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Morphotectonic Study of the Ijai Watershed, in Parts of Kangpokpi, Tamenglong and Noney Districts Manipur, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study aims to describe and bring out the tectonic nature of Ijai watershed in parts of Kangpokpi, Tamenglong and Noney districts of Manipur. Ijai watershed has an area of 184.0 Km^{2}which is also tectonically active as depicted by the analysed values of different geomorphic indices like SLK index, Valley Floor Width to Valley Height ratio (Vf),Transverse Topographic Symmetry (T), Drainage Basin Asymmetry (AF), Basin Elongation Ratio (Eb), hypsometric curve and its integral. The data for the analysis of the geomorphic indices are extracted from the DEM and SENTINEL-2 satellite data and SOI-toposheets. Along the stresses of the rivers there are numbers of regions having SLK index greater than 2 depicting presence of knick points.Vf values

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ranges from 0.053 to 0.144 showing V-shaped valleys with streams that are actively incising and are commonly associated with uplift. Average value of T of Ijaiis found to be 0.4182, which reflects asymmetric in nature. The results of AF is 36.47 %, signifies the upliftment of the eastern side of the basin resulting the shifting of the river to western side in general. The result of Basin Elongation ratio (Eb) is 0.59 which signifies elongated basin undergoing tectonically activities. The result of hypsometric curve and hypsometric integral (Hi) 49 % reveals that basin is passing through early mature stage under the cycle of erosion.

Keywords: Drainage basin; morphotectonics; active tectonics; morphometry; hypsometry.

1. INTRODUCTION

To study the landforms and relative degree of tectonic activity of the study area, various geomorphic indices are precisely calculated. “Quantification of different geomorphic indices after obtaining necessary information from satellite date, topographic maps and aerial photographs gives useful information about tectonic history of an area” [1]. “A constructive multidisciplinary approach with the help of geomorphological, structural and neotectonism gives useful information in evaluation of active tectonics of an area” [2]. “The study of longitudinal profile and analysis of channel gradient of different reaches of rivers give valuable information regarding lithological variation, climatic and tectonic history of the area” [3,4]. Since, Morphotectonic features are very useful and being important indicator in exploring the relative tectonic activity [5-7], six geomorphic indices has been analysed namely hypsometric integral [8] along with inverted S-shaped hypsometric curve, Stream length gradient index [3], drainage basin asymmetry factor [9,10], basin elongation ratio [11], valley floor width to valley height ratio [5], topographic asymmetric factor (T). All the computed values are then corelated to understand the relative tectonic activities and tectonic history of the study area.

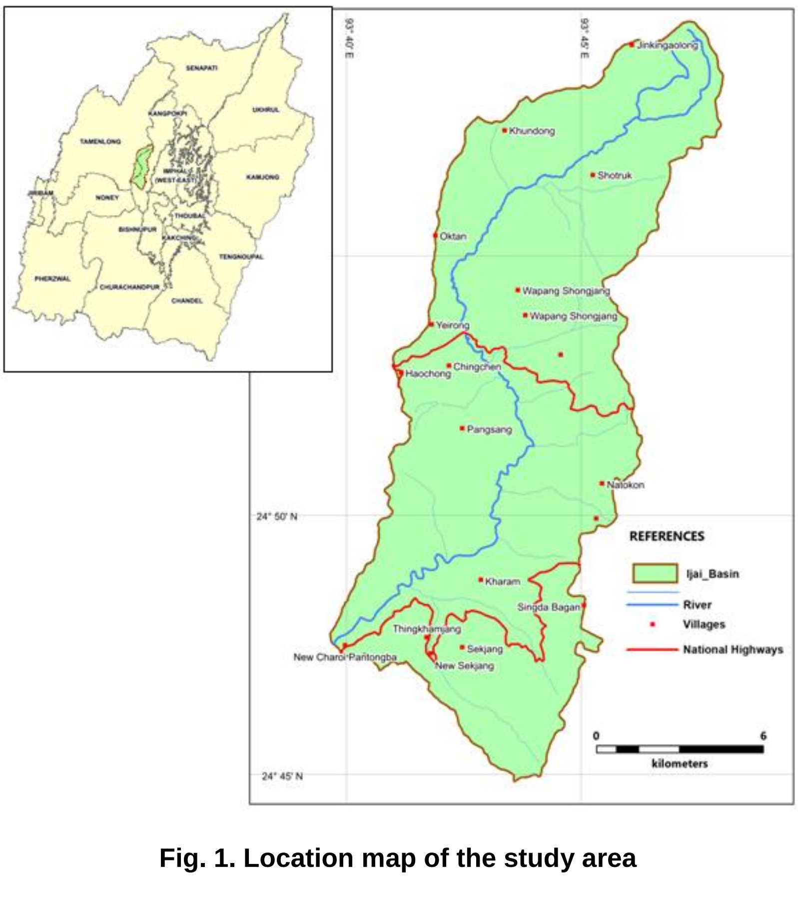


Fig. 1. Location map of the study area

2. LOCATION OF STUDY AREA AND ITS DRAINAGE CHARACTERISTICS

Ijai river basin is located between latitudes 24°59'31.22'' and 24°44'52.88" N and longitudes of 93°39'38.31'' and 93°48'02.55" E and on the western side of Imphal valley. The study area lies in the Kangpokpi, Tamenglong and parts of Noney districts of Manipur state, India (Fig. 1). It has a total catchment area of 184.0 Km². On the western side of it, there lies, Iring river and on the south Tupul river flows.

