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Remote sensing data application in digital elevation model for feature extraction of Jaisalmer region, Thar Desert, Rajasthan, India

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Abstract
Remote Sensing Cartosat-1 data reflecting the interpretation of relief features of Jaisalmer region, constituting a central part of the Thar Desert of Rajasthan in Indian sub-continent have been used for generation of the Digital Elevation Model (DEM). High resolution space-borne remote sensing image data exemplify a high level of details and aid in remote sensing applications. Digital Elevation Model data and ortho-rectified imagery have been analysed and interpreted. Multi-view images are treated as stereo image pairs to obtain stereoscopy. A novel methodology for DEM generation from Cartosat-1 Indian satellite data of Thar Desert at 2.5m, using stereo strip triangulation (SST) geometric modeling technique has been elaborated. Cartosat-1- DEM is valuable for the interpretation of macro and meso relief, and provides opportunity for mapping especially at medium scales (1:100,000 and 1:50,000). Geomorphic parameters have been applied to identify and illustrate geomorphologic forms and processes, which were extracted by using the software elevation, contour, aspect, slope angle and drainage network.

Keywords: Cartosat – 1 data, Digital Elevation Model, Jaisalmer, Thar Desert, Rajasthan, India.

1. Introduction

The first satellite to provide stereoscopic images has been SPOT during 1986 that allowed extraction of Digital Elevation Model (DEM) over large areas of the earth's surface. At this stage, a variety of analogue or digital sensors in the visible spectrum have been flown providing users with spatial data for extracting and interpreting 3-D image of the earth's surface. This model is a digital demonstration of the earth's relief that consist an ordered array of elevations comparative to a datum, and referenced to a geographic coordinate system. Generating digital elevation models from satellite stereo data have been comprehensively used and people have applied satellite stereo data for the generation of DEM using satellite photogram metric approach. The digital elevation models provide the usable information that is still not available for a good deal of the earth, and when such data are available they require adequate accuracy. In deserts, complex features are hard to sustain at suitable elevation, as sand dunes create different elevation at different times. Hence, the changes should be observed over a period of time. The elevation in a desert abruptly changes due to intra-dunal gaps and different shapes of sand dunes in high relief regions resembling mountains, which have stable heights, may have marginal shifts in elevation is trivial bit considerably low overall relief in deserted landscape, precise measurement of differential elevation gains, importance and hence accuracy is very important in desert elevation.

The digital format of a DEM has primed it comfortable to derive additional information for various applications; therefore, the elevation modelling has turned out to be an important component of the international research and development programme related to geospatial data. The application of digital elevation model is at present essential for many geo-scientific applications, such as: (a) production of 3D base maps in the optimum alignment surveys, (b) corridor route planning in the terrain areas, (c) subsidence and erosion monitoring in the watershed management, (d) urban planning in Undulating Areas, (e) tower site location in the flight simulation, (f) linear network extraction and map updationand (g) imagery intelligence in the mission planning.

The paper deals with a descriptive methodology for automatic generation of DEM of Thar desert using CARTOSAT-1 data and Stereo Strip Triangulation (SST) geometric modelling technique. The generated DEM is further used to compute slope, contour, and drainage pattern of the study area.

Study area

The study area is located in Jaisalmer district of Rajasthan, India is confined to a terrain having a radius of about 60 km is stony and rocky. The area is rather infertile, undulating with sand dunes and slopes towards the Indus Valley and Runn of Kutch. Geographically, the Jaisalmer is one of largest districts in India, spreading over 38,401 km^2. Climate of the area indicates that winter season is cold and temperature drops down to 1^0 C, during the summer maximum temperature rises to 49.2^0 C and temperature varies from morning to noon and late midnight. The annual average rainfall has been noted as 164 mm.

