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Identification of Open Cast Mining Areas using CARTOSAT-I: A Case Study of Jharia Coal Fields

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ABSTRACT

Monitoring of changes in topographic databases is one of the main requirements of planners, urban decision-makers and managers. The practice of open cast mining in the coal seams of Jharia coal field has left a legacy of pits and overburden dumps. Thus the need for deriving present date elevation models of better accuracy arises. With high resolution satellites giving stereo images, satellite photogrammetric techniques emerge as a good solution for getting cost effective and high accuracy elevation models. The present study aims at mapping topographical changes induced due to open cast mining activity in Jharia Coal field area using CARTOSAT-I stereo dataset. The elevation models generated using contour information and spot heights from SOI topo maps and CARTOSAT-I stereo images were analysed. The analysis clearly indicated the areas of major topographical changes in the study area, which are also matching with the sites of open cast mining.

Key words: Open cast mining, topographical change analysis, cartosat-I, digital elevation model, stereo dataset

INTRODUCTION

Coal reserve in India approximates around 211 billons tones of which more than 99.5% are estimated from Gondwana Coalfields. Jharia Coalfields (JCF) is one of the most important coalfields in India, located in Dhanbad district, between latitude 23° 39' to 23° 48' N and longitude 86° 11' to 86° 27' E. This is the most exploited coalfield because of available metallurgical grade coal reserves. Mining in this coalfield was initially in the hands of private entrepreneurs, who had limited resources and lack of desire for scientific mining. The mining method comprised of both opencast as well as underground. There are 23 large underground and nine large open cast mines. The mining activities in these coalfields started in 1894 and had really intensified in 1925 (Saxena, 1994).

Open-pit mining, also known as open-cast mining, open-cut mining and strip mining, refers to a method of extracting rock or minerals from the earth by their removal from an open pit or borrow. Often the mineral deposit is covered by soil, which must first be stripped off, usually by large machines such as walking draglines and bucket-wheel excavators. The ore deposit is then broken up by explosives. The practice of open cast mining in the coal seams of the Jharia coalfields has left a legacy of pits and overburden dumps. The opencast mining areas were not backfilled, so large void is present in the form of abandoned mining. It is also projected that if proper reclamation measure is not followed, a total of 200 sq. km will be converted to badland topography:100 km^2 as quarried land and another 100 km^2 as overburden dump area (Ghosh *et al.*, 1998).

Monitoring of changes in topography is one of the main requirements of planners and managers (Saxena, 1994). The topographical changes due to open cast mining should be mapped properly in order to facilitate the reclamation process. Thus the need for deriving present date elevation models of better accuracy arises. There are various approaches of deriving updated elevation models, namely direct survey, Aerial photogrammetry, Satellite photogrammetry, Radargrammetry, Interferrometry and Laser Altimetry (Edward *et al*., 2001).

With high resolution satellites with stereo images, satellite photogrammetric techniques emerge as a good solution for getting cost effective and high accuracy elevation models (Lutes, 2006).

Cartosat-1, launched in May 2005, has two cameras to collect stereo data at better than 2.5 m resolution: one near-nadir-looking and the other forward-looking (Nandakumar *et al*., 2005; Raghava Murthy, 2005). A single stereo pair covers a ground area of about 800 sq. km The two stereo components, labeled AFT and FORE images to indicate the look direction, are designed to produce Digital Elevation Models (Krishnaswamy and Kalyanaraman, 2002; Kumar, 2006).

The basic aim of the research is to map topographical changes induced due to open cast mining activity in Jharia Coal field area. To fulfill this broad objective, following sub-objectives needs to be carried out:

- To generate DEM from SOI 1:50,000 toposheet surveyed in 1973-1974
- To process high resolution satellite stereo dataset for DEM generation
- To detect topographical change in the area

MATERIALS AND METHODS

Study area: Jharia coalfield is located in the eastern part of India, about 250 km NW of Kolkata. The Coalfield is lying North of the Damodar river, covers an area of about 450 km^2 and stretches between latitudes 23°38' N and 23°50'N and longitudes 86°07'E to 86°30'E. Figure 1 shows the Jharia coal fields which was investigated for the topographical change analysis. The study was conducted in 2008.

