPR) for hydroelectric (HE) projects. Integrated remote sensing and GIS technology has proved its potential application for contour mapping (Rabus, et al. 2003) in various stages of hydroelectric project. This prospective application of integrated remote sensing and GIS technology has been explored using SRTM Digital Elevation Model (DEM) data for generation of contour plan and 3D perspective view of Dam area, Dibang Multipurpose Project, Arunachal Pradesh.

Data Source:

The Shuttle Radar Topography Mission (SRTM) is a joint project of NASA and the U.S. National Imagery and Mapping Agency (NIMA). The SRTM data have been collected using C-band Spaceborne Imaging RADAR (SIR-C) and X-band Synthetic Aperture RADAR (X-SAR), by a shuttle flight in February 2000. The SIR-C/X-SAR is multifrequency, multipolarization imaging RADAR system, accompanied by additional antennas located at the end of a 60m long post which deployed from the shuttle after reaching orbit. This configuration produces single-pass interferometry and during the mission SRTM imaged the Earth's entire land surface between 60 degrees north and 50 degrees south. The C-band SRTM data has been processed into DEMs. Much of this data was finally released to the public in 2003 and has rapidly moved to a position of prominence as a result of the extent of its coverage and superior resolution. SRTM DEM data is not offered to the general public at full resolution. Instead, the 30m data is averaged to 90m resolutions. However, remote sensing technique offers a number of standard DEM products, and can produce DEMs from IKONOS, CARTOSAT-1, SPOT and ASTER stereo imagery which can also used for generation of contour map.

Toposheet prepared by Army Map Service (PV), Corps of Engineers U.S. Army, Washington, D.C. Compiled in 1954, 1:250,000 scale, NH 46/16, edition 1927 has been used in the present study for further estimation of DEM as reference for comparative analysis.

Geology and Seismotectonic setup

The north-eastern part of India is one of the most active seismic regions of the world and has been experiencing earthquakes since times immemorial. Like other parts of Himalayas, the easternmost Himalayas of Arunachal Pradesh exhibit considerable seismic activity with occurrence of two of the great earthquakes of 1897 and 1950 to its close proximity. The earthquake of 1897 was located near the northern edge of the Shillong Plateau while the earthquake of 1950 was located in the Mishmi Hills. For Arunachal Himalayas, the seismicity appears to be related to the MBT (Nandy,1976; Verma, 1991; Verma and Krishna Kumar, 1987). It may also be observed that many earthquakes are located close to the MCT. The focal mechanism solutions obtained from earthquakes occurring in the eastern Himalayan region indicate predominantly thrust mechanism with a few strike-slip mechanisms along some transverse tectonic features (Verma, 1991; Verma and Krishna Kumar, 1987). However, on the basis of data of earthquake in 1950, Seeber and Armbruster (1981) have concluded that this earthquake was caused by the detachment along the Himalaya which can be considered as the locus of all great Himalayan earthquakes, whereas Chen and Molnar (1990) suggested that a shallow-dipping thrust plane was responsible for this earthquake.

Data processing

Shuttle Radar Topography Mission (SRTM) DEM data is one of most useful digital topographic data sources of the earth, because of its high spatial resolution and near-global coverage. However, it's widely usage has been limited by some void areas occurred in SRTM DEM data. These data holes are especially concentrated along rivers, in lakes, and in steep regions often on hillsides with a similar aspect due to shadowing. This non-random distribution of data holes, ranging from 1 pixel to regions of 500 sq. km. encumber the potential use of SRTM data, and has been the subjected of a number of algorithms for missing data correction through various spatial analysis techniques. These include spatial filters, iterative hole filling, and interpolation techniques, many of which are still under development and testing (Martin, 2004).

Although they are modified into finished SRTM DEM by using a complicated process by National Geospatial-Intelligence Agency (NGA), in which a lot of void areas have been filled with correct data. However, some void areas are till present, especially in the water area. In addition, the accuracy of the finished SRTM DEM might be hindered because of no global accurate DEM as a reference and the finished SRTM DEM can't be freely downloaded from internet and also limits its usage in some extent. In the present study, 3-arc second SRTM DEM, N28E095.hgt stile was downloaded from http://edcftp.cr.usgs.gov/pub/data/srtm/Eurasia, and the missing data are corrected using ENVI 3.6 (Environment for Visualizing Images 3.6). The corrected SRTM DEM data exported in Geotiff format for processing in ArcGIS 8.3. Further, the corrected 3arc second SRTM DEM data has been resmapled to 10 meter spatial resulation DEM. Various interpolation methods, viz., Inverse Distance Weighted (IDW), Spline and Ordinary Kriging method have been carried out. However, the results of Ordinary Kriging method have been found to be most suitable in the present study.