The drainage characteristics of the Ijairiver basin is shown in Fig 2. Ijai river originates from Jinkingaolong of Kangchup-Leimakhong protected forest and extended up to Tupul of Noney District, where it confluence with Tupul river. It generally flows in the NE to SW up to Tupul with a perennial course of about 37.67 km. The Ijai river basin generally shows Trellis to dendritic drainage patterns.

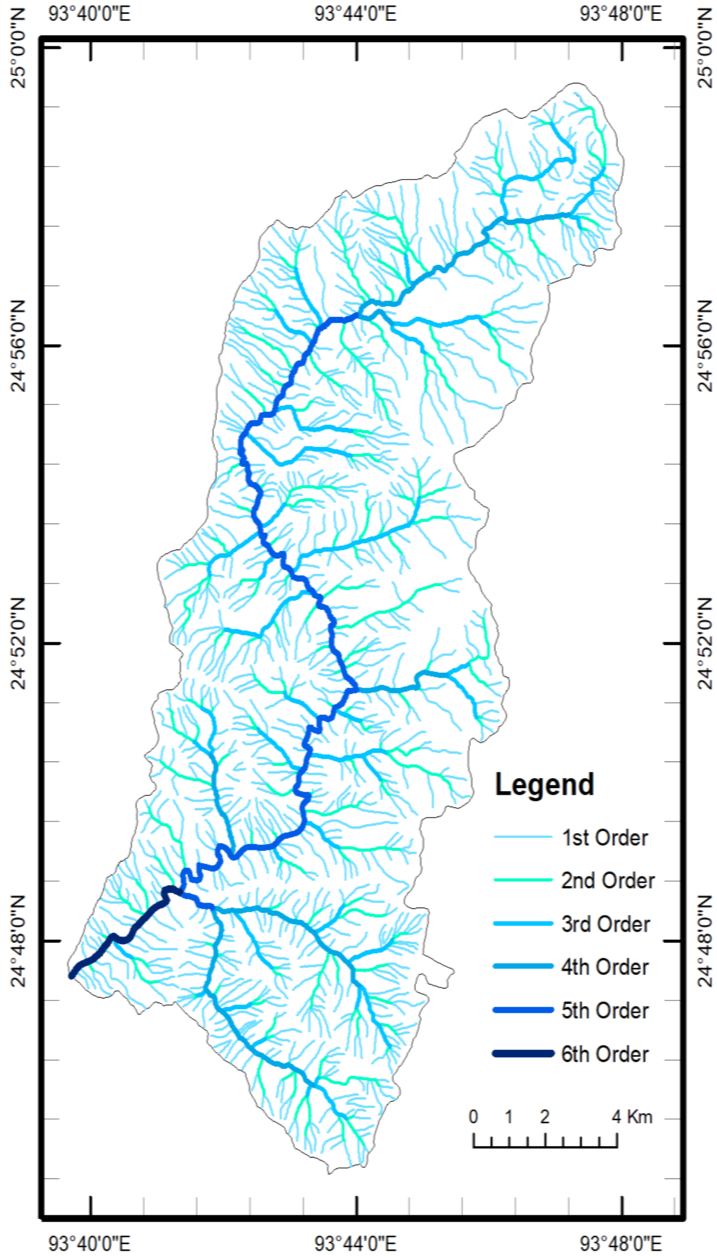


Fig. 2. Drainage characteristics of Ijai River basin

3. REGIONAL GEOLOGY AND TECTONIC SETTING

Geological formations of Manipur are mainly identified as the Tertiary and Cretaceous sediments with minor igneous and metamorphic rocks. However, Ijai watershed is dominated by Palaeocene to Oligocene rocks namely Barail and Disang groups of rock. Evans in 1932 [12] coined the term Barail to describe a huge thick column of arenaceous beds interbedded with shales which overlies the Disang and Jaintia Groups. This Group has been divided into three formations (Laisong Formation, Jenam formation and Renji formation). Laisong Formation, the lowermost of the three is characterized by alteration of shale and fine to medium grained sandstones which give rise to typical turbidite sequence. Just above on it, the sequence is followed by Jenam Formation, characterized by extensive carbonaceous shale with silt and sandstone band occurs.

The upper most of the formation has Renji Formation which is characterized by massive to bedded sandstones. Mallet [13], coined the term Disang, to described a thick column of splintery, dark grey to black shales inter bedded with siltstone and fine grained sandstone. It is observed that the study area is dominated by Barail group of rocks (Eocene to Oligocene) over Disang group of rocks (Palaeocene to Eocene). The entire Ijai fault serves as the faulted contact of Barail occupying Makhombot with the Disang in the valley. The geological map of the study area is shown in Fig. 3.

