



Application of TecDEM in morphometric studies of Imphal River

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Abstract: The present study highlights the application of TecDEM in the generation of morphometric maps for surface dynamics and basin analysis in the study of Imphal river basin. The study area is located along the proclinal Churachandpur-Mao-Thrust (CMT) in the tectonically active zone of Indo-Myanmar region. TecDEM, a MATLAB toolbox used in conjunction with Global DEMs for the extraction of tectonic geomorphologic information, allows the extraction of parameters such as isobase, incision, drainage density and surface roughness maps. TecDEM also provides tools for basin asymmetry and hypsometric analysis. The study reveals the findings of morphotectonic interpretation of the Imphal River basin.

Keywords: Basin asymmetry, Hypsometry, Isobase map, Incision map, Surface roughness, Drainage density.

I. Introduction

TecDEM (Tectonics from Digital Elevation Model) is a MATLAB toolbox which is used in conjunction with Global DEMs. Digital elevation models (DEMs) are replacing traditional topographic maps in geosciences with the advent of Space Technology and has provided us with the automatic drainage network extraction. It is observed that the drainage responds rapidly to tectonic changes and thus it is a potential parameter for tectonogeomorphological analysis. Digital elevation models (DEMs) provide an opportunity to quantify the influence of neotectonic processes on landscape development. Here, we present the surface dynamics and basin processing options that are available in TecDEM (Shahzad and Gloaguen 2011a, 2011b). This includes preparation of morphometric maps for surface dynamics and basin analysis and produce maps of Isobase, Incision, Surface Roughness, Drainage Density, Basin asymmetry and Hypsometry. This study also investigates the tectonics of the Imphal River basin. The relationship between the degree of basin tilt and the stage of the landscape's response to tectonic perturbation was investigated using TecDEM.

II. Study Area

The study area is located on the Senapati-Mao sector along the National Highway NH-39 (Figure 1) and is a part of the Imphal river system located along the proclinal Churachandpur-Mao-Thrust (CMT) in the tectonically

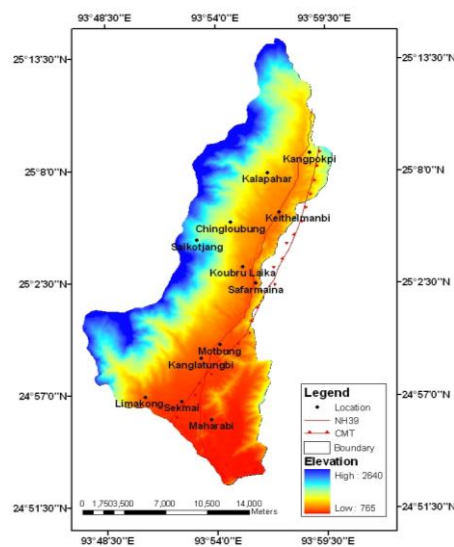


Figure 1: DEM of the Study Area

active zone of Indo-Myanmar region. Imphal River originates in the hill ranges of the Senapati District and flows south, forming the boundary line demarcating the Thoubal Districts on its north and the west. Maohing and Changoubung are the main sources of the Imphal River. It covers a total area of 339 Km² with the geographical position of 24.8757° to 25.2415°N and 93.79° to 94.0021°E. . The elevation of the area ranges from 765m to 2640m. Many tributaries join the Imphal River. Some of the tributaries that join the main river are Thumkhong Lok, Ising Lok, Hawa Lok, Sipi Lok, Gun Lok, Limakong River and Tumnoupokpi Lok.

III. Methodology

Two data sets are used for the current work: DEM (ASTER) and an automatically extracted drainage network. Both datasets are used to further implement the above stated morphometric indices in the framework of TecDEM. The digital elevation model serves as an input parameter. It first extracts the drainage network using Deterministic-8(D8) algorithm. D8 algorithm is the most convenient and widely used method to extract drainage network and its related basins (Hogg et al., 1997; Maidment, 1993). This extracted drainage network consists of streams as a function of spatial location with elevation and contributing area.

