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Research Paper

Application of DEM and GIS in Terrain Analysis: A Case Study of Tuirini River Basin, NE India

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Rivers are the most sensitive component of the fluvial environment and play an important role in the evolution of various landforms in a river basin. The study has demonstrated that the applicability of remote sensing, DEM data and GIS tools for basin analysis with reference to the tectonics. The Tuirini river basin is typically Tertiary mountainous terrain and major portion of the area comes under the steep slope category. The Tuirini river drains over an area of about 420 sq.km and the drainage system is governed by tectonics along the existing lineaments and faults. The results of river profiles show graded curves which reflect the nature of the bed rocks as well as the intensity of tectonic activities of the region. As the area is tectonically active, most of the tributaries follow lineaments/fractures, and the course of main river (Tuirini) is structurally controlled by lineaments and major faults at several sectors. Hence, this study would be helpful for basin management plan and conservation of natural resources for sustainable development of the area.

Keywords: River profiles, Lineament, Tectonics, GIS, River basin, Mizoram

Introduction

River basins are the ideal units of the fluvial landscape and are considered to be efficient and appropriate for natural resources management and its subsequent planning as well as implementation of various developmental plans. Further, conservation of natural resources are an important aspect of basin management for sustainable development. So, the study of the topographical features of a terrain is essential for estimating soil erosion, groundwater conservation measures, minimizing land degradation and disaster management studies, especially in mountainous terrain like Mizoram. The tectonics of this terrain and its adjoining regions involve the late Cenozoic deformation caused by collision tectonics between the Indian plate and the Eurasian plate in the north, and subduction tectonic along the Indo-Myanmar Ranges in the east (Molnar and Tapponnier, 1975; Kayal, 1998 and 2008; Sikder and Alam, 2003; Bhattacharya et al., 2008). Moreover, tectonogenesis of this

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folded area is closely associated with geodynamics and nature of subduction of the Indian plate below the Myanmar micro-plate of the Eurasian continent (Khan et al., 2002). Besides, the entire Mizoram state is characterized by rugged mountainous topography and forms a part of Tripura–Mizoram miogeosynclinal basin which evolved after the regional uplift of the Barail sediments (Evans, 1964). Being a mountainous terrain, there are numerous rivers with small tributaries those have played an important role forming the landforms as well as in agriculture and associated activities in the state. The mountain ranges of the state are inclined north to south direction in parallel series and the hill ranges are separated from one another by narrow deep river valleys. Most of the rivers are originate from the central part of the state and flow either towards north or south direction. The northern part of the region forms a part of the Barak River System, and the main northerly flowing rivers are Tlawng (Dhaleswari), Tuirial (Sonai) and Tuivawl which drain water into the Barak Valley of Assam. Similarly, the prominent rivers which flow towards southern portion of the region are Mat, Chhimtuipui and Karnaphuli, and drain water to Bangladesh and Myanmar. As the terrain is geologically unstable and tectonically active in nature compared with other regions of Northeast India (Ahmed et al., 2012; Ahmed and Rao, 2016a), hence most of the river systems are lithologically and structurally controlled, and follow the existing structural valleys.

Tectonism plays vital role in the evolution of drainage networks and associated landforms in a river basin. Detailed analysis of river profiles provides an additional tool to evaluate the tectonic history of the region. Since rivers are sensitive to changes in tectonic deformation, adjusting over different periods of time depending on the climate, physical properties of the host rocks and tectonic activity (Gloaguen et al., 2008). The usefulness of river profiles in deriving information related to recent tectonic activity of the region have reported by Hack (1957 & 1973), Burnett and Schumm (1983), Seeber and Gornitz (1983), Keller (1986), Kirby and Whipple (2001), Radoane et al. (2003), Duvall et al. (2004), Goldrick and Bishop (1995), Harmar and Clifford (2007) and Larue (2008).

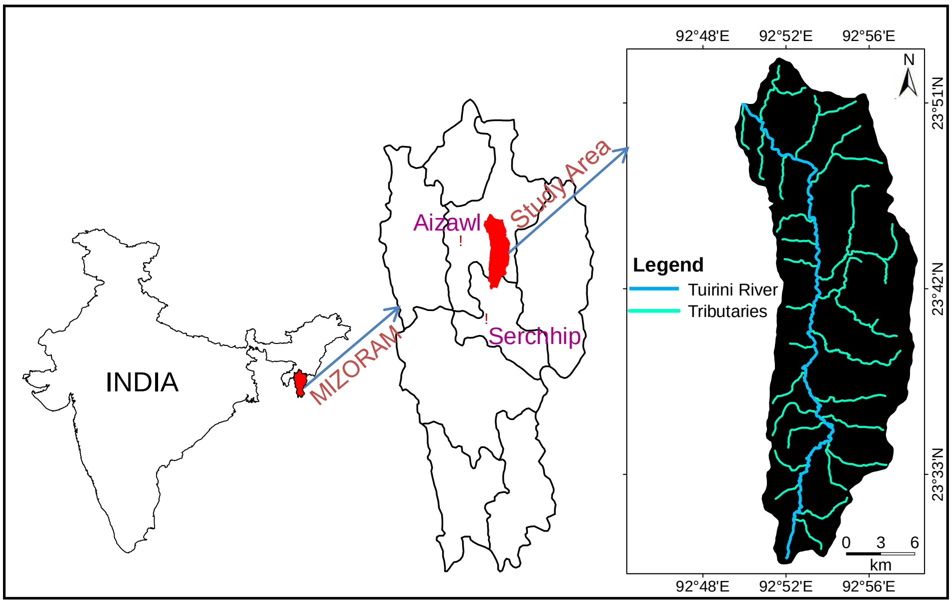
In the recent decades, Digital Elevation Model (DEM) and Geographic Information System (GIS) have become efficient tools in the river basin analysis and its conservational measures. GIS plays an important role for evaluating various terrain parameters like topography, slope, lithology, soil etc. and manipulating spatial data related to river basins. The increasing availability of DEM has significantly application to hydrological, geomorphological and environmental investigations (Moore et al., 1991; Hancock et al., 2006; Liu, 2008). DEM is a digital representation of a terrain in three dimensions and made the direct application in terrain analysis with the existing GIS tools, and is an effective way for obtaining accurate terrain information. Multiple approaches are used to create river morphology mapping and DEM is a common approach in generating river terrain models (Walsh et al., 1997; Tate and Wood, 2001; Bishop et al., 2003). Therefore, DEM data coupled with GIS are found as a key component for the river profiles analysis and extraction of the topographical features of the basin area.