Further, toposheet over the area which was originally prepared by Army Map Service (PV), Corps of Engineers U.S. Army, Washington, D.C. Compiled in 1954, 1:250,000 scale, NH 46/16, edition 1927, has been geo-rectified (UTM). The contour lines are digitized, keeping the scanned geo-rectified (UTM) image in the background. The contour elevation values have been assigned to the corresponding contour lines to generate an arc coverage file. This arc coverage file has been converted to point coverage file with vertical coordinate axis (Z - axis) as elevation value in meter. This point coverage file has been ultimately converted into grid (raster) format using Krigging method of interpolation with output cell sizes of 10 meters. Spherical semi-variogram model has been used to calculate elevation surface image (DEM) in this Krigging method.

Results and discussion

Digital Elevation Model surrounding the proposed Dam area of the Dibang Multipurpose Project has been generated from SRTM data (2000) in 1: 50,000 scale, as shown in Fig. 1. The DEM generated from SRTM (2000) shows that the minimum elevation is 290m and maximum elevation is 1972m. The whole area has been classified into five major elevation zones viz., 290-400m, 400-800m, 800-1200m, 1200-1600m and 1600-1972m. The river Dibang with flood plain is in the elevation range between 290m to 400m from the Dam area (Munli) to the alluvial fan. Further, the DEM surrounding the proposed Dam area of the Dibang Multipurpose Project has also been generated from U.S. Army Service Toposheet (1954) in 1: 50,000 scale, as shown in Fig. 2. The DEM generated from U. S. Army Service Toposheet (1954) shows that minimum elevation is 297m whereas, maximum elevation is 1953m for the study area. Figure 2 indicates a larger area of the river course lies in the elevation range 297-400m. Maximum elevation of the range of 1600-1972m / 1958m has been observed in North-West and North-East part in both the generated DEM. The change in elevation of the river course would probably be caused by composite activity of ongoing tectonic process in the Himalaya, erosion and down cutting in channel course, land slides etc.

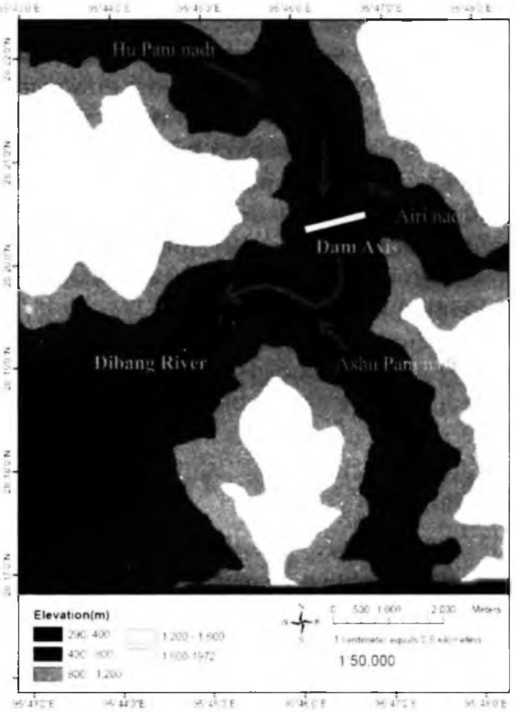


Fig. 1. Digital Elevation Model generated from SRTM data (2000)

Slopes surrounding the proposed Dam area of the Dibang Multipurpose Project have been estimated from the generated DEM using SRTM data (2000), which has been

