ISSN: 2277-5536 (Print); 2277-5641 (Online)

EXTRACTION OF MORPHOTECTONIC FEATURES USING DEM AND TERRAIN GENERALISATION ON THE AREA AROUND LANJA, DISTRICT RATNAGIRI, INDIA.

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ABSTRACT
The present study aims to use Digital Terrain Analysis to extract major morphotectonic features from DEM of the study area. The methodology is based on generation of colour coded DEM and terrain generalization to identify morphotectonic features and associated phenomena. The colour coded DEM was generated with the help of SRTM data. Terrain generalization algorithm was applied to DEM to reduce the noise formed by insignificant details which in turn enhances the major morphotectonic features. These techniques are found to be helpful to recognize and demarcate major geomorphic domains, linear and curvilinear lineaments, ridge lines, valley forms along with triangular facets.

KEY WORDS: Digital Elevation Model, Digital Terrain Modeling, Terrain Generalization.

INTRODUCTION

Digital Elevation Model (DEM) represents the spatial distribution of elevations above some arbitrary datum in a landscape, whereas, Digital Terrain Model (DTM) is an ordered arrays of numbers that represent the spatial distribution of terrain attributes (Moore et al. 1993). DEM provide an image of bare land surface and yield digital terrain information not fuzzy by land cover features and hence, allow characterization of land surface quantitatively in terms of slope, gradient and curvature. Digital Terrain Analysis (DTA) can be implemented on digital elevation model in order to derive various terrain attributes (Jordan and Peckham, 2007). In this study, DTA has been carried out by means of the combined use of: 1) elevation analysis with the colour coded DEM and 2) terrain generalization to identify major morphotectonic features for tectonic interpretation. Morphotectonic features represented by digital elevation models of the Lanja area, district Ratnagiri, Maharashtra, were extracted, described and interpreted in terms of geomorphology and morphotectonics. The analysis of multi-source data was implemented by means of GIS operations.

Study area:

Lanja region, district Ratnagiri, from Konkan plains of Maharashtra is part of northern section of western passive continental margin of India. Its major morphotectonic features from west to east are coast line, Konkan Coastal Belt (KCB) and Western Ghat Scrap (WGS) (Fig. 1). The KCB is distinct morphotectonic feature, whose average width is about 50km. Geomorphologically this belt exhibits numerous small and short butte and mesas at different altitudes near the coast line and further east it suddenly rises to great heights forming scrap facing towards west. The region is traversed by numerous westerly flowing rivers. The Konkan plains north of $16^{0}30'$ N latitude and the main Maharashtra plateau east of WGS are covered by horizontally disposed basaltic lava flows of Deccan Traps of Upper Cretaceous to Eocene age. The significant processes related to the effusion of flood basalts are the northward movement of Indian plate over the Reunion Hotspot resulting crustal arching, rifting and down faulting of western arm of the rift (Cambell and Griffith, 1990; Radhakrishnan, 1993). The basement of southern traps is composed of heterogeneous stratigraphic formations which mainly include Dharwar Supergroup, Kaladgis and Bhima Groups and spans about 3000 million years of the earth's history.

The KCB is the major belt of tectonic disturbance and it has experienced few numbers of seismic events of moderate magnitude (Naini and Talwani, 1983). It is characterized by strong concentration of lineaments in an approximately N-S, NW-SE and NE-SW directions (Powar, 1980 and 1993). The NW-SE trending major lineaments in the southern Deccan Traps coincides the structural trends in the basement exposed at its south and hence indicate these are as the results of rejuvenation of weak zones or faults in the basement. According to Widdowson and Mithchel (1999), the major lineaments along which the pattern of modern drainage is controlled are possibly an expression of extensive fracturing or small scale faulting and their details are not clear.