On the other hand, the study of lineaments has become an important part in terrain analysis as they provide certain significant clues to understand the geologic structures and tectonics aspects of any region. Similarly, analyses of lineaments provide useful information about the evolution of drainage system, groundwater potential zones and geomorphic features of the terrain. Lineaments are the linear, rectilinear and curvilinear features of tectonic origin. Such features may be represent faults, fractures, joints, straight course of streams, long and narrow lines of different rock formations. In areas of gently folded or horizontal strata, lineaments are related to fractures and faults, and their orientation and number gives an idea of the fracture pattern of rocks (Arlegui and Soriano, 1998; Cortes et al., 1998). Remotely sensed data due to its synoptic view of the large inaccessible area and is found to be very useful in studies of lineaments. Several studies have been carried out on extraction of lineaments and mapping using satellite imagery and aerial photos (National Remote Sensing Agency, 1981; Drury, 1983; Department of Space, 1990; Naganna and Lingaraju, 1990; Budkewitsch et al., 1994; Karnieli et al., 1996; Srinivasan and Sreenivas, 1977; Nijagunappa et al., 1999; Ganesha, 2001). In this context, present paper describes the results of the river profiles and lineaments of the Tuirini river basin in order to understand the terrain characteristics with reference to the tectonic activity using DEM, remote sensing and GIS tools. Hence, the data can be used for basin management, its planning and other hydrological activities.

Study Site

The geographical extension of the Tuirini river basin lies in between 92°49'34"–92°58'22"E to 23°28'37"–23°53'20"N in the Mizoram state in north-east corner of India (Figure 1) and the forest type is mainly tropical semi evergreen forest. The Tuirini basin has an area of about 420.07 sq.km with total number of streams 2729 and geomorphologically, the area is occupied by a series of ridges with structural valleys (Ahmed and Rao, 2015a and b). The Tuirini river is the major river in the study area and the river has been named as Tuirini, after the Tuirinikai village. It originates from Buhkangkawn hill at an elevation

Figure 1: Map of the Research Area



780 m above mean sea level (msl) near the Buhkangkawn village in Serchhip district and then it confluents to Tuirial river near Tuirinikai village at an elevation 78 m above msl in Aizawl district of Mizoram. The Tuirini river flows for a total length of 56.75 km in a south-northerly direction and traverses in a northwesterly direction to joins the Tuirial river from the right bank (Figure 2b). The major tributaries of this river are Khuai, Lungding, Saibual, Kaihzawl, Kang, Tuikhan, Inran, Inrum and Chhimluang (Figure 6 and Table 1). There are also numerous left bank tributaries with short in length and have small drainage area. The average annual precipitation is about 2300 mm and average annual temperature is about 22^{0}C throughout the basin.

Figure 2: Field Photograph Showing (a) Panoramic View of Narrow Crested Hills with Alternate Narrow Valleys; (b) Confluence of the Tuirini River Near Tuirinikai Village

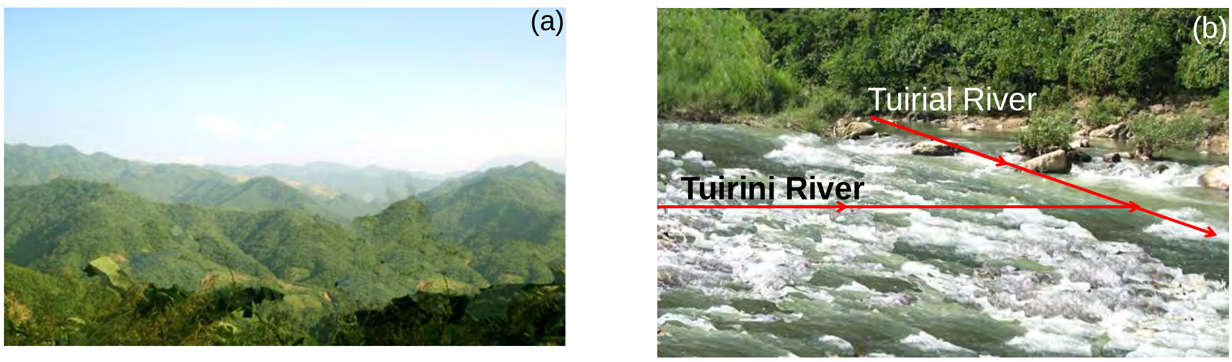


Figure 3: Structural Map of the Study Area

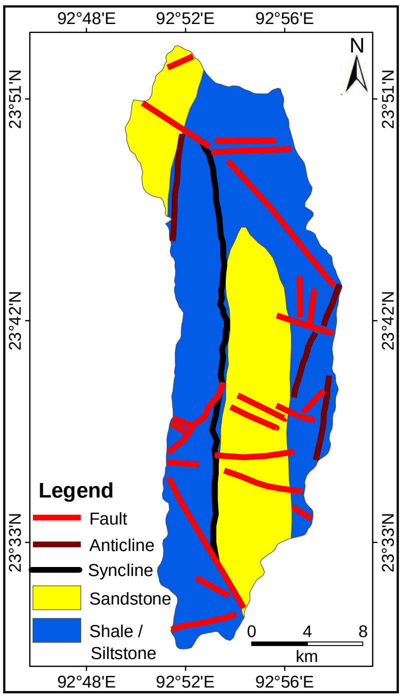
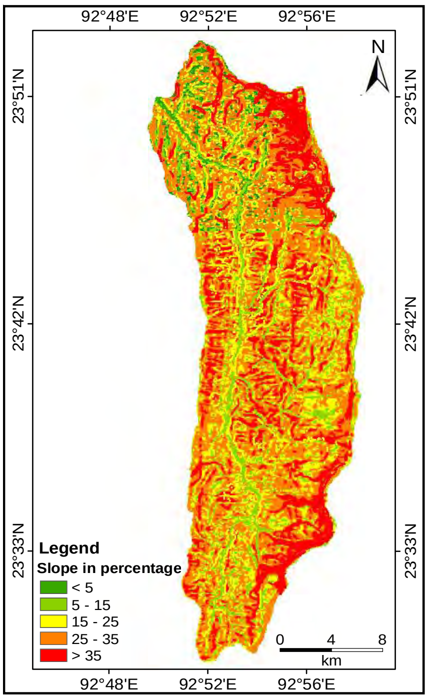


Figure 4: Slope Map of the Study Area



Structural Features of the Area

The hills of Mizoram are considered to be forming an integral part of the mobile belt constituted of tight, elongated, sub-parallel, asymmetrical, doubly plunging folds. These folds are slightly arcuate in shape with westward convexity which comprises a series of approximately N-S trending, longitudinally plunging, strongly folded anticlines and synclines (Ganguly, 1975; Srivastava et al., 1979). These anticlines and synclines are commonly dislocated by numerous longitudinal faults and thrusts (Ram and Venkataraman, 1984). Similarly, the study area is highly deformed due to the folding and faulting, resulting from the tectonic activities around the area. Geologically, the basin area is occupied by the sedimentary rocks like sandstones, shales and siltstones of Tertiary age, belong to Middle Bhuban and Upper Bhuban Formations of Surma Group (Figure 3, 5a & 5b). Structurally, these rocks are folded into number of anticlines and synclines with doubly plunging. The anticlines are tight and asymmetric in nature while the synclines are narrow valleys. The eastern limbs of the anticlines are steeper than the western limbs with approximately north-south trending. The prominent folds have been noted in the study area are Thingsulthliah Anticline, Keifang Anticline and Tuirini Syncline. There are several transverse faults present in the area having general trends of NW-SE and NE-SW prominent (Figure 3).