Geology and Geomorphology

The Jaisalmer study area is dominated by the presence of sedimentary sequence comprising of the Palaeozoic (boulder beds, sandstones, limestones), Mesozoic (sandstones, shales, limestones), Cenozoic (sandstones) and Quaternary (gravel beds, evaporates). These rocks cover a large extent having wind-blown sands from the Quaternary period (Pareek, 1981). The landforms of Jaisalmer basin are heterogeneous and complex. The main reason for this nature can be assigned to the change of climate from warm-humid (Neogene) to the present-day hot arid conditions with the wet periods (Early Pleistocene, Early Holocene) and semi-arid (Middle and Late Pleistocene) phases (Swain *et al.*, 1983; Ramakrishnan, 1997) [7, 4]. Quaternary sediments are displayed in varied forms, such as residual, fluvial, and aeolian. Most of the Tertiary and pre-Tertiary sandstones, shales and limestones, with horizontal or gently dipping beds, have been shaped as high-level rocky structural plains.

Geomorphic unit has a usual landform sequence and from the escarpment towards the dip slope of a cuesta, followed by a narrow serer plain, and then a broadly convex hammada. Dissection of this landform has in many areas resulted in the development of mesas and buttes. The low-angle pediments, with a thin covering of pebbles, cover extensive areas and are in general associated with structural plains and gravelly pavements. In this area, recession of the Tertiary sea was followed by a first phase of plantation under warm humid conditions. Development of the iron duricrust is attributed to this period (Dassarma, 1983) [2]. Late Neogene to Early Quaternary period was dominated by tectonic activity, fluvial erosion and deposition, evidenced by fluviatile, non-fossiliferous, ferrugenised sequences of the Shumar Formation. Older flood plains and palaeo-channels represent the Late Pleistocene to Early Holocene period. This was followed by another plantation under aeolian conditions. During the Sub-Recent to Recent time, the area witnessed several phases of the dune making and stabilization.Soil unit varies with its wide-ranging topography of arid plains, hilly tracts of the Aravallis, flood prone plains of Eastern Rajasthan and the oldest range of Aravalli Hills. Soil is also affected by availability of water, continuous soil erosion and recurrence of droughts. The study area has alkaline and saline soils with a calcareous base (Table 1). There is some nitrate concentration in the soil of these regions. The region has Aeolian sand that varies from sand to sandy loam. Ground water level is very low (30 to 61 m b.g.l) due to over-exploitation and limited, inconsistent annual rainfall of 364 mm.

Table 1: Geological succession and lithology of Jaisalmer area (after Ramakrisnan, 1997)

Age	Formation	Lithology
Recent to	Sumar	Dune sands, gravels with ferruginous noduls.
	Bandah	Foraminiferal limestone clayey at the base.
	Khuila Sanu	Shale with limestone beds and Calcareous silts. Friable sandstone with minor clays
Pliestocene	Parh	Marls and arenaceous limestone
Middle Eocene	Gorup Hapur	Marls and silty shale marls and arenaceous limestone Sandstones and shales Shale and sandstones
Lower Eocene	Pariwar Badasar	Baisakhi Shales and Sandstones
Paleocene	Jaisalmer	Limestone
Upper Cretaceous	Lathi	Clay, Clay stone and Shale
Lower Cretaceous	Sumarwali	Sandstones and clay stones.
Upper Jurassic	Karampur	Shale and sand stones.

Material and Methodology

Data Base

Cartosat-1, ISRO's first satellite with a long track stereo capability was launched in May 2005 providing high-resolution stereo imagery with 2.5 m resolution of earth's surface for cartographic applications. Providing relevant ancillary information along with the data product is the general practice followed by satellite data providers. Rational Polynomial Camera (RPC) model is used to represent the imaging geometry of Cartosat-1, which is expressed as a ratio of two cubic polynomials that are functions of ground coordinates. One of the key products realised for Cartosat-1 is Stereo Orthokit. The Cartosat-1 Orthokit products are already in demand among global users who are able to perform the required geometri processing including DEM generation and ortho-rectification (Singh *et al.*, 2008) [5].