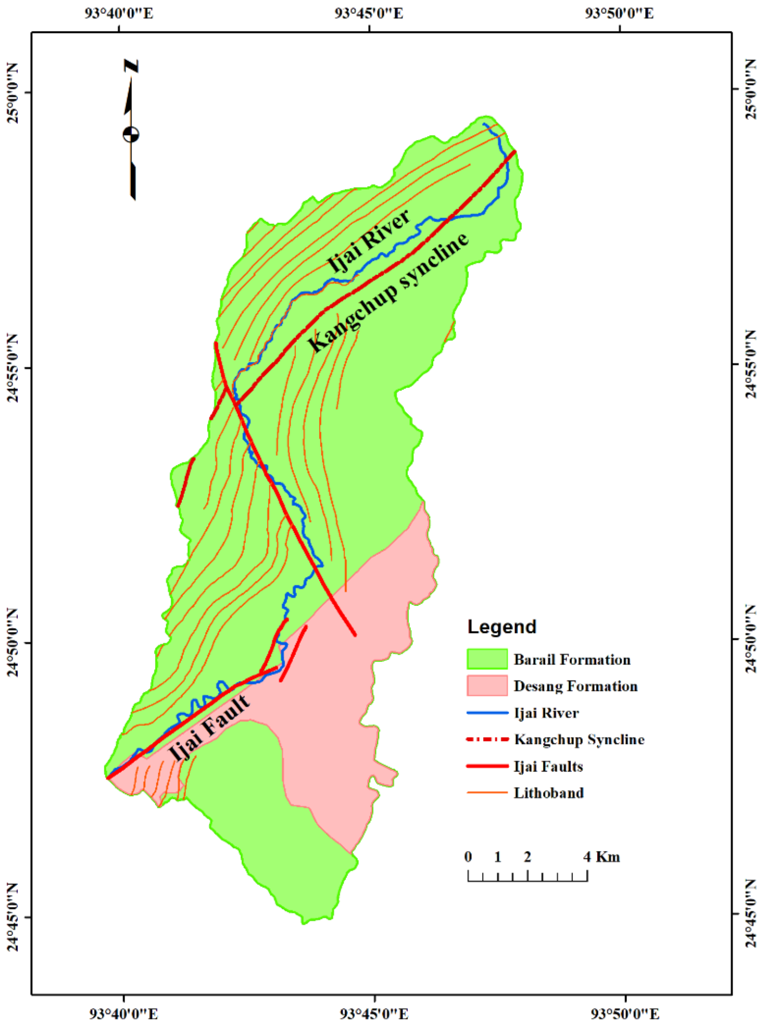


Fig 3. The geological map of the study area (GSI, 1992)

Table 1. Geological succession of Ijai watershed

Litho-Unit and Age	**Description of rocks**	
Alluvium (Quaternary to Holocene)	Brownish to dark grey sand, silt, clay deposits with considerable amount of cobbles and gravels.	
.........……………………………Stratigraphic break……………………………..		
Barail Group (Upper Eocene to Oligocene)	Jenam Formation	Intercalation of thinly bedded fine grained sandstone and shale
	........…………………Gradational contact …………………	
	Laisong Formation	Regressive sequence of shale, sandy shale and fine to medium grained sandstone with sedimentary structures like cross lamination, ripple marks etc.
……........………………………. Gradational contact …………………….....…….……		
Disang Group (Palaeocene to Eocene).	Upper Disang	Dark grey splintery Shales intercalated with Siltstone and fine Sandstone. Shales are arenaceous and laminated. Probably similar to Litan formation.
	Lower Disang	Dark grey Shale interbedded with mudstone and Sandstone. Gritty sandstone, Conglomerate, calcareous rocks. Probably Ukhrul Formation.

The structural and tectonic setting of the study area is mainly transitional between the NE-SW trending pattern of Naga-Patkoi Hills and N-S trend of Mizoram and Chin Hills. It is bounded by Churchanpur Mao Thrust in the East, Langka Fault in the west and by Dalang fault in South-west. The general lithological and tectonic trend of the rock formation of the study area is NNE-SSW, frequently varies between N-S and NE-SW and sometimes NNW-SSE. Dip of the lithounits varies between moderate to steep angle towards East or West.Synclinal axis along the Marangching is clearly observed.

4. MATERIALS AND METHODS

Survey of India toposheets (scale of 1;50,000) bearing nos. 83H9 and 83H13 were used to define the study area and for planning the works which is to be executed. For the calculation of geomorphic indices like stream length gradient index (SL index), valley floor width to valley height ratio (Vf), Drainage basin asymmetry factor (AF), Traverse topography asymmetry (T), Basin elongation ratio (Eb), Hypsometric curve and hypsometric integral, SENTINEL-2 satellite data and DEM together with 'software' Global Mapper version (20.1) were used, as these helps in the identification of tectonically active regions and specific sites in the study area [1].

5. RESULTS AND DISCUSSION

5.1 Stream Gradient Index (SL)

The stream length gradient index provides valuable information regarding the diastrophic forces that shaped the area and tectonic history of the area [3]. SL in corresponds to change in relation to slope, lithology or introduced load. As such, this provides a platform for evaluating stream response to uplift and displacement associated with active tectonics [3,6,7,14-17].

"River generally develops smooth concave longitudinal profiles. However, due to lithology variations or due to tectonic activity their gradient fluctuates from an ideal smooth shape. River that are tectonically disturbed are predicted to approach a convex type of gradient profile at sudden reaches" [18]. "Anomalously high SL values in the rocks of low to uniform resistance are a possible indicator of active tectonics" [1]. Therefore, changes in river profiles may be interpreted as response to ongoing tectonism. The stream gradient index (SL) for a particular reach is defined (Fig. 4a; [3]) as follows:

$$SL = \Delta H / \Delta L * L \quad (1)$$

Where SL is the stream length gradient index, ΔH / $\Delta L$is the channel slope or gradient of the reach, and L is the total channel length from the point of interest where the index is being calculated upstream to the highest point on the channel.