Data used and methodology

DEM preparation: The Shuttle Radar Topography Mission (SRTM) elevation data on a near-global scale was used to generate high-resolution digital topographic database. Filled and finished data of 3arc second WRS-2 of 90m resolution has been downloaded from the GLCF site. Two tiles of height data of WRS-2 was used for the further preprocessing and generation of DEM. The tiles were mosaiced and image subset of study area was clipped from the whole scene. The gaps in data were filled and negative values and oceans were removed in ArcGIS environment. The SRTM data (90m resolution) was then converted into grids 30m resolution with the help of bicubic polynomial interpolation algorithm (Keeratikasikorn and Trisirisatayawong, 2008). The procedure for converting raw SRTM data to DEM was adapted as suggested by Borut Vrščaj et al., 2007 and presented in the form of colour coded map (Fig. 2).

Terrain generalization: The DEM at a resolution of 30m shows many small topographic details, which disturb the clear portrayal of the main relief features. In the case of GIS environment, when standard raster filter operations are applied to digital terrain data relatively significant ridges and valley edges are blurred, and their characteristic shape is not depicted successfully in shaded relief. The recently developed software for method of generalization is 'terrain sculptor', which removes insignificant details and preserves the main landform (Leonowicz et al., 2010) has been implemented to DEM of Lanja area. In this generalization method successive raster operations divide the terrain into mountainous and lowland areas and separately generalize these major morphological areas in different raster operations and afterwards recombine them into one elevation model. Imhof, (1982) has formulated this principle for accentuating ridge lines in high mountain areas and river valleys on flat plains. The procedure of generalization of DEM follows the algorithm shown in the flowchart (Fig. 3).

Spatial filtering: The first step of the generalizing procedure filters the DEM with a low-pass mean filter, which computes a new pixel value by averaging the values within its immediate vicinity. Mean filters are frequently used for smoothing images (Burrough and McDonnell, 2000) and are also applicable to the removal of details from digital elevation models. A mean filter of 5 x 5 pixels was applied 16 times to smooth the SRTM terrain at a spatial resolution of 30m. These parameters were adjusted by visually inspecting the preliminary results to ensure that all unnecessary terrain details were removed from the elevation model (Fig.4A).

Detecting ridges and valleys: For the purpose of detecting ridges maximum and plan curvature coefficients, whereas to identify valleys minimum curvature were applied (Fig. 4B). Plan curvature measures the rate of change of aspect along a contour line in the horizontal plane; it differentiates between convex and concave forms, and defines sharp and clear lines of ridges and valleys (Hutchinson and Gallant 2000).

Exaggerating ridges and valleys: The next processing step determines weights to vertically exaggerate ridges and valleys. Two weights are computed for each cell in the digital elevation model: one for exaggerating ridges, and the other for deepening valleys. The weight for deepening valleys is calculated from minimum curvature; the weight for exaggerating ridges is calculated as a sum of maximum and plan curvature. Two DEMs were generated one for exaggeration and another for deepened model (Fig.4C and D). The exaggerated and the deepened models are calculated by multiplying the filtered model by a curvature weights, according to the equations (1) and (2), which are applied to each cell of the elevation model:

$$h_{mount} = w_r \cdot h_{ex} + (1 - w_r) \cdot h_{fl} \quad (1)$$

$$h_{low} = w_v \cdot h_{deep} + (1 - w_v) \cdot h_{fl} \quad (2)$$

Where,
h_{mount} = elevation of mountain DEM
h_{low} = elevation of lowland DEM
w_r = weight of ridges
w_v = weight of valleys
h_{ex} = elevation of exaggerated DEM
h_{deep} = elevation of deepened DEM
h_{fl} = elevation of filtered DEM

Combination of mountain and lowland models: The final step combines the mountain and lowland models into one elevation model (Figure. 5). First an additional grid is created that indicates where the mountain and the lowland models are to be applied. Terrain parameters, such as slope or elevation range, can be used as indicators for this differentiation. The mountain and lowland models are combined according to equation (3), which is applied to each cell of the elevation models. The mountain grid is used in areas with high slope values, and the lowlands grid in areas with low slope values.

$$h_g = w_s \cdot h_{mount} + (1 - w_s) \cdot h_{low} \quad (3)$$

Where, h_g = elevation of generalized DEM,
w_s = slope weight
h_{mount} = elevation of mountain DEM
h_{low} = elevation of lowland DEM.