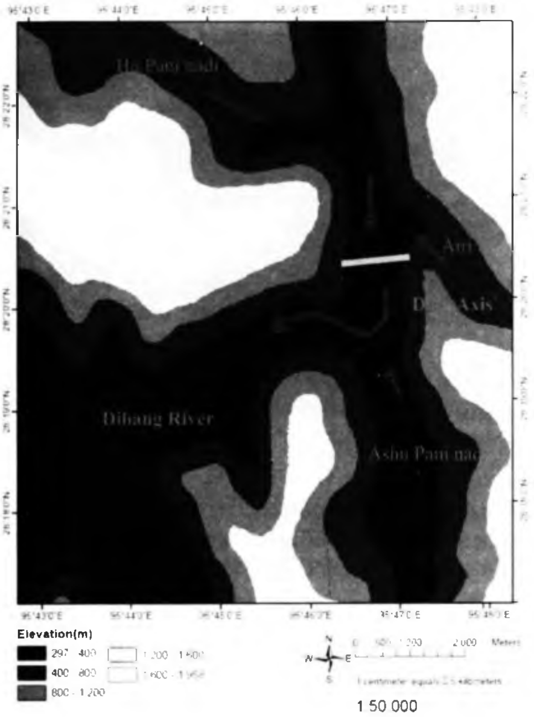


Fig. 2. Digital Elevation Model (DEM) generated from Toposheet of US Army map service (1954)

presented as a slope map (Fig. 3). Gentle slope has been observed along the river course. The alluvial fan of the river Dibang has also been observed as gentle slope (0^0 to 10^0). The slope of most of the part is in the range of 40^0-50^0. The classified slope map shows that the steepest slopes are found around the tops of topographic ridges. Fourteen prominent lineaments have been demarcated along the gentle slope (0^0 to 10^0) of slope map (Fig. 3).

Aspects of elevations surrounding the proposed Dam area of the Dibang Multipurpose Project have been calculated from the generated DEM using SRTM data (2000). This has been shown in Fig. 4. Aspect data displayed as a grey-scale image similar to the shaded relief map, but aspect information is independent of illumination parameters and, therefore, accurately locates valley lines, slope breaks and ridges. Sixteen prominent lineaments have been marked.

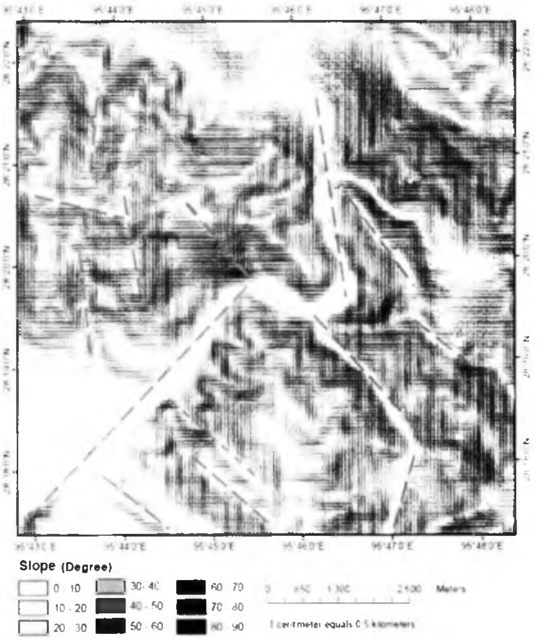


Fig. 3. Slope map extracted using DEM generated from SRTM data (2000)

Figure 5 shows a 3D digital terrain model generated by draping of Landsat ETM+ imagery over the estimated DEM using Toposheet of US Army map service (1954).

Fig. 4. Aspect map extracted using DEM generated from SRTM data (2000)

Figure 6 shows a 3D digital terrain model surrounding the proposed Dam area of the Dibang Multipurpose Project, generated by draping of Landsat ETM+ imagery (band 5, 3, 2 as RGB) over the estimated DEM using SRTM data (2000). Whereas, the morphometric / topo lineaments, slide zones and some settlement have been identified and marked on both the terrain model. Total 24 lineaments have been marked on terrain model generated from SRTM data (2000), whereas, 22 lineaments have been marked on terrain model generated from US Army Toposheet. Both the terrain model indicates two predominant lineaments trending in NW-SE and NE-SW direction. Few numbers of lineaments have also been identified in E-W trend. The two prominent slides (marked by blue dotted boundaries) present in the either side of Dibang River has been demarcated as lineament (Fig. 6). These lineaments are identified as major fault / thrust named as Roing Fault by field verification and marks the boundary (marked by green dotted boundary) between Tertiary sediment and low grade metamorphics of Hunli Formation (Fig. 6).