Distribution of Slopes in the Area

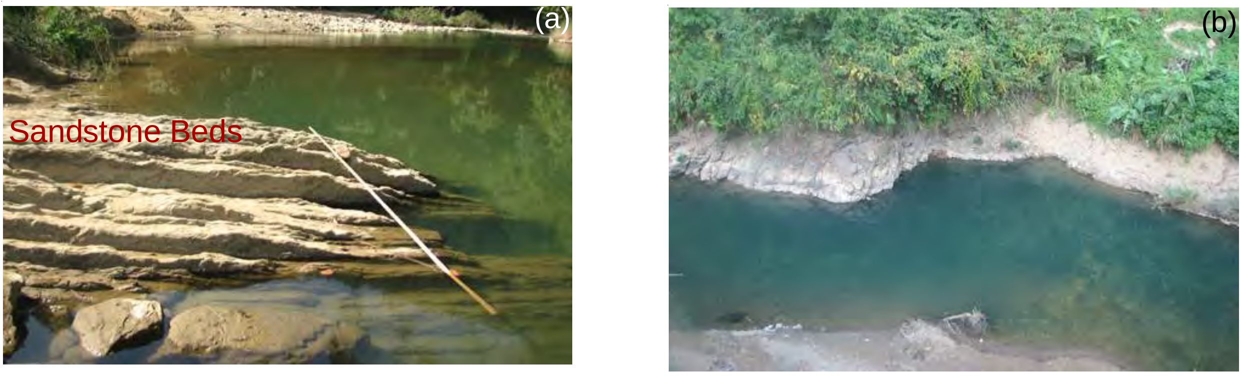
The degree of slope controls the amount of run-off, velocity of river, erosion, transportation and deposition, and plays an important role in the development of the drainage network (Bibby and Mackney, 1969). Slope of the study area is divided into five classes and varies from gentle to very steep sloping (Figure 4). Right side of the river basin shows more irregular distribution of slope than the left side, which are discussed below.

1. Gentle slope: 0 – 5 % is gentle slope class which is along the lower river valleys occupies very limited area of about 12.75 sq.km of the study area.
2. Moderate slope: 5 – 15 % is moderate slope category covering small part of about 48.25 sq.km of the basin area. This slope type is associated with the upper valley slopes of the study area.
3. Moderately steep slope: This category of slope in the ranges of 15 – 25 % comprises about 96.53 sq.km and is evenly distributed throughout the study area.
4. Steep slope: Major portion of the basin area of about 134.47 sq.km falls under steep slope category varies from 25 – 35 %. Almost all the tributary basins of the study area are characterized by steep slopes.
5. Very steep slope: About 128.07 sq.km of the study area comes under the very steep slope class i.e. above 35 % and mostly found in the northeastern and southeastern parts of the basin. This slope type is associated with mountainous uplands of the basin.

Database and Methodology

The Tuirini river basin falls in the parts of Survey of India (SoI) topographic maps index number 84A/13, 14 and 15 at a scale of 1: 50,000. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global DEM 30 m data (ASTGTM2_N23E092) and IRS (Indian Remote Sensing satellite)-1D, LISS-III of geocoded False Colour Composites (FCC) data, generated from the bands (2, 3, 4) on 1: 50,000 scale were used as fundamental data source for

Figure 5: Field Photograph Showing (a) Eroded Sandstone Beds Along the Tuirini River Near Tuirinikai Village; (b) Sandy-Shale Outcrop Exposed in the River Bank with Steep Valley Side Slopes in the Upper Reaches



the terrain features analysis. The DEM has been obtained with a pixel size of 30 m resolution having projection geographic and datum WGS84 was re-projected into polyconic projection system for further use. The river networks were digitized from SoI topographical maps as well as updated from satellite imagery using ArcGIS v. 10.2. Based on the ASTER digital elevation data, river profiles have been generated in GIS platform. The lineaments were identified from satellite imagery through visual interpretation. These lineaments normally show spatial variation in tone, colour, texture, soil tone, ridge lines, drainage course and vegetation alignment in satellite data. Further, lineament extraction, digitization and analysis were carried out with the aid of ArcGIS v. 10.2 and ERDAS Imagine v. 9.2 image processing software. The orientations of the lineaments were analysed with the aid of rose diagram. The slope map (percentage function), TIN model and hill shade map have been generated from DEM derived from ASTER data using ArcGIS software. The structural map of the study area has been prepared from the previously published map (Ganju, 1975) and based on field observations. For better accuracy of the thematic maps, ground truth verification has been done in accessible areas.

Figure 6: 3D View of the Tuirini River Basin (Drainage map Superimposed Over DEM)

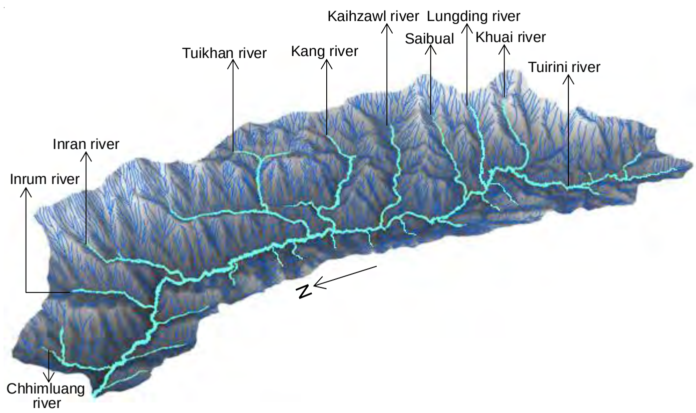


Table 1: Characteristics of Tuirini River and its Major Tributaries

Name of Tributaries/Rivers	Drainage Area (sq. km)	Source Height (m)	Confluence Height (m)	Length of Tributaries (km)	Gradient in Ratio
Khuai	21.76	1710	340	6.92	1: 5
Lungding	12.68	1340	310	6.38	1: 6
Saibual	22.58	1020	298	7.36	1: 10
Kaihzawl	34.83	1180	250	13.9	1: 14
Kang	35.57	780	238	11.44	1: 21
Tuikhan	65.65	1280	235	13.89	1: 13
Inran	24.82	1460	180	9.59	1: 7
Inrum	27.73	1380	160	9.15	1: 8
Chhimluang	20.68	870	100	7.24	1: 9
Tuirini	420.07	780	78	56.75	1: 81

Results and Discussion

River Profile Analysis

Rivers play an important role in the evolution of a landscape and its profile provides information of landform characteristics, erosion rates, tectonic changes and different stages of valley evolution. River profiles are the representation of the cross-section of the nature of surface configuration of a region and are divided into two types viz. (1) Longitudinal profile and (2) Transverse or cross-valley profile.