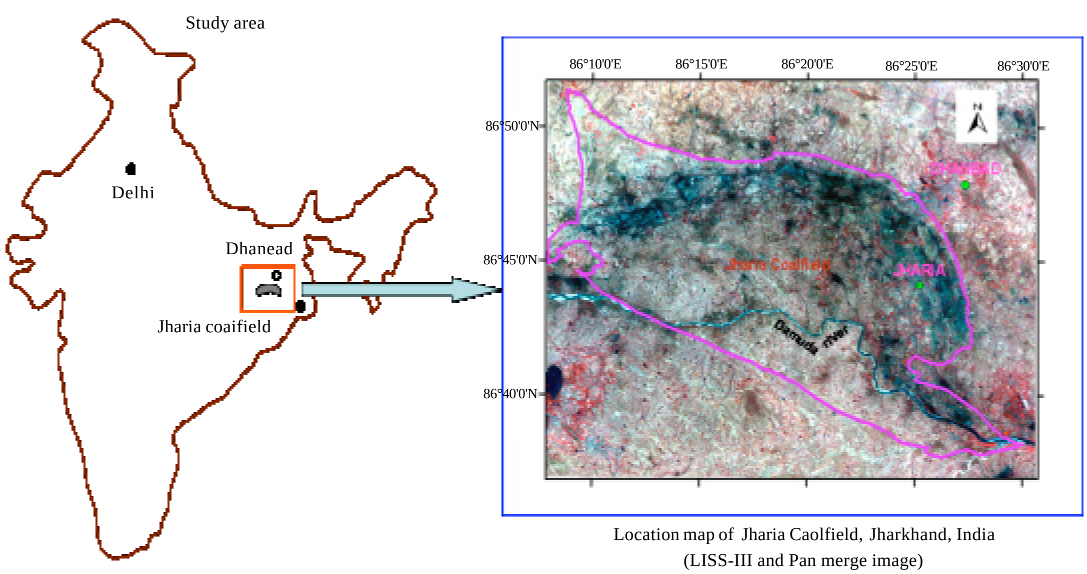

Fig. 1: Study area

Data used:

- A high resolution panchromatic stereo pair from the CARTOSAT I satellite with a spatial resolution of 2.5 m acquired on April 04th, 2006 Path: 578, Row: 287 (Fig. 2a)
- SOI Toposheet 73 I/1, 2, 5 and 6 (Fig. 2b)
- Control points, spot heights

Methodology: The elevation models used for final analysis were generated using two data sources- contour information and spot heights from SOI topo maps and stereo images procured from space based sensor. The capabilities of ERDAS IMAGINE v 9.1 were utilized for processing and final analysis of the data. Photogrammetric module (Leica Photogrammetric Suite) was exploited to automatically extract elevation information from CARTOSAT I stereo data product. The overall methodology adopted in the study is presented Fig. 3. The Cartosat-stereo dataset was processed and DEM was generated. The DEM was also generated using SOI toposheets and the change was analysed. Elevation Model for the study area was generated by digitizing the contours of SOI toposheet as well as from Stereo restitution of the stereo dataset:

- Fore and Aft looking image data can be obtained associated with metadata, which can be interpreted to obtain interior orientation parameters
- Combine data collected from topomap, GPS measured control points for exterior orientation of image pair
- Automatic extraction of DEM after 3-D modeling process, interpolation, proper modification and accuracy assessment
- Contour information was extracted from SOI toposheets at 1:50,000 scale and used to create raster elevation model. Related processing and accuracy assessment was done

The stereo pair was oriented using Rational Polynomials supplied. The orbital parameters were calculated and DSM was extracted. Orbital parameters were refined using few Ground Control Points (10 in number). Ground Control information for this area was collected from the topomaps Surveyed by the SOI. The exterior orientation parameters were refined using GCP's and automatically generated tie points through triangulation. Figure 4 shows the distribution of control points within the study area. The GCP's were choosen in such a maneer so as to provide control in all parts of the image.