RESULTS AND DISCUSSION

Analysis of Coloured DEM

The coloured relief map nicely dictates the physiographic setting of the study area (Fig. 2). The number of linear features emerges from this model are Western Ghat Scarp, en-echelon shaped West Coast and major and minor lineaments. With this model it was easy to divide the study area into three geomorphic domains, from east to west are 1) Western Ghat escarpment and foot hills (FH), 2) the middle low laying land (LL) and 3) tilted tableland (TT). A colour coded elevation image also shows a general decrease in elevation from east to west, indicating that the entire area is sloping towards the west.

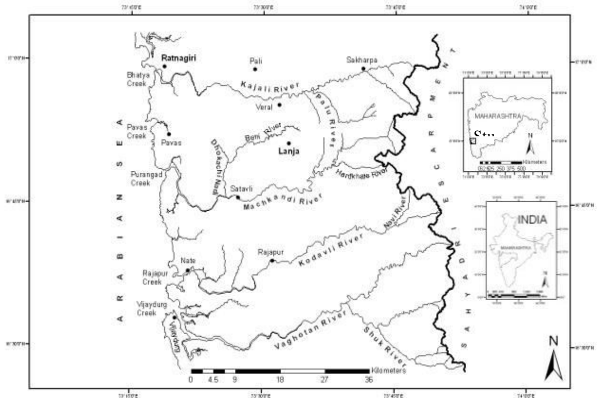

Figure 1. Location map

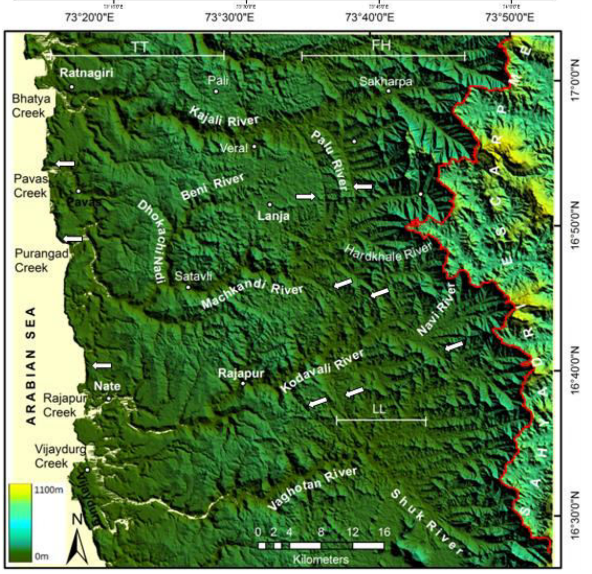

Figure 2. Digital Elevation Model of the study area with colour coded elevations showing geomorphic domains (FH, LL and TT) and major lineaments (arrows).

Westerly flowing major rivers, from north to south, are Kajali, Machkundi, Kodavli and Vaghotan, traverse these three domains. The rivers flow over basaltic substrate. Though laterites encountered at western part of the study area and near the mouth of these rivers, the rivers deeply incise laterites and underlying basaltic substrate. The channels of rivers lack a continuous cover of alluvial sediments but at places there are presence of thin and patchy mantles of alluvium and landslide derived boulders and cobbles formed by short term pulse of rapid sediment delivery. It is better to describe these channels as "mixed bedrock-alluvium channels" (Whipple, 2004). Segments of streams having bedrock channels are characterized by cascades, waterfalls, deeps and sometimes interconnected potholes, steep valley walls, deep incision etc. The FH domain is characterized by high relief, trellis drainage pattern and deformed geomorphic surfaces associated with a dissected landscape.