Longitudinal Profiles

The longitudinal profile of a stream is a property of stream geometry that can provide clues to underlying materials as well as insights into geologic processes and geomorphic history of an area (Hack, 1960). Generally, longitudinal profile expresses the channel gradient or course of a river from its source to mouth, which can represents graphically by plotting of distance in the abscissa and the elevation as ordinate. River response to active tectonics is generally reflected in its longitudinal profile and longitudinal profiles of rivers have been used to identify the river morphological response to climate, lithology, structure and tectonics (Hack, 1957; Rhea, 1993). Further, when a river passes through the tectonically active zones, its longitudinal profile shows effects of deformation. Therefore, longitudinal profile and its corresponding concavity and steepness are used to characterise the tectonics and base level change (Mackin, 1948; Gomez et al., 1996; Holbrook and Schumm, 1999; Marple and Talwani, 2000; Lave and Avouac, 2000 and 2001). In addition, a smooth and graded river longitudinal profile though has been expected to occur in rapidly eroding areas with large erosional power of streams (Flint, 1974; Snow and Slingerland, 1987).

The longitudinal profile of the Tuirini river (Figure 7) shows sudden drop from its source elevation of 780 m to 480 m within a short distance of 2.8 km. The profile also shows five prominent breaks in slope, two of which at the levels of 480 m and 400 m with steeply sloping up to 3.0 km in the upper reaches, and another

Figure 7: Longitudinal Profile of the Tuirini River

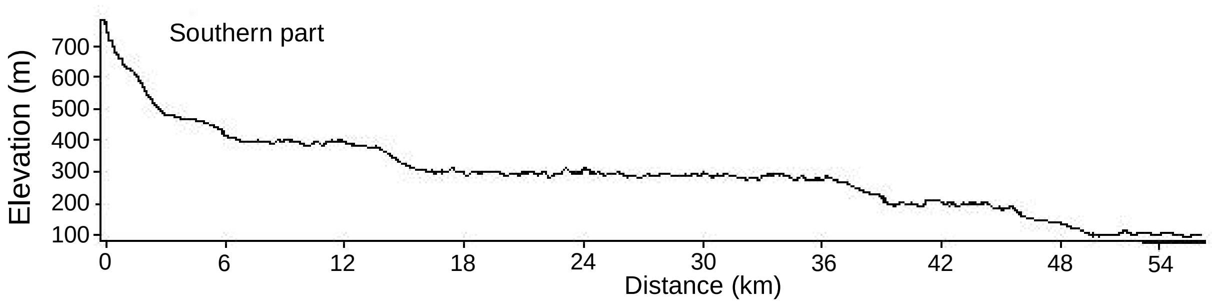


Figure 7A: Longitudinal Profile of the Khuai River

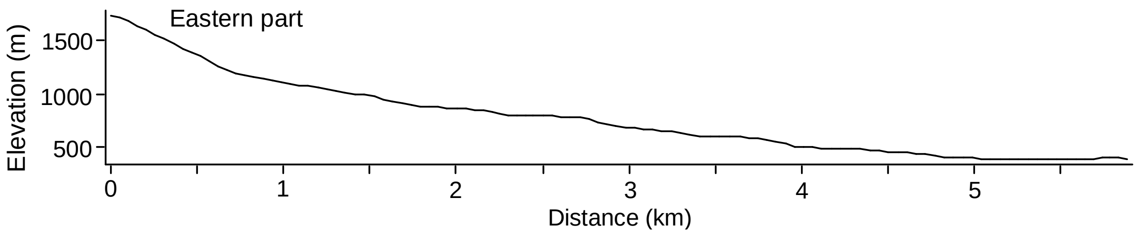


Figure 7B: Longitudinal Profile of the Lungding River

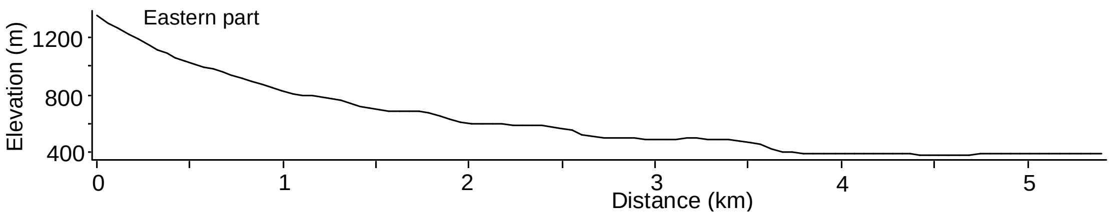


Figure 7C: Longitudinal Profile of the Saibual River

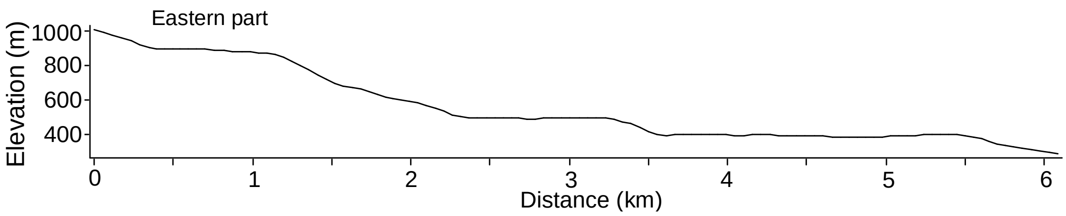
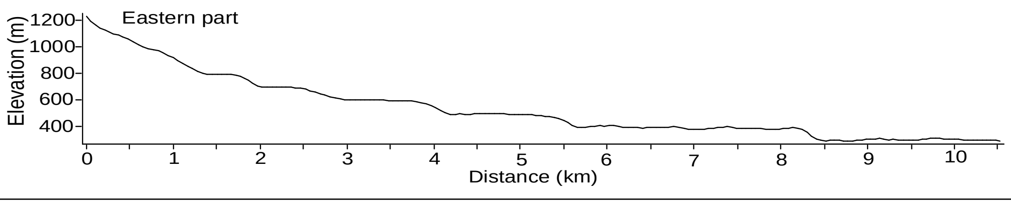


Figure 7D: Longitudinal Profile of the Kaihzawl River



three at 300 m, 190 m and 100 m in the middle and lower reaches, indicates base level changes along with different stages of development. Several small knickpoints are developed along the profile either due to the presence of various resistance rocks or due to tectonic activities along the path of the river.