Toutin (2001) [10] dedicated the stereoscopic capabilities and techniques for DEM extraction from VIR satellite sensors (Figure 2). To obtain stereoscopy with images from satellite scanners, two solutions are possible: (1) the along-track stereoscopy with images from same orbit using fore and aft images and (2) the across-track stereoscopy from two different orbits.

Digital Elevation Model Derivation.

The generation of DEM, is carried out with the use of geometric and stereoscopic models equivalent to co-linearity and co-planarity equations in photogram metric analysis (Figure 1, 2). Software employs the geometric modelling method, based on the co-linearity condition method, developed by Toutin (1995) [8]. This method reflects physical reality of the complete viewing geometry and following distortions that may occur during the image formation such as: (1) distortions due to the platform (position, velocity, orientation); (2) distortions relative to the sensors (orientation angles, instantaneous field of view, detector signal integration time); and (3) distortions relative to the Earth (geoid-ellipsoid including relief);and deformations relative to the cartographic projection (ellipsoi – cartographic plane).

Methodology of DEM extraction from artosat- 1 data has been displayed (Figure: 1).

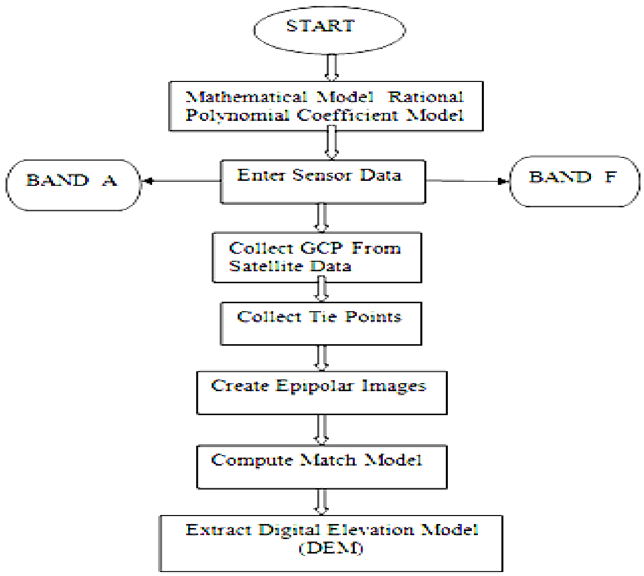

Fig 1: illustrating the extraction of geomorphic parameters with help of DEM

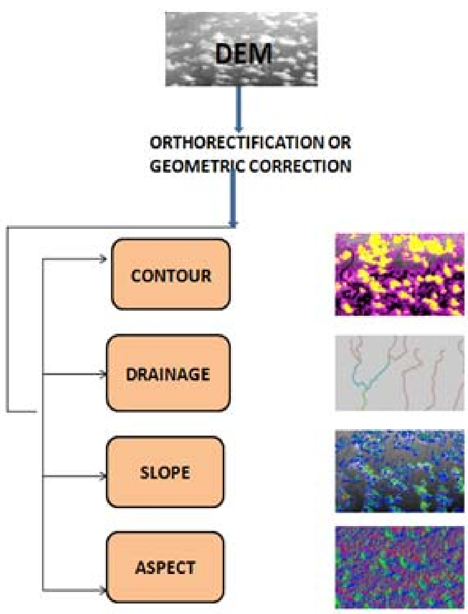

Fig 2: Ground control point collection.

With the help of software, read imagery and supplementary information such as ephemeris and attitude data from CARTOSAT- 1. GCPs were collected to compute or refine the stereo-model geometry with a least square adjustment process in order to obtain a cartographic standard accuracy. With the parametric modelling method, based on the co-linearity condition method, developed by Toutin and Cheng (2000) [11] at CCRS, used in software, few GCPs are required. The accuracy depends on a number of GCPs. The GCPs should be spread at border of stereo pair to avoid extrapolation in planimetry. It was also preferred to cover the full elevation range of the terrain. To extract an absolute DEM, we collected the GCPs and optionally tie points for each image. Cartographic coordinates of GCPs were obtained from global positioning system (GPS), air photo surveys and map digitizing, etc. Software allowed GCPs collection from various sources using techniques like enter GCPs coordinates manually; from geocoded image files; from geocoded vector files; from a Chip Database file, including correlation; collected GCPs from digitizing tablet; and import GCPs from text file.