A. Basin Asymmetry

The Basin Asymmetry analysis is carried out on the 2 Basins of Strahler order 4 with the value of T-index calculated at a distance of 2km using TecDEM. Cox (1994) suggested that streams migration can be studied using the transverse topographic symmetry factor (T). This approach helps us to rapidly assess the tilted element in active orogens by quantifying the variation of drainage symmetry along the stream length. This variation is calculated by measuring the ratio of the distance of a theoretical basin's mid-line to the actual stream location and basin boundary (Cox, 1994; Garrote et al., 2006, 2008).

B. Basin Hypsometry

The hypsometric curves have been used to infer the stage of development of the drainage network and also it is a powerful tool to differentiate between tectonically active and inactive areas (Keller and Pinter, 1996). The curve is created by plotting the proportion of total basin height against the proportion of total basin area (Figure 4a). Convex hypsometric curves characterize young slightly eroded regions; S shaped curves characterize moderately eroded regions; concave curves point to old, highly eroded regions. In the present study, all basins are automatically processed to calculate Basin hypsometry. The simplest way to characterize the shape of hypsometric curve for a given drainage basin is to calculate its hypsometric integral.

In theory, hypsometric integral value ranges between 0 and 1. Low hypsometric integral values indicate old and more eroded areas and evenly dissected drainage basins. High values of the hypsometric integral value indicate that most of the topography is high relative to the mean, such as a smooth upland surface cut by deeply incised streams indicating young and less eroded areas.

C. Isobase Map

Variations in stream Strahler orders have a strong connection to topography. Streams with the same Strahler orders are related to similar geological events and hence are of similar age. The dynamics of stream Strahler orders and topographic variations can be studied using an Isobase map (Garrote et al., 2008; Golts and Rosenthal, 1993; Grohmann, 2004; Grohmann et al., 2007). Isobase lines represent erosional surfaces which have formed due to recent tectonic and erosional events (Filosofov, 1960). Studies suggest that Isobase maps are prepared by interpolating the elevation at the location of 2nd and 3rd order streams (Golts and Rosenthal, 1992, 1993; Grohmann, 2004). Sharp changes in the isobase map indicate the possible location of faults and/or lithological contrasts.

D. Incision map

The Incision map shows relative or local relief and is a tool for quantifying relative elevation. It is calculated by measuring the difference between the maximum and minimum elevation in a moving window. The calculation of relative relief is influenced by the shape and size of the moving window and is a well documented problem (Ascione et al., 2008; Klinkenberg, 1992; Guzzetti and Reichenbach, 1994). The moving window should be large enough to include at least two major ridges and/or valleys otherwise the results will not represent local relief but simply the slope gradient (Evans, 1972).

E. Surface Roughness

The surface roughness of a given region is represented as the variation from vector normal planes to surface normal planes. In highly deformed regions, surface roughness is extremely high because the areas of vector normal plane and surface normal plane exhibit high variability. Previous studies suggest that surface roughness can be used to study the morphological characteristics of a region (Grohmann, 2004; Grohmann et al., 2007,

2009). In any square grid, surface roughness is described as the ratio between surface area and flat area. The grid size is a user-defined input and can be changed depending upon data resolution and the region of interest.

F. Drainage Density

Schumm et al., (2006) suggested that drainage density is an important parameter which not only determines the length of slope failures but also channel spacing and hence is related to erosion rate. The analysis of drainage network density (m/m^2) represents the sum of fluvial segment length inside a grid cell and shows the evolutionary stage of a basin from the point of view of its fluvial dissection rate (Schumm et al., 1987). A high drainage density reflects a highly dissected drainage basin with a relatively rapid hydrologic response to rainfall events, while a low drainage density means a poorly drained basin with a slow hydrologic response (Melton, 1957). In the present study, the drainage density has been drawn from the extracted drainage network and categorized into high, medium and low.