The uncontrolled block exhibited significant Y parallax of up to 50 pixels. Figure 5 shows elevation model generated with uncontrolled block, which exhibits major errors. The heights in this elevation model are erroneous and misleading. The E.O. parameters were refined using automatically generated tie points. The triangulation error thus obtained was 1.7 pixels. The error in X, Y and Z were in the range of 10-100 m. The controlled block (GCP's +tie points) exhibited a triangulation error of 0.2 pixels. The error in X and Y ranged from 0.3 to 15 m whereas in Z it was 0.1 to 6 m. The point exhibiting maximum error may be due to placement uncertainty in fore image as the image was radiometrically smoother and geometrically distorted.

The elevation information extracted using the uncontrolled block resulted in prominent errors in many areas. The uncontrolled elevation model (Fig. 5) shows problems in the depiction of minor topographic features. The matching process is more robust when Ground Control information was incorporated. The topography of the area, even small residual hills and minor streams are clearly seen in the refined elevation model (Fig. 5). In addition to the elevation model generated using

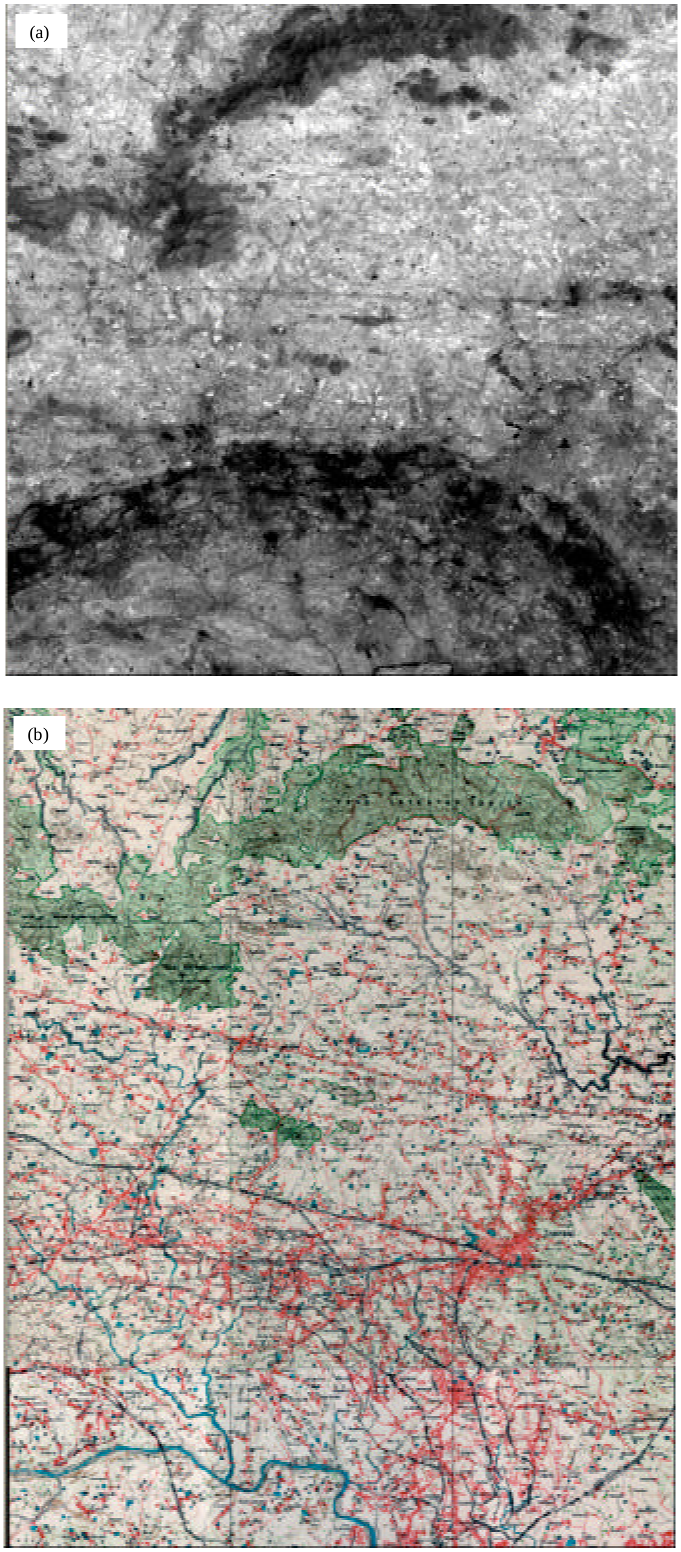

Fig. 2: (a) CARTOSAT 1 Stereo data of Jharia and (b) SOI Toposheet 73 I/1,2,5 and 6