Elevation Parallax Extraction.

An area based automated image matching procedure was used to extract the elevation parallax, and produced the DEM through a comparison of the respective grey values on each of these images. This procedure utilized a mean normalized cross-correlation matching method with a multi-scale strategy to match image with the help of collected statistics in defined windows. Matching was performed by considering the area surrounding of given pixel in the left quasi-epipolar image and moving this template within a search area on the right epipolar image. The actual matching method generated correlation coefficients between 0 and 1 for each match pixel, where 0 represents a total mismatch and 1 represents a perfect match. A second-order surface was then fitted around the maximum correlation coefficients to find the match position to sub-pixel accuracy. The difference in location between the centre of the template and best matched pixel position provided disparity or parallax arising from the terrain relief, from that the absolute elevation value was then computed. A further advantage arising from the matching method is that it tolerates any spatially invariant, linear radiometric relationship between two images.

Dem Post-- Processing.

After computing the elevation parallax and producing DEM, it is imperative for post-processing the extracted elevation data: e.g., to eliminate blunders, to fill the incompatible areas and to smooth DEM. To fill holes and noisy areas software employs interpolation functions to replace mismatched values interpolated from good elevation values of the failed areas (Cheng, 1999) [1].

Geomorphomic Analysis

Geomorphic parameters are useful for the identification and illustration of the geomorphologic features of the area. With the help of DEM, we have extracted elevation, contour, aspect, slope angle, and drainage (Figure 3, **4,** 5, 6) network of the study area. The elevation has been graphically offered in a hypsometric map with eight classes; and noted highest elevation of dunes as 216 m.

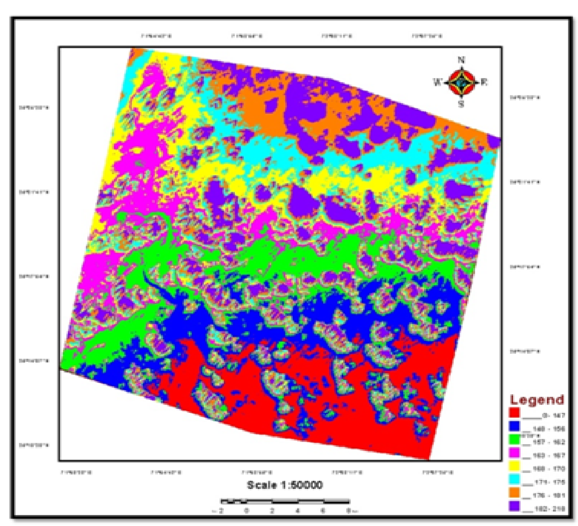

Fig 3: Elevation map of Jaisalmer area Rajasthan, India,

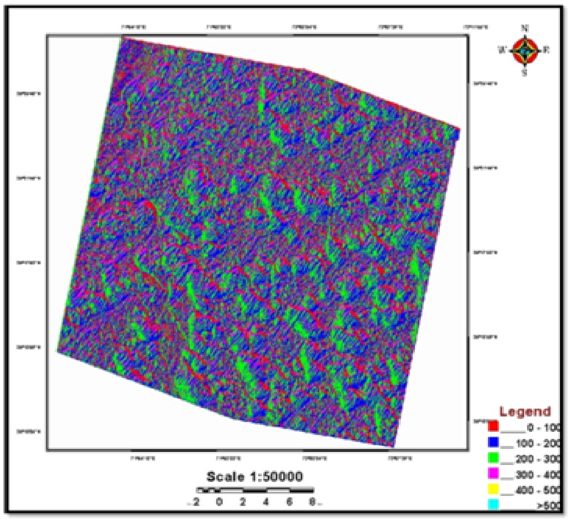

Fig 4: Aspect map of Jaisalmer area, Rajasthan, India.