IV. Results and Discussion

The generation of morphotectonic maps for surface dynamics and basin analysis using TecDEM is an important tool for tectonogeomorphological analysis. These types of analyses are especially suitable in regions with drainage network anomalies and relief pattern discontinuities (Gloaguen et al., 2007, 2008; Kurz et al., 2007).

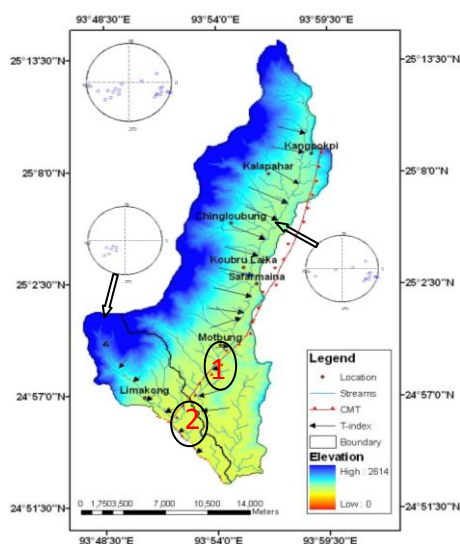


Figure 2: Drainage Basin Asymmetry

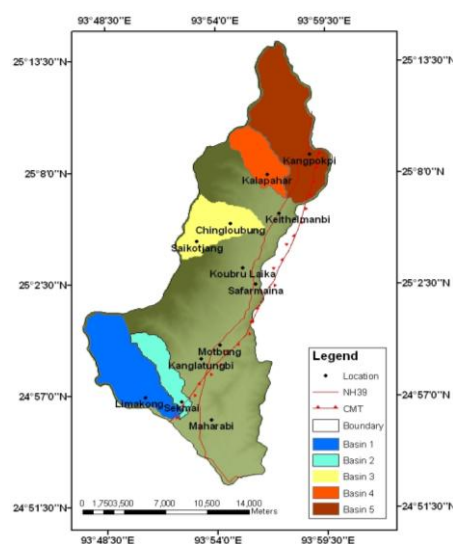


Figure 3: Watershed Extraction of Strahler order 3

Basin analysis of the study area has been performed using the Basin asymmetry and Hypsometric curves. Basin asymmetry is conducted on basins of Strahler order 4 and T-Index is calculated at a distance of 2km as shown in Figure 2. The basin of Strahler order 4 represents the complete Imphal river system of the study area and distance of 2km is chosen to achieve a reasonable density of asymmetry vectors. Two anomalous locations are identified where asymmetry vectors approach zero. The strong influence of drainage on the tectonic features is shown at locations 1 and 2. These anomalous locations are correlated with the CMT that passes through it. The calculated Transverse Topographic Symmetry (T-index) provides evidence for active tilting in the region (Figure 2). In the study area, basin tilting can be the cause of faults on either side of basins i.e. CMT. This concurrence illustrates active faulting as the cause for the tilting. The inset on the top left corner shows the combined polar plot of the vectors of both basins. The individual polar plots of both basins show different stories. The Imphal River basin shows maximum tilting in the NNE. This can be explained by a NNE orientation of CMT as is clear from the tectonic features. Similarly, in the Limakong River basin, maximum tilting is in the direction of local thrusting, i.e. SE. Evidences of neotectonism have been recorded in the northern part of the Imphal valley along a lineament trending N35°W-S35°E and can be traced along the Limakong River, a tributary of the Imphal River. The river sections expose a sequence of folded and tilted peat beds of probable Pleistocene age overlain by a blanket of undisturbed Upper Pleistocene and Holocene fluvialite sediments (G. K. Kesari et al., 2011).