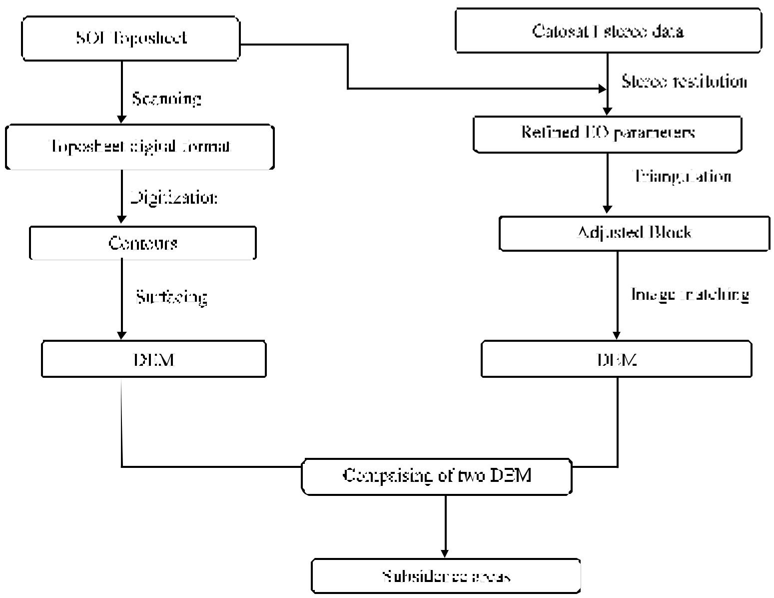

Fig. 3: Methodology

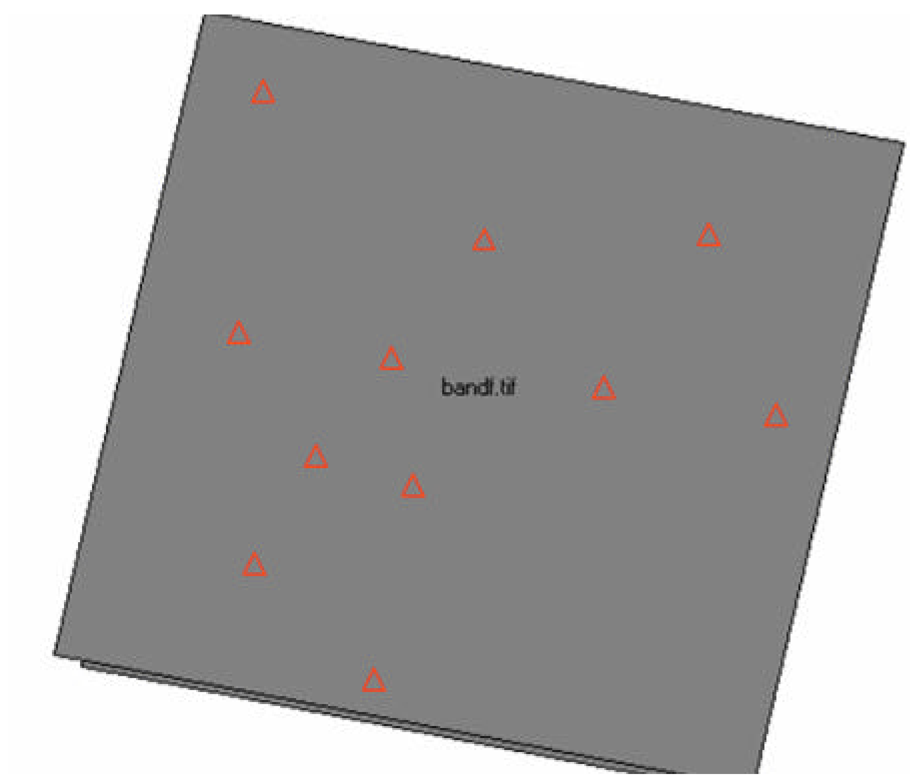

Fig. 4: GCP distributions in area

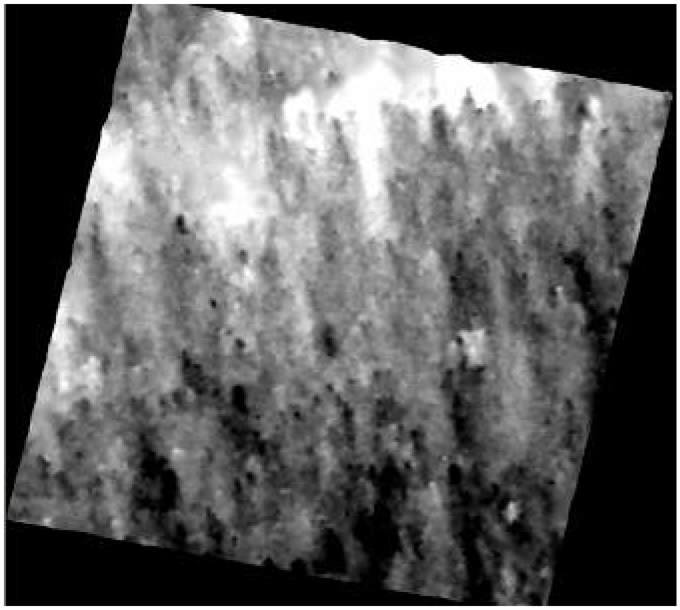

Fig. 5: Uncontrolled elevation model, Controlled elevation model

Fig. 6: Digital Elevation Model using SOI toposheet

high resolution image pair SOI topomaps(1; 50000 scale) were scanned, merged and digitized to create surface map to be used for estimating topographical change areas (Fig. 6).

The reference and current digital elevation models were compared to find out topographic change areas in the study areas.

ANALYSIS AND RESULTS

In the virtual GIS module of ERDAS IMAGINE 9.1 a virtual 3-D view was created to highlight the subsidence areas (Fig. 7). Figure 7 clearly shows large voids in the topography in and around the area. The reference DEM (DEM from SOI toposheet surveyed in 1973-74) was compared with satellite image derived DEM (Acquired on April 4th 2006). The difference map was generated which highlighted the open cast mining areas as compared to 1973-74 topography (Fig. 8). The