According to Hack [3], the stream channel is also considered to be a connected series of segments of various length each are of logarithmic in nature. The value K which defined the steepness of the logarithmic profile for such a segment are used to normalize the SL. The calculated values of SL/K of Ijai river have a maximum of3.82 indicating significantly steeper channel gradient.

5.2 Valley Floor Width to Valley Height Ratio

Valley floor width to valley height ratio (Vf) is another sensitive indicator that quantifies the valley incision in an uplifted area [5], and is defined as follows:

$$Vf = 2Vfw / [(Eld-Esc) + (Erd-Esc)] \quad (2)$$

Where, Vf is the valley floor width to valley height ratio, Vfw is the valley floor width of the valley for given profile at fixed length, Erd and Eld are the elevation of right and left divided for a given section line, respectively, facing downstream, and Esc is the valley floor elevation (Fig. 5a).

Vf can be classified as V-shaped valleys with the values <1.0, where streams that are actively incising and are commonly associated with uplift; moderately active tectonics with the values between 1.0 and 1.5, and U-shaped valleys with the values >1.5 subjected to major lateral erosion [5].

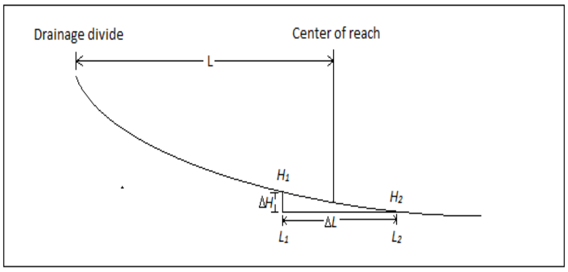


Fig. 4a. Idealized diagram showing how SL index is calculated for a particular reach (after [3])

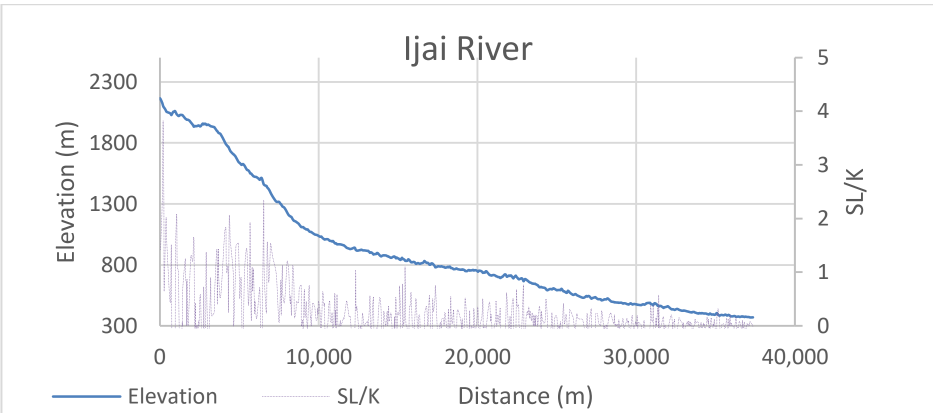


Fig. 4b. Stream profile showing SL/K values along with their respective elevation

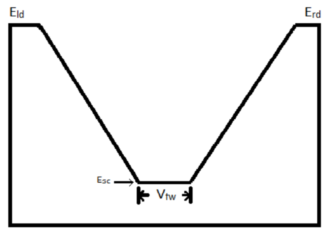


Fig. 5a. Sketch showing parameters used in calculating Valley floor width to valley height ratio