Hypsometry analysis is based on investigating the shape of basin hypsometric curves which vary from concave to convex. Here 5 basins of Strahler order 3 are studied in the region of the Imphal river system (Figure 3). A combined hypsometric plot of all the basins is shown in Figure 4(a). Blue coloured (basin 1) curve represents the basin that exhibits convex behavior. This shape type is usually attributed to youthful basins, while the basin

2 reveals a concave shape that suggests maturity. This means that the basin 1 is the youngest basin while basin 2 is the oldest one.

We also observe that most of the curves are either overlapping or intersecting each other. Statistical moments can distinguish between individual curves as shown in Figure 4 (b). HI values of basins range from 0.17 to 0.28 indicating erosional stage and level of tectonic activity of basins differs from each other. Values of skewness and kurtosis are used to study the erosional processes in the basins. Descriptive statistics and HI values of basins are given in Table 1. Interestingly the curves of the basin 2 and 5 are positively skewed which point to an increase in head-water erosion. The analysis suggests that the drainage evolution in this area is sensitive to recent tectonics.

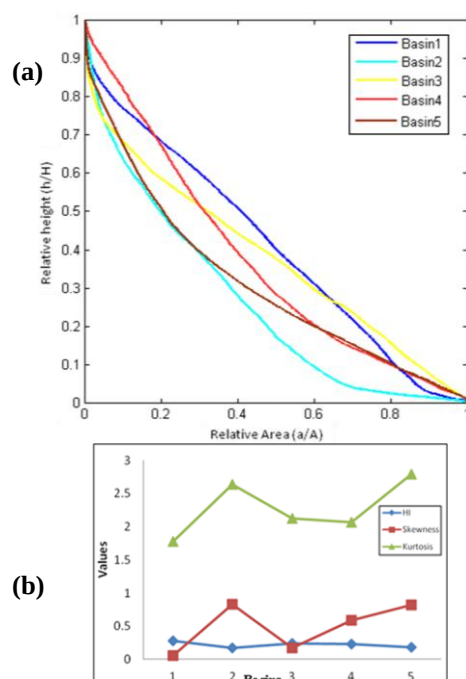


Table1: Descriptive statistics and HI values of Basins

Basin No	HI (Hypsometric Integral)	Skewness	Kurtosis
1	0.27662	0.05735	1.7732
2	0.1701	0.82922	2.6348
3	0.23744	0.17491	2.1257
4	0.22649	0.59174	2.0686
5	0.18583	0.81669	2.7908

Figure 4(a) Combined hypsometric plot of all 5 basins and (b) their statistical moments.