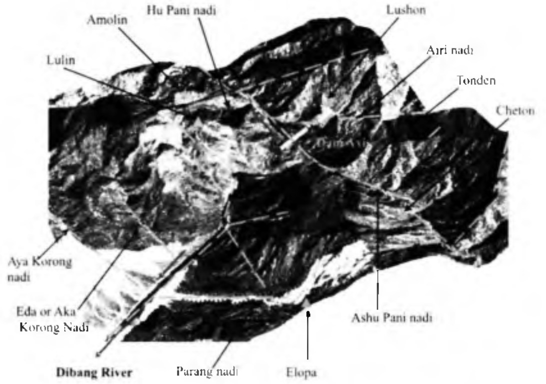


Fig. 5. 3D digital terrain model generated by draping of Landsat ETM+ imagery over the estimated DEM using Toposheet of US Army map service (1954)

These slide developed along sheared and fractured rocks associated with the thrusting. The lineaments 3, 4, 5 and 6 define a major tectonic boundary (marked by green dotted boundary) in this area, which separate high grade metamorphic Ithun Formation from Hunli Formation (Fig.6).

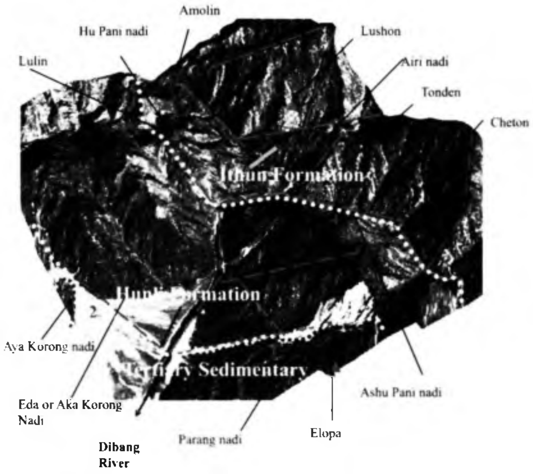
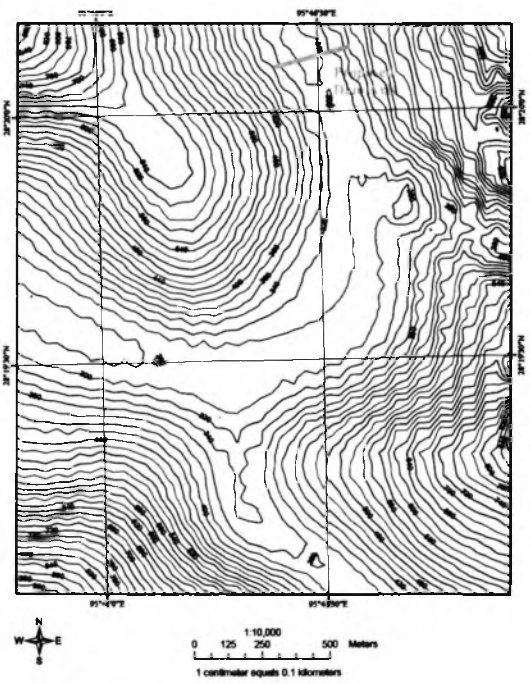


Fig. 6. 3D digital terrain model generated by draping of Landsat ETM+ imagery (5,3,2) over the estimated DEM using SRTM data (2000).

Finally, a contour map in 1:10,000 scale has been generated from SRTM data and presented in Fig.7. A smaller part covering the proposed dam area has been selected



Fig, 7. Contour map (1:10,000) generated from SRTM data for better visibility. The contours have been shown in a 20m interval. The Dibang River is flowing in about 300m level near the proposed Dam axis (Fig. 7). The highest ridge of 900m has been observed in SW part.

Conclusions

The Morpho-structural analysis suggests an interesting geological past over the area. The present day channel pattern of Dibang River evolved after a series of fluvio-tectonic activities which are directly related to active tectonics of this area. The imprints of these activities are well preserved on the landforms and quaternary deposits. The seismic activities in this region indicate the ongoing Himalayan orogeny. These tectonic processes rejuvenate the river system resulting in increased erosional activity of this region.

US Army Service Topographic map does capture more variability, but might not necessarily are variability that exists in reality exaggeration from the manual photogrammetry. The limitation of state of art of the topographic survey during 1954 may be the possible causes. SRTM data is however very detailed and would likely be very useful for morpho-structural analysis/ neotectonic study and contour mapping for preliminary study to prepare Prefeasibility report and Feasibility report of Hydroelectric Project of remote rugged hilly terrain.

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