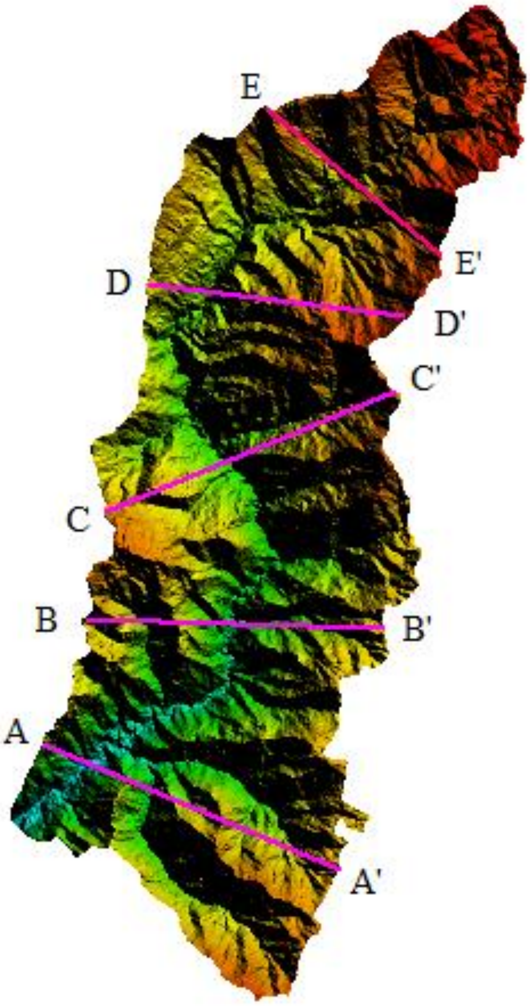
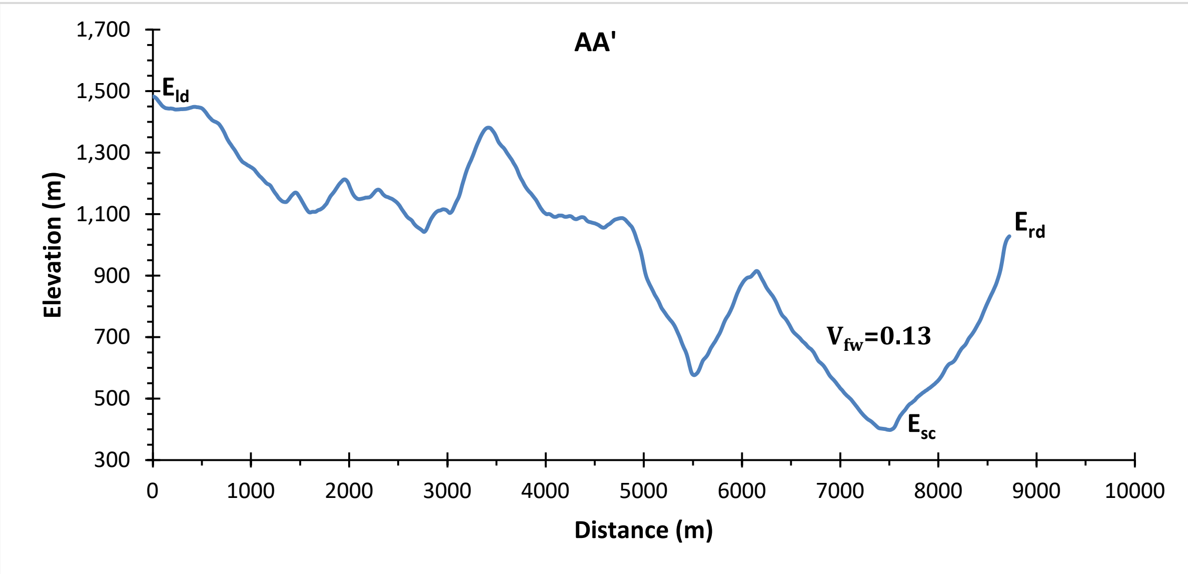
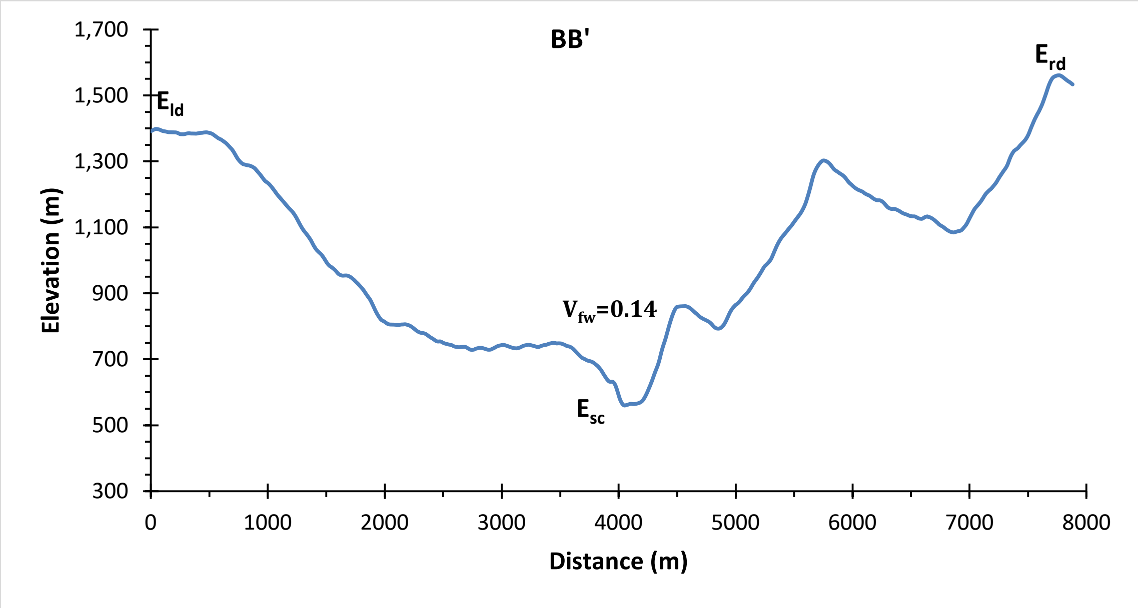