This domain has high stream gradients with low sinuosity which is indicative of uplift. TT domain is also characterized by highly dissected landscape and exhibit higher stream gradient, deeply incised streams and moderate relief. The TT domain has westerly / seaward tilted basaltic lava flows (2^0 to 6^0) with laterite capping (Widdowson and Mithchel, 1999). Thus these features are indicate, the TT regime has uplifted and tilted towards west. As compared to FH and TT domain, the LL domain is characterized by low relative relief, rivers with relatively gently sloping surface and low river gradient, but high river sinuosity. Sudden increase in sinuosity of rivers in LL domain also indicates the higher vertical movement of FH domain than LL domain. Increase in sediment flux causes patchy occurrences of thin veneer of sediments in the bed. All these features and characters indicate that the
FH and TT domain have uplifted whereas the middle LL domain has been subsided.

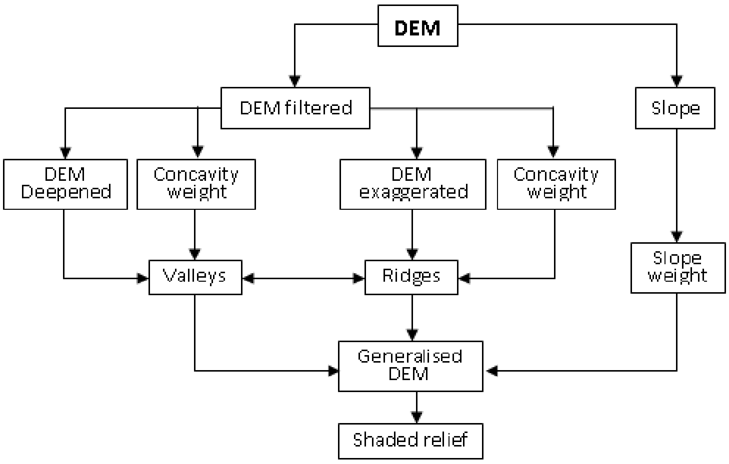

Figure 3. Processing steps leading to generalization of DEM. (modified after Leonowicz et al., 2010)

Analysis of terrain generalization

Images obtained by terrain generalization technique are presented in figure 4 (A, B, C and D). The resultant DEM (Figure 5) of combination of two models (mountain model with exaggerated ridges and lowland model with deepened valleys) has been generated by process of DEM generalization.

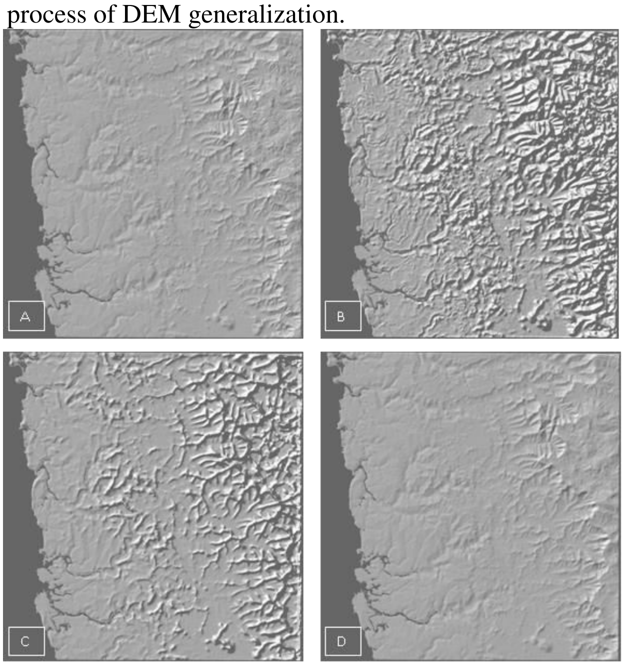

Figure 4. Steps of generalization method. A: low pass mean filtered image, B: ridges exaggerated and sharpened, C: ridges exaggerated, ridge details removed and valleys deepened, D: low-land image, valleys deepened and widened to generalize low areas.