The Khuai (Figure 7A), as a short hilly river and its longitudinal profile shows steep fall in initial travel from the height of 1710 m up to 1200 m within a short distance of 0.70 km and joins with the Tuirini river after traveling a distance of 5.8 km. On the other hand, Lungding river (Figure 7B) also shows steep fall in initial travel from its source height of 1340 m up to 800 m within a short distance of 1.0 km and joins with the main river after traveling a distance of 5.5 km. Four breaks in slope are noted in the Saibul river (Figure 7C), one at 890 m, two of which at the levels of 510 m and 380 m and another at 298 m, showing four phases of cycle in its journey. In the upper reaches the profile also shows concave face indicates the scarp. The longitudinal profile of Kaihzawl river (Figure 7D) is characterised by numerous knickpoints and these knickpoints have drops of about 790 m, 730 m, 600 m, 470 m, 400 m, 260 m and afterwards nearly level in the lower reaches.

The Kang river (Figure 7E) shows the well development of slope breaks in their course representing steep slopes of up to 0.8 km, moderately steep up to 4.7 km and thereafter gentle slope indicates three different base levels. The Tuikhan river (Figure 7F) gradually grades down its height within 2.5 km and has small knickpoints with 580 m, 500 m, 420 m elevation drops and travels around 11 km before meeting the Tuirini river. The longitudinal profile of Inran (Figure 7G) shows gradual decrease in gradient up to 5.3 km and again suddenly grades down its height at 290 m and 200 m within a distance of 2.1 km. Similarly, river Inrum (Figure 7H) shows gradual decrease in gradient up to 3.5 km with steep slopes and afterwards flowing almost 3.5 km in the middle gradient and again suddenly drops its height at 200 m in the lower reaches. River Chhimluang (Figure 7I) shows gradually drop from its source height of 870 m and maintain its flows in the lower reaches showing two phases in its journey.

From the Figures 7 to 7I, it is also observed that most of the longitudinal profiles represent steeper gradients in the upper reaches with concave face near the scarp and changes in gradients represented by breaks in slope. In addition, prominent breaks in slope occur along the course of the rivers due to the structural disturbances and lithological variations. It is further reveal that the several small knickpoints are observed along the profiles due to uplift of river beds and ongoing tectonic processes. The overall longitudinal profiles of river show graded curves indicating the mature stage of geomorphic development with a major structural control over the area. In fact, all the major fault and lineament reflect as slope difference along the river profiles due to the influence of tectonic activities in the basin area.

Cross-Valley Profiles

Cross-valley profile or transverse profile represents the surface configuration across the river beds. The cross-valley profiles indicate the different stages in the cycle of erosion, slope differences, terrace formation, characteristics of the valley forms and also reflect tilting of river floor in tectonically active region. The Tuirini river has been divided into three reaches (upper, middle and lower reaches) and cross-valley profiles have