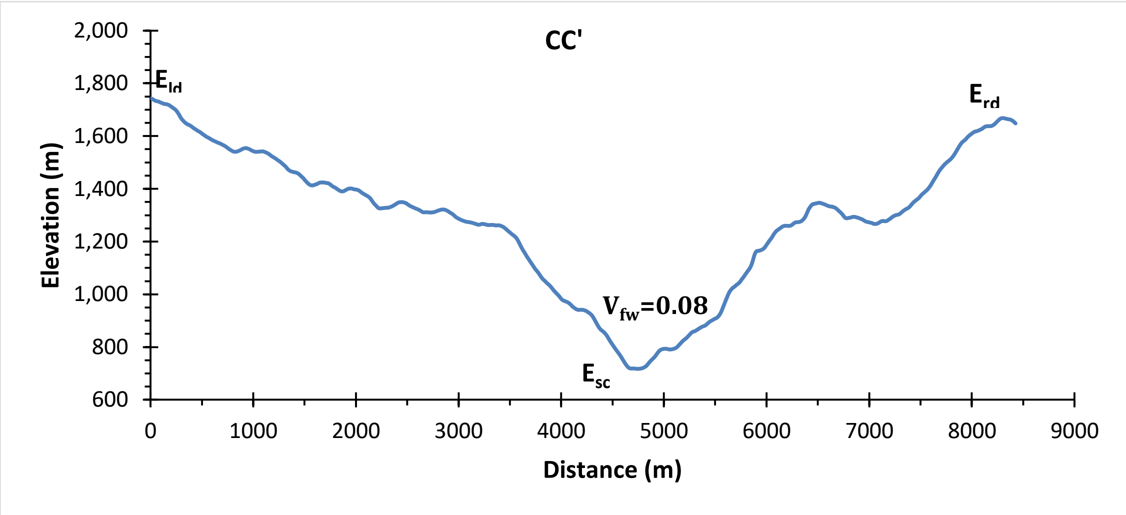
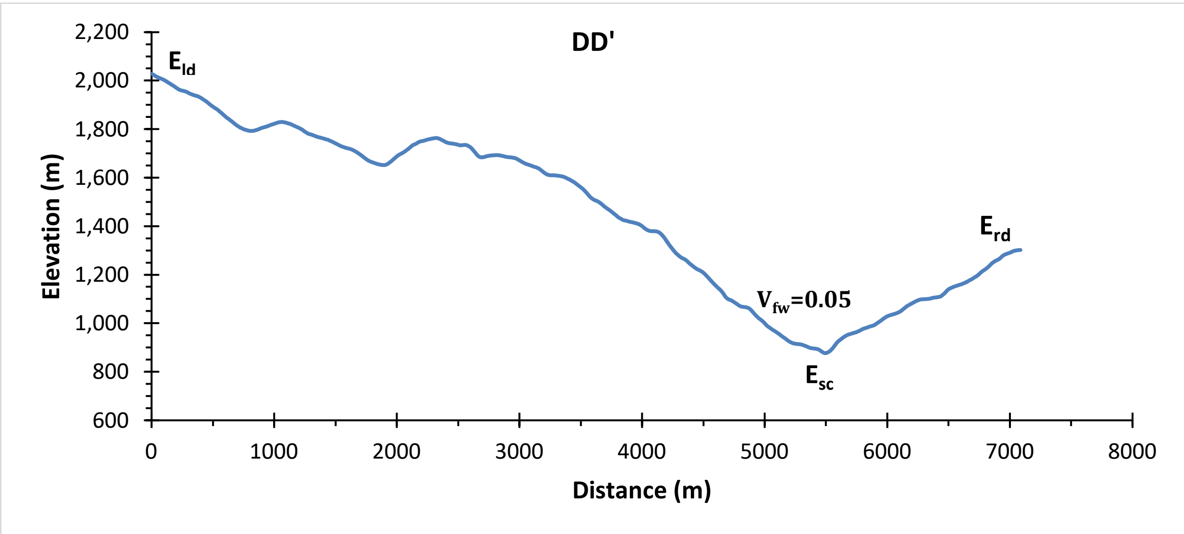