Morphological features indicative of tectonic phenomena such as linear valleys, ridgelines, slope-breaks, steep slopes and morphological depressions were enhanced by the process of terrain generalization. The main linear feature emerges is N-S trending WGS (Figure 4A and D). Linear and curvilinear weak zones emerge out and can be attributed to major lineaments trending N-S and NW-SE directions. The major lineament trending NNW-SSE, visualized in the image was shown with the help of arrows (Figure 5). Other major and minor lineaments (not shown in figure) can be interpreted with the help of morphological feature such as slope breaks and uniform aspect. The trend of ridge lines were traced in the GIS environment and represented in the form of rose diagram (Figure 5B). Majority of ridge lines are trending N-S. The secondary trend direction of ridge lines is E-W formed because of erosional activities by E-W running rivers. Evidently the general trend of valley forms is also E-W. The curvilinear lineament and pattern of array of triangular facets (arrows) was identified and shown in figure 5A. The occurrence of linear array of triangular facets is indicative of presence of fault plane. A ridge line paralleling the array of triangular facet shows slope break on both of its side can be interpreted as presence of listric fault.

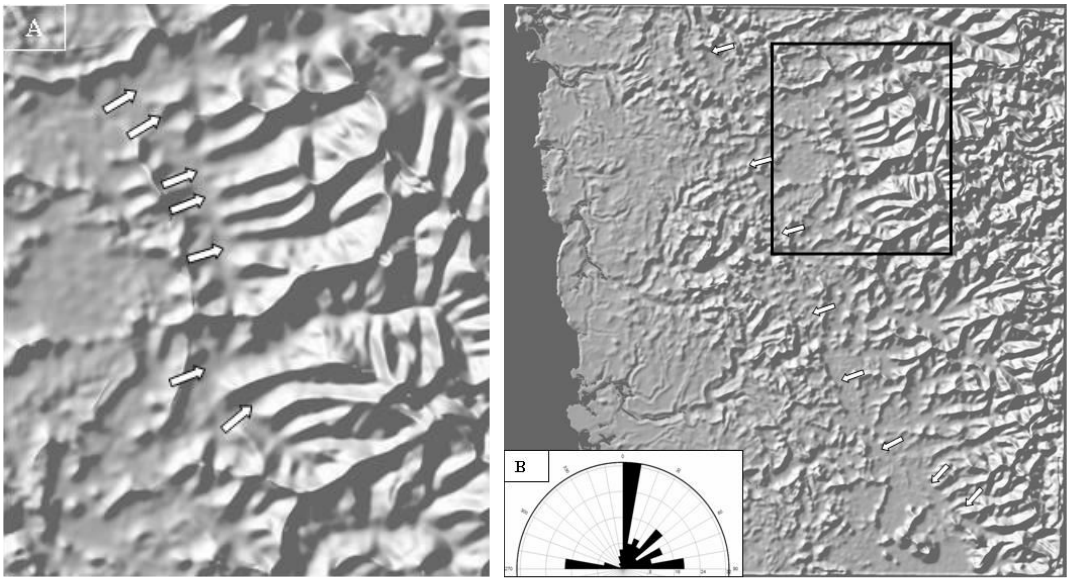

Figure 5. Combination of mountain model (exaggerated ridges) and lowland model (deepened valleys) of final shaded relief model. Arrows in the main figure shows enhancement of major lineament due to image generalization. Part of the image (A) in the rectangle was zoomed. Arrows shows triangular facets at mountain front emerged due to generalization of image. Inset shows Rose diagram (B) of ridge line's azimuth.

CONCLUSION

Colour coded DEM is helpful to identify and demarcate major geomorphic domains, lineaments and areas of uplift and subsidence. Terrain generalization method was found to be helpful to extract a major lineament trending NNW-SSE, ridge lines, valley forms as well as triangular facets which was unrecognizable in colour coded DEM.

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