Figure 7E: Longitudinal Profile of the Kang River

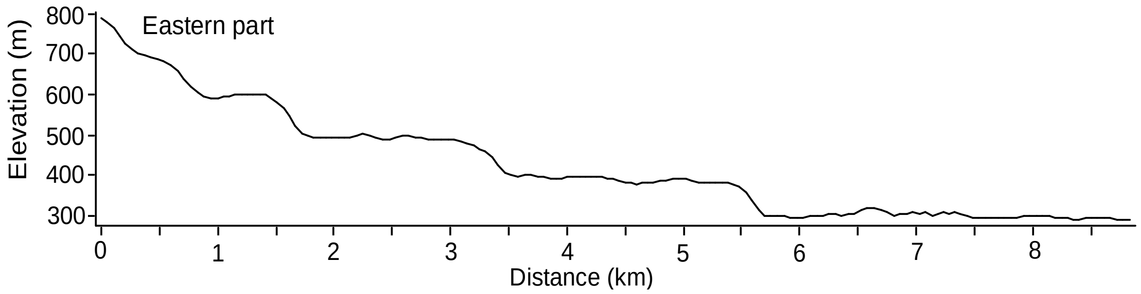


Figure 7F: Longitudinal Profile of the Tuikhan River

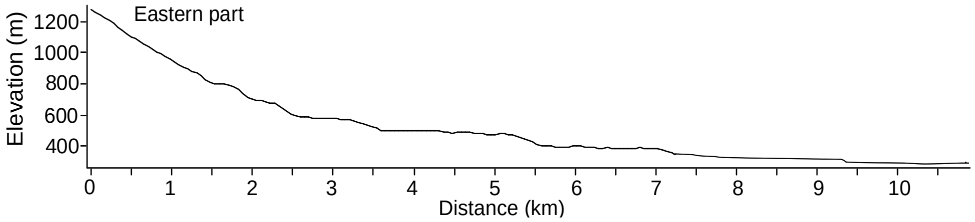


Figure 7G: Longitudinal Profile of the Inran River

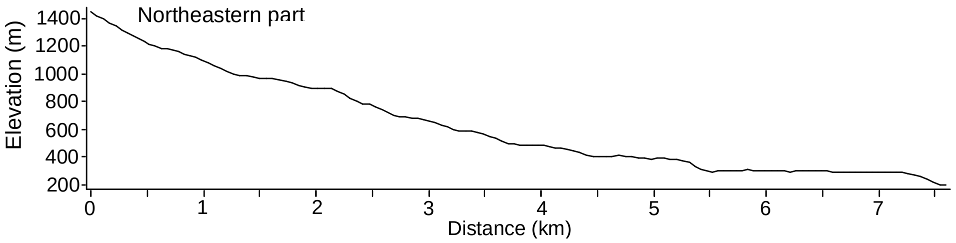


Figure 7H: Longitudinal Profile of the Inrum River

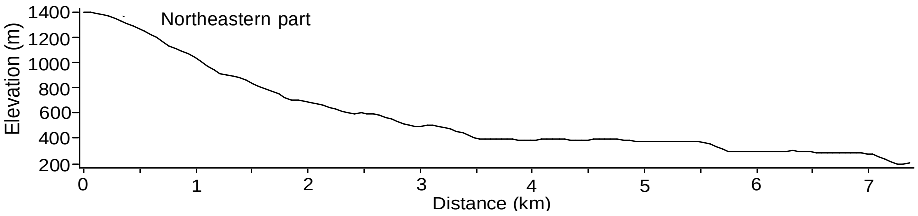


Figure 7I: Longitudinal Profile of the Chhimluang River

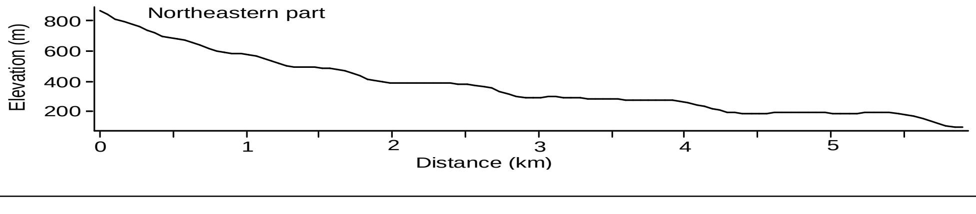
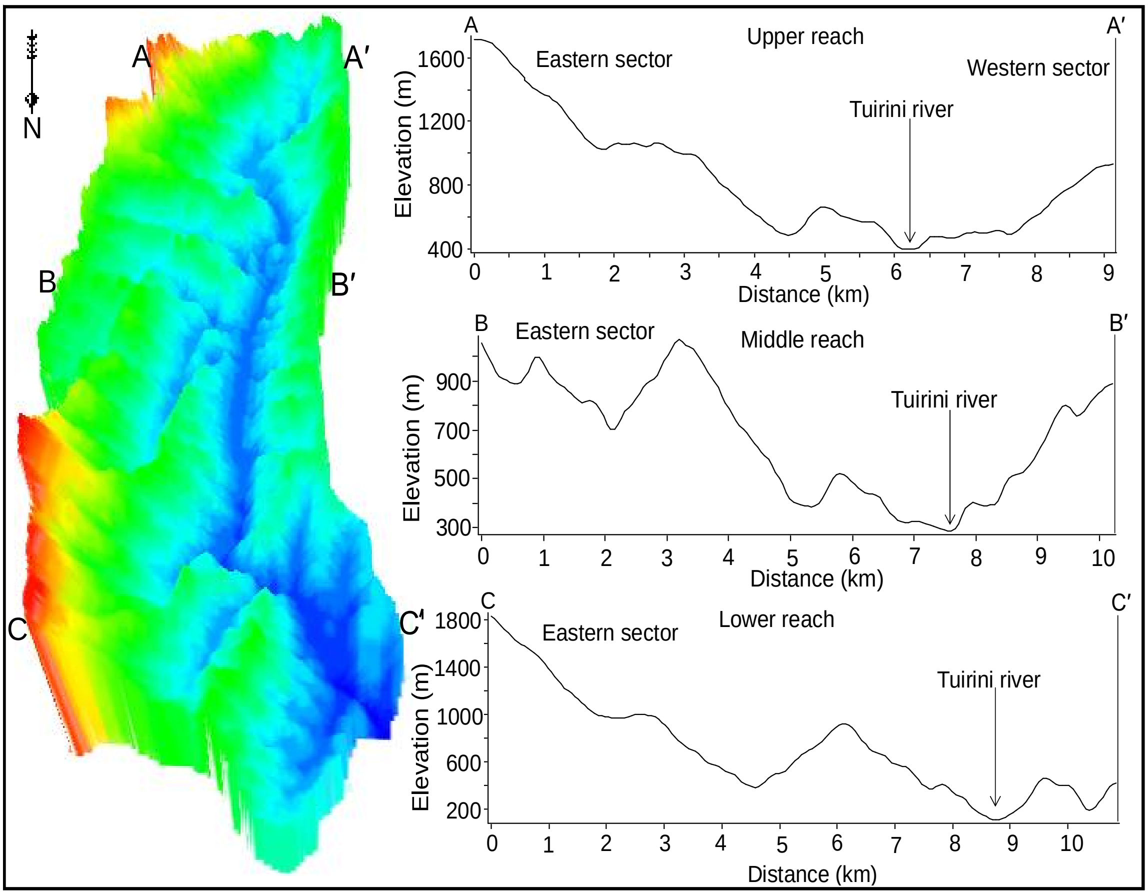


Figure 8: Cross-valley Profiles of the Tuirini River

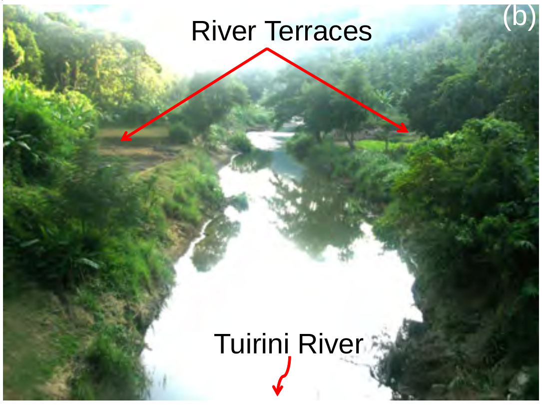


been drawn from the right bank (east) to the left bank (west) at three different locations (AA', BB' and CC') across the river and viewed from the north (Figure 8). It is observed from the profiles (Figure 8) that the eastern sectors of the basin have higher elevation in comparison to the western sectors. The upper and the middle valley slopes are moderate to moderately steep whereas lower valleys are relatively gentle and the general trend of slope is towards south to north direction. Further, the cross-valley profiles of the Tuirini river shows a mature stage of river development, where down cutting becomes almost imperceptibly slow and valley widening becomes dominant. These changes in characteristic river activity mark the transition from youth to maturity (Thornbury, 1954). The cross-valley profiles of the Turini river also indicate the tilting of the river floor is towards the western sector of the river. Moreover, the terrain as a whole is tilted towards the west with asymmetric nature and attains mature stage of landscape development in the basin area (Ahmed and Rao, 2016a and b).

Lineament Analysis

In the study area, structural hills and valleys are the prominent structural landforms following the definite trend lines. Lineaments have been identified from

Figure 9: Field Photograph Showing (a) Small Knickinpots in the Upper Reaches of the Tuirini River Near Buhkangkawn Village; (b) The Fault Controlled Straight Course of the Tuirini River in the Middle Reaches



the satellite data on the basis of tonal differences, textural contrasts and structural alignments, which are of varying dimensions with different orientations in this area. The lineaments developed in the study area may be the results of faulting and fracturing of rocks, and most of the tributaries are flowing along the lineaments or fractures reflect the structural controlled on the evolution of the drainage network (Ahmed and Rao, 2016c). The lineaments extracted in the study area are shown in Figure 10.