Fig. 5b. Location for VF calculation




BB'
Elevation (m)
Distance (m)
E_ld
E_rd
V_fw=0.14
E_sc


CC'
Elevation (m)
Distance (m)
E_ld
E_rd
V_fw=0.08
E_sc


DD'
Elevation (m)
Distance (m)
E_ld
E_rd
V_fw=0.05
E_sc

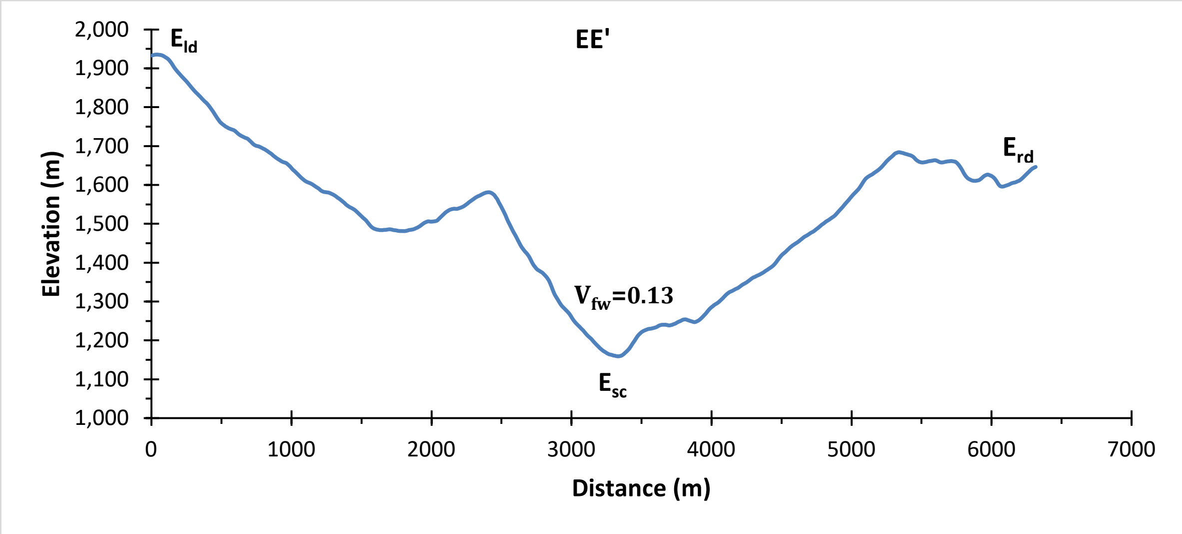


Fig. 5c. Profiles of Valley floor width to Valley height ratio along AA', BB', CC', DD', EE' as shown in Fig 5b

The Vf values for the Ijai river basin has been calculated from five different location namely AA',BB' CC' DD' and EE' (Fig. 5b) and their profiles (Fig. 5c). The calculated values ranges from 0.053 to 0.144 (Table 1). The Vf value of the study area suggest that the valley is V-shaped valley with streams that are actively incising and commonly associated with uplift.

5.3 Hypsometric Curve and Integral

"Hypsometric curve represents the phase of geomorphic maturity of a basin. Hypsometric curve of any catchment gives its relative area below or above a given altitude" [8]. "It acts as a one of the powerful tools to differentiate between tectonically active and inactive areas" [10]. "The shape of the hypsometric curve and the value of hypsometric integral (Hi) provides valuable information not only on the erosional stage of the basin, but also on the tectonic, climate and lithological factors controlling it" [13,19,20]. "High values of Hiindicate that most of the topography is high relative to the mean such as upland surfaces cut by deeply incised streams whereas intermediate and low values reflect exposure of terrain to extended erosion which are associated with more evenly dissected drainage basins. Therefore, high values would be expected for youthful or young stage of landforms and low values for old ones" [8,10] (Demoulin 1998). The formula for calculating hypsometric integral (Pike and Wilson 1971) is as follows;

$$Hi = Hmean – Hmin / Hmax – Hmin \quad (3)$$

Where Hi is the hypsometric integral, Hmean is the mean elevation, and Hmin and Hmax are the lowest and highest elevations of the basin, respectively. Hmin, Hmax, Hmean and all required parameters for estimating the hypsometric integral are calculated using ArcGis's Raster calculator and Zonal statistics tools. Hypsometric curve for the basin is created by plotting relative area (a/A) against relative height (h/H), where "a" is the surface area within the basin above a given line of elevation. "A" is the total area of the basin. "h" is the elevation from where the value is to be calculated, and "H" is the highest elevation of the basin. Fig. 6 is the hypsometric curve of the study area with their respective calculated values of h/H and a/A.

The calculated Hivalue for Ijai river basin is 0.49 and its inverted S-shape hypsometric curve (Fig. 6) indicating that the watershed is passing through early mature stages under the cycle of erosion.

5.4 Drainage Basin Asymmetry (AF)

The asymmetry factor helps in determining tectonic activity based on tilt of river basin [6]. The trunk stream of a drainage basin will migrate in relation to tectonic tilting (Morrish, 2015). This tilting nature of AF perpendicular to the direction of mainstream course helps in determining tectonic activity in a river basin [21,17].