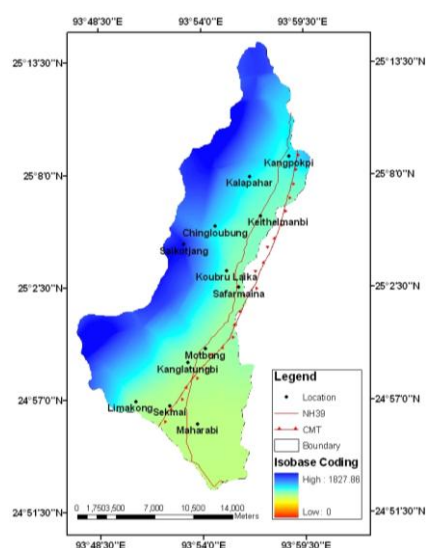


Figure 5: Isobase Map

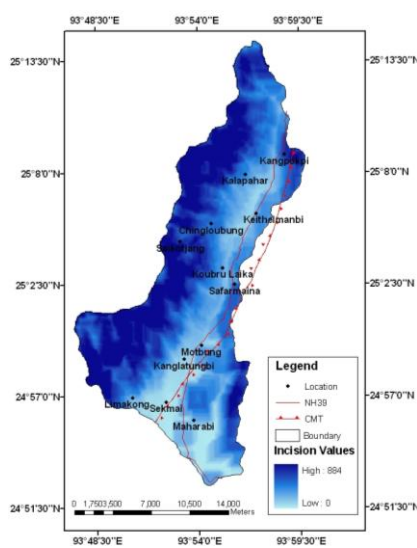


Figure 6: Incision Map

The analysis of surface dynamics parameters such as Isobase, Incision, drainage density and vertical dissection maps provides insight into the tectonic geomorphology of the study area. These parameters might reveal major tectonic features. The Isobase map of the study area (Figure 5) which shows the location of 2nd and 3rd order streams is versatile. Changes in the relative position of 2nd and 3rd order streams at high or low relief correlate with some of the geological and tectonic features. A lithologic boundary of two rocks (Disang and Barail) of

different erosional properties is found which results in a change in the local order base-levels. This is the Disang unit that has been thrust till the basin mid-line. Other minor changes in the Isobase map might be related to residual morphotectonic features. The incision map or local relief is used to identify regions of high gradients (Guzzetti and Reichenbach, 1994). The incision map of the study area is also prepared using a moving window of 1 km² and again shows steep changes to the west of the study area. This map also shows a series of sharp changes in the NW side of the study area (Figure 6).

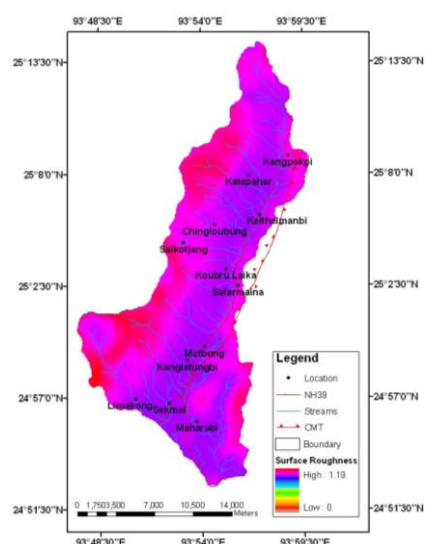


Figure 7: Surface Roughness

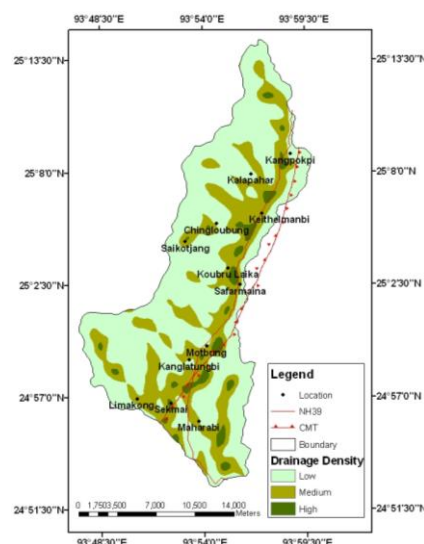


Figure 8: Drainage density Map

The surface roughness map of the study area as shown in Figure 7 has been prepared by using a moving window of 1km². Terrain segments are interpreted on the basis of the surface roughness (flat to mountainous terrain). The flat region is the valley occupied by Imphal River and its tributaries. A region of high surface roughness is occupied by structural hills. High surface roughness indicates highly deformed regions. The Incision map shows a very good correlation with drainage density. Drainage density analysis in Figure 8 shows that the uplifted areas show low drainage density, and the depressed area has a dense network.

V. Conclusion

The application of TecDEM is significant in tectonogeomorphological analyses. Surface dynamics, basin analysis and the generation of morphometric maps help in the study of the tectonics of the study area. Thus, the study reveals the morphotectonic findings of the area.

VI. Acknowledgements

The author wishes to thank Faisal Shahzad, Remote Sensing Group, Freiberg University of Mining and Technology, Germany for giving guidance of the methodological development and also for providing constructive comments and reflections that are very helpful to improve the manuscript and make it easier to read and understand. The author is also thankful to Department of Earth Sciences, Manipur University for providing the necessary facilities in carrying out this work.

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