Figure 10: Lineament Map

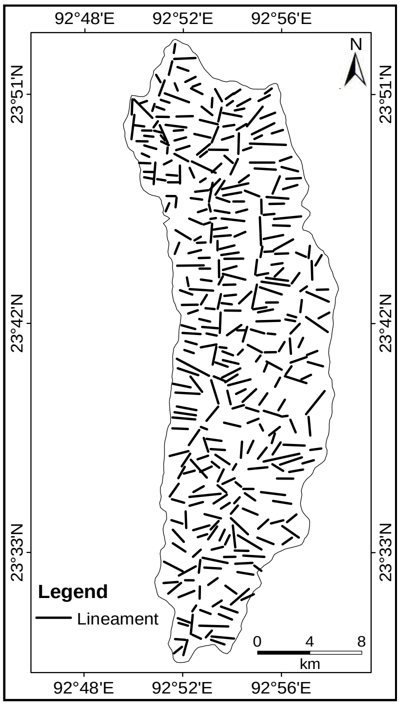
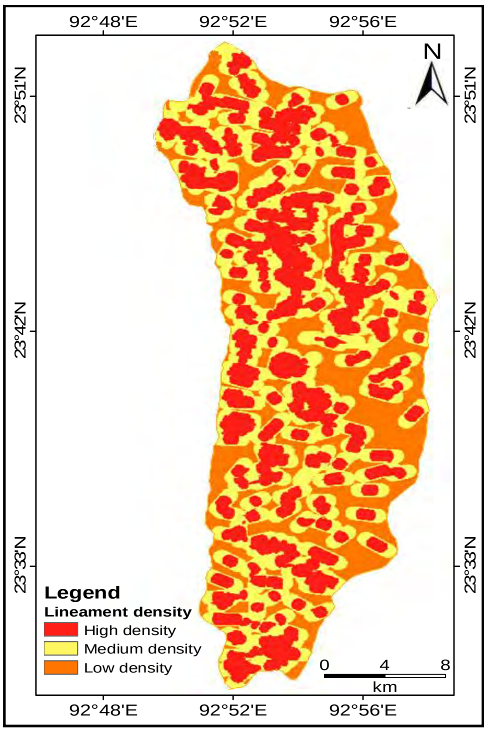


Figure 11: Lineament Density Map



The estimated number of lineaments of the study area is about 260 (Table 2). Out of 260, 109 numbers (41.92 %) of lineaments are in N60^{0}W–W direction, 63 numbers (24.23 %) of lineaments are in N60^{0}E–E direction, 37 numbers (14.23 %) of lineaments are in N30^0–60^{0}E direction, 31 numbers (11.93 %) of lineaments are in N–N30^{0}E direction, 12 numbers (4.61 %) of lineaments are in N30^0–60^{0}W direction and 8 numbers (3.08 %) of lineaments are in N–N30^{0}W direction. The length of the each lineament is also computed (Table 2) and the total length of lineaments are 243.80 km in the study area. Based on the distribution of lineaments, a lineament density map has been prepared as shown in Figure 11 and is categorized into three zones viz. high, medium and low density. The high lineament density is observed in the northern part of the basin.

The distributions of the lineaments in the basin are shown in the form of a rose diagram (Figure 13), and the interpretation of the rose (azimuth-frequency) diagram shows the trends of the lineaments are NEN-SWS, NE-SW, ENE-WSW, WNW-ESE, N-S and E-W directions, mark the

Table 2: Lineament Data of the Tuirini River Basin

Azimuth Range (In degrees)	Number of Lineaments	Frequency (%)	Lineaments Length (km)	Length (%)
0 - 10	11	4.23	10.58	4.33
10 - 20	9	3.46	7.90	3.24
20 - 30	11	4.23	10.81	4.43
30 - 40	10	3.84	8.67	3.55
40 - 50	13	5.00	11.92	4.88
50 - 60	14	5.37	12.45	5.10
60 - 70	12	4.61	10.91	4.47
70 - 80	29	11.15	27.32	11.20
80 - 90	22	8.46	20.84	8.54
90 - 100	59	22.69	58.18	23.86
100 - 110	35	13.46	34.03	13.95
110 - 120	15	5.67	13.67	5.60
120 - 130	9	3.45	7.62	3.12
130 - 140	1	0.38	0.82	0.34
140 - 150	2	0.76	1.58	0.65
150 - 160	1	0.38	0.78	0.31
160 - 170	3	1.5	2.05	0.84
170 - 180	4	1.54	3.67	1.50
Total	260.00	100.00	243.80	100.00

Figure 12: Lineament Map Superimposed Over Drainage Map of the Tuirini Basin

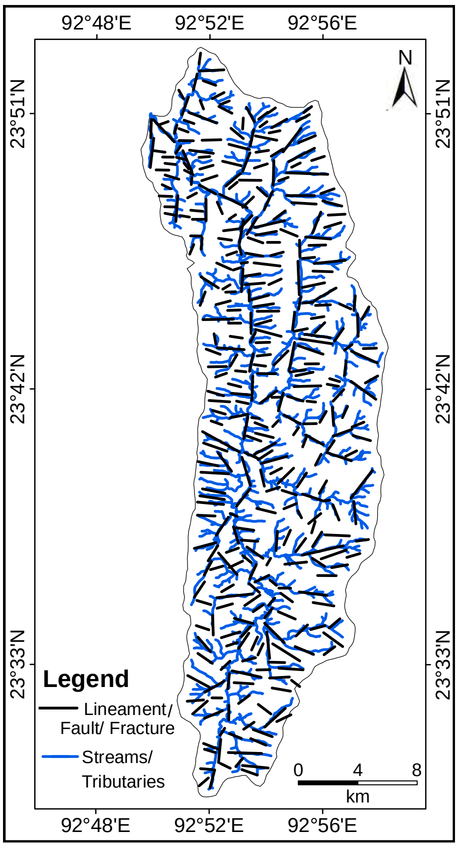
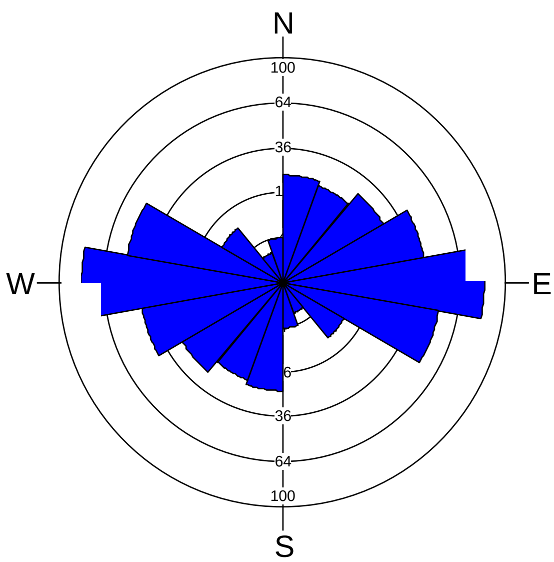