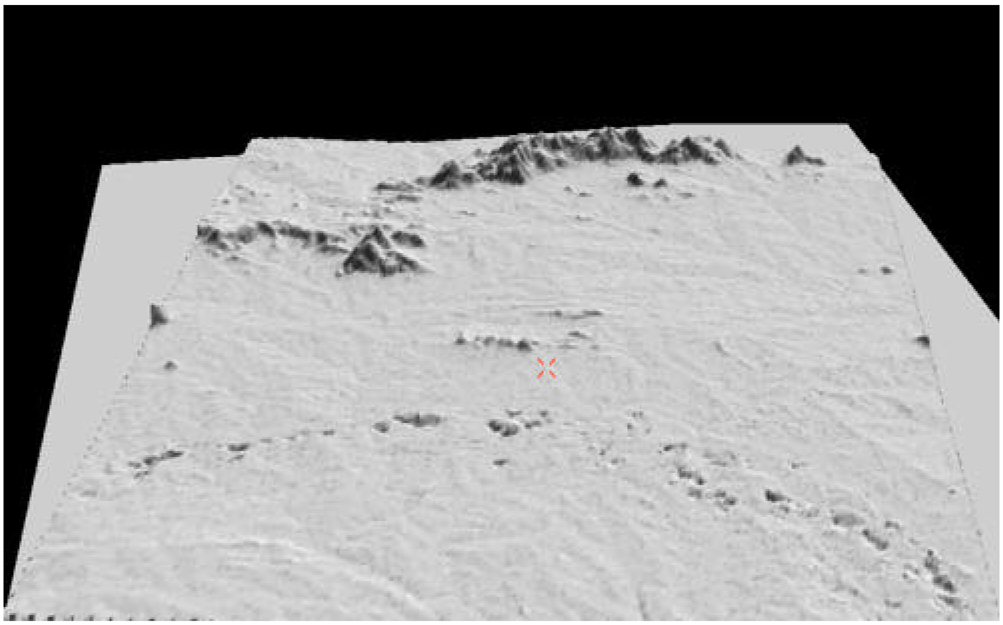

Fig. 7: Virtual 3D model of the area showing subsidence

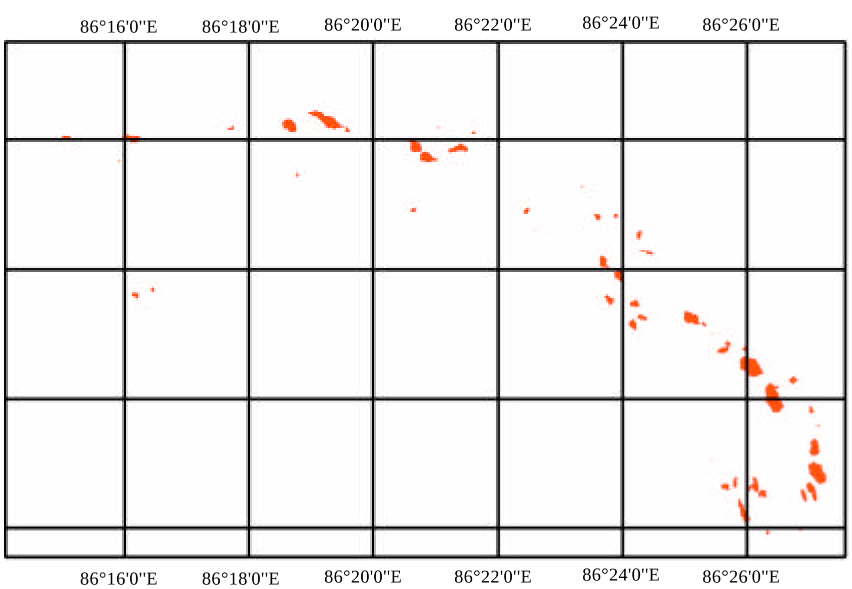

Fig. 8: Topographical change area in Jharia Coal Fields

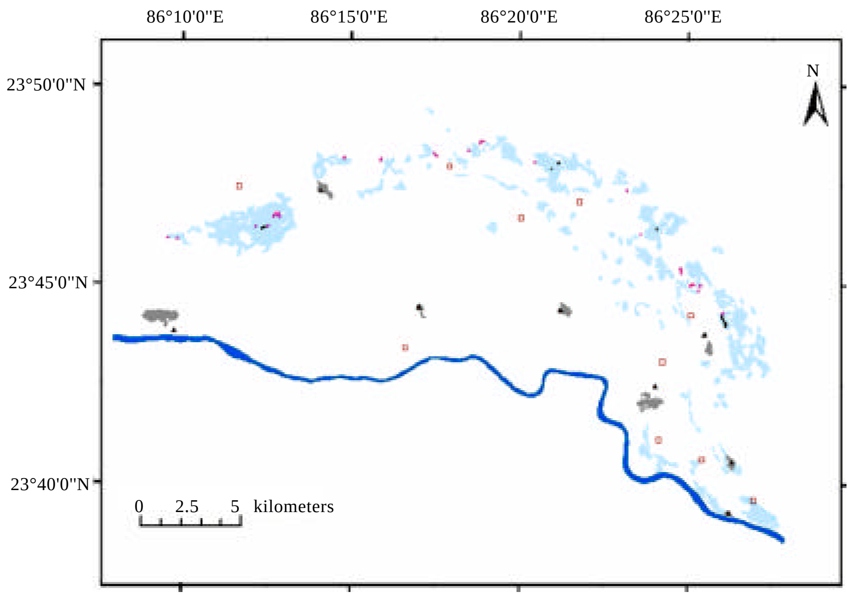

Fig. 9: Open Cast mining areas in Jharia Coal Mines

results of the study were compared with published data about open cast mine areas. Figure 9 shows published data about open cast mining areas within Jharia Coal Field. When compared with the topographical change areas, it is exhibited that the areas taken out by this technique are matching the areas of open cast mines with 89% confidence level. Thus the results obtained were in concurrence with the existing map.

CONCLUSIONS

The study highlights usefulness of high resolution satellite derived DEM for topographical change analysis. The resolution of reference DEM is not comparable to that of satellite derived DEM. It is recommended to use better resolution DEM as reference if possible. Further analysis using image data varying spatially and temporally can be used for better understanding of the pattern of overburden dump areas and pits.

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