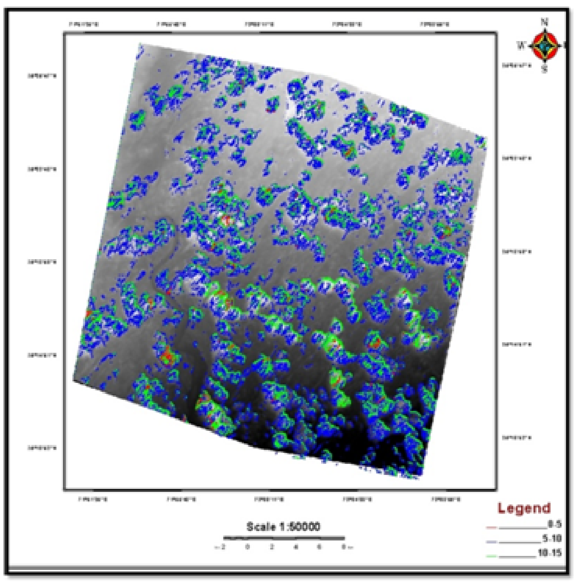

Fig 5: Slope map of Jaisalmer area Rajasthan, India.

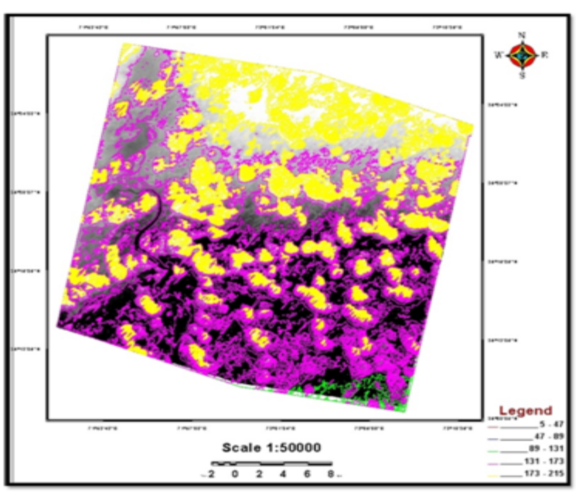

Fig 6: Contour map of Jaisalmer area, Rajasthan, India.

Topography, in general, has been recognized into six aspect classes, and this helped in the identification of geomorphologic features. For example, differences in aspect were indicator of dunes symmetry. The map demonstrates the slope angle in three classes (0-5, 5-10, and 10-15). Another map exhibits contour on 5 m interval, according to elevation points contour is divided in to five classes between 5- 215 m.

Conclusion

This study has demonstrated that the digital elevation model (DEM. **Figure** 2**)** has been prepared with Cartosat-1 remote sensing data in respect of the Jaisalmer area of Rajasthan. Results of the study area reveal that the DEM is very useful for the profound geomorphic analysis of any area. The scale of a DEM sets the limits for the level of detail for geomorphologic analysis. Cartosat-1 DEM presents relatively enormous detail of the study area, very easy to develop, cliff faces and steep slopes are easy to identify and available for many parts of the Earth. Moreover, it provides the opportunity for mapping at medium scales (1:100,000 and 1:50,000), and for extracting elevation information from nadir and after images.

In cases, where precise GCPs cannot be obtained, it is possible to generate DEMs through TPs alone. The effect of DEM resolution on ortho image accuracy illustrates that enough care has to be taken in selecting DEM resolution while generating an ortho image. Terrain parameters such as slope, aspect, and drainage network were automatically extracted from DEM. Drainage network analysis reveals the DEM resolution size affects the lower order drainages.

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