Figure 13: Lineament Orientation Diagram



drainage network of the Tuirini basin. NW-SE and NWN-SES trending lineaments are few in numbers (Table 2). From the map (Figure 12), it is observed that the majority of higher order streams flow along lineaments and the direction of the flow are strongly controlled by the underlying geological structures. Apart from this there are some lower order streams which follow the minor lineaments and fractures in the study area. Further, the Tuirini river follows N-S trending lineaments with sharp bend in its course controlled by the NW-SE trending lineaments and existing faults. Moreover, it is seen from figures 6 &12 that the upper and lower courses of the Tuirini river shows a sudden change in its flow directions and take sharp bends in the downstream direction, this can be due to the influence of active tectonism. The overall analysis reveal that the Tuirini river and its tributaries are structurally controlled by the faults and lineaments to a considerable extent, as a result, most of the drainage networks follow the existing structural valleys. Therefore, good groundwater potential zones can be attributed along the valleys in the area.

The azimuth data are tabulated at 10^0 class interval and for each frequency is calculated. The lineament azimuth density is high in 70^0 – 80^0, 80^0 – 90^0, 90^0 – 100^0 and 100^0 – 110^0 classes. In the study area, the prominent trends of lineaments are WNW-ESE, ENE–WSW and NE-SW directions.

Figure 14: Hill Shade Map

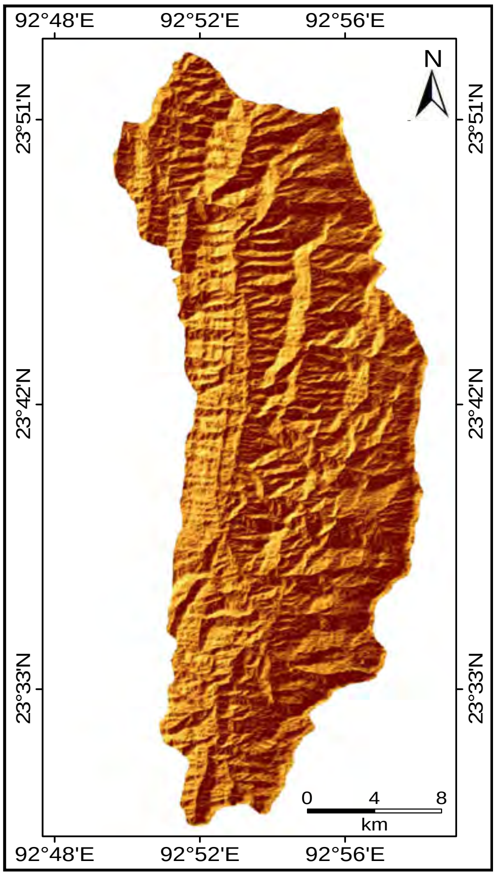
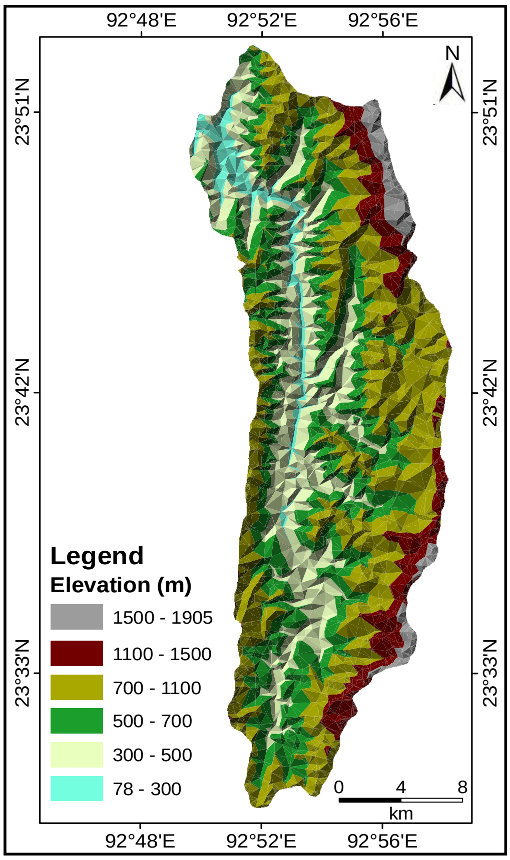


Figure 15: TIN Model of the Study Area



Hill Shade and TIN Model of the Tuirini river basin

Hill shade shows how the terrain looks with the interaction between sunlight and surface features. A mountain slope directly facing towards sunlight will be very bright and a slope opposite to the light will be dark. From the hill shade map (Figure 14), it can be seen that west facing slopes of the basin have higher brightness as compare to east facing slopes and the hills are trending approximately north-south with the topographic slopes towards north.

The topography of a land surface is represented by digital elevation data and the Delaunay triangulation is commonly used to generate Triangulated Irregular Network (TIN) models for representation of the surface morphology. In vector based systems the elevation data is represented in the form of TIN that uses a sheet of continuous connected triangular facets based on a Delaunay triangulation of irregularly spaced nodes which approximates the land surface with a series of non-overlapping triangles. The TIN model of the study area is divided into six zones range from 78 m to 1905 m (Figure 15) and represents highest elevation zones are in the northeastern and southeastern sectors of the basin. It is also observed that the eastern part of the basin is highly elevated and undulating as compare to western part.

Conclusion

The study shows that, most of the tributaries are originate from the high altitude (>800 m) and show more or less straight courses due to the structural effect. The terrain attained mature stage of landscape development with balance condition between erosion and deposition as inferences from the graded nature of the curves as seen in the longitudinal profiles. Further, several small knickpoints are found along the profiles reflect the lithological variations and ongoing tectonic processes. The northern part of the basin shows high lineament density which might be due to highly faulting and fracturing of rocks. As a whole, the terrain is tectonically active as supported by the existence of number of lineaments, fractures and faults. Therefore, from the study it can be concluded that the remotely sensed data and DEM data coupled with GIS techniques recognised to be a competent tool in terrain analysis, which would be helpful in various developmental activities and conservation of natural resources of the basin area.

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