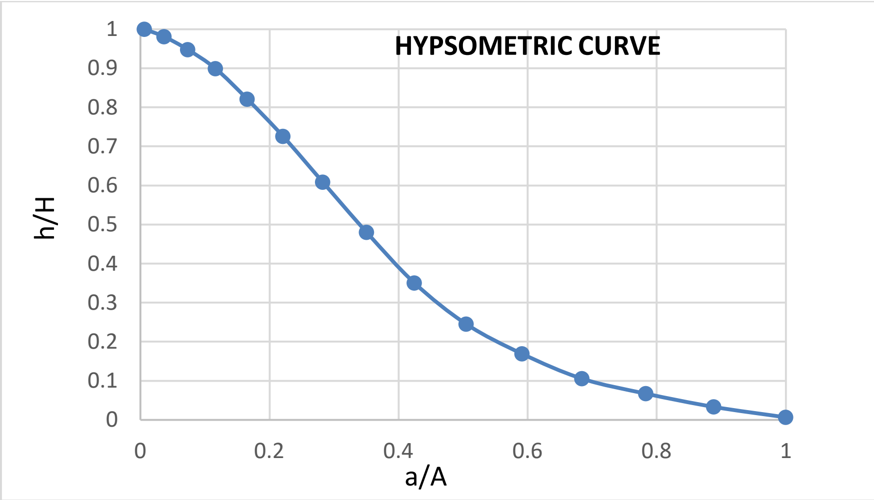


Fig. 6. Hypsometric curve of Ijai watershed

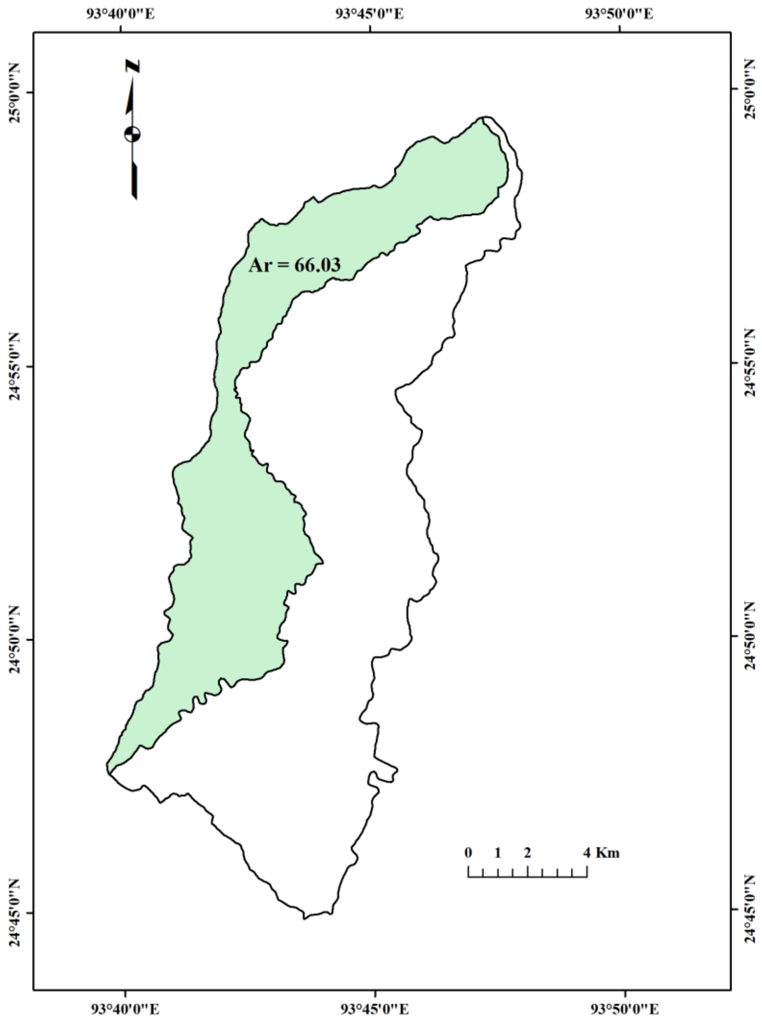


Fig. 7. Total area and area to the right side of trunk channel of the Ijai watershed facing downstream

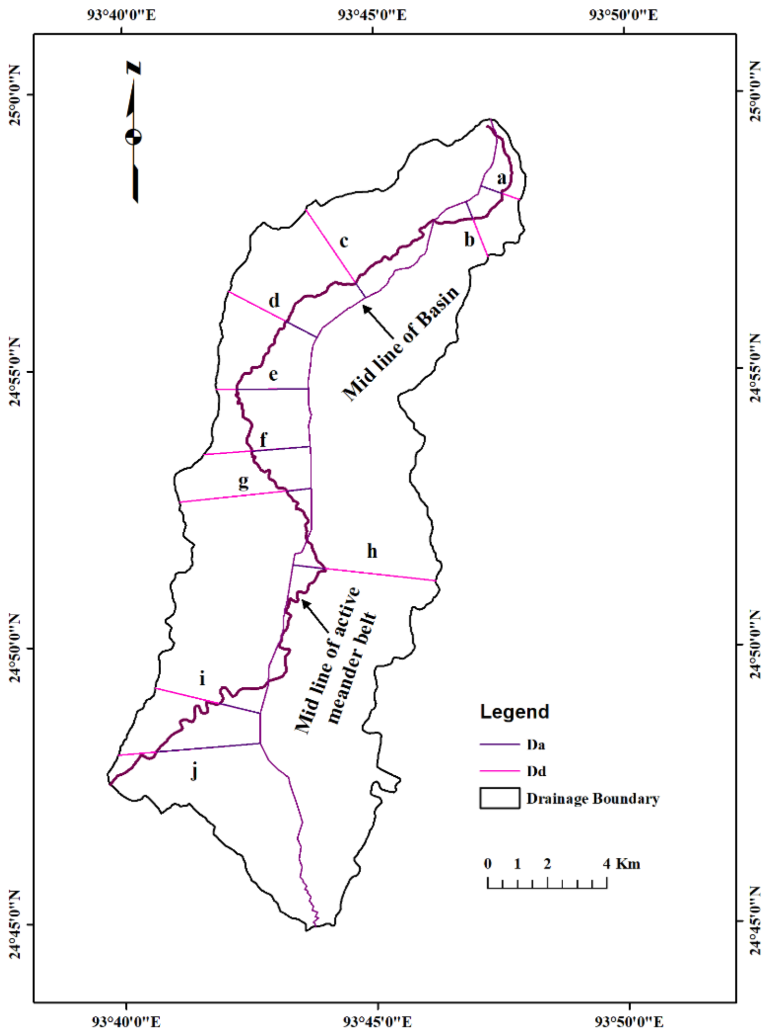


Fig. 8. Location map from where the value T is calculated

"Drainage developed in the presence of active tectonic deformation has distinct pattern and geometry. The asymmetry factor was developed to detect tectonic tilting" (Hare and Gardner 1984) and is defined as follows:

$$AF = 100\ (Ar / At) \tag{4}$$

Where AF is the asymmetry factor, Ar is the area of drainage basin to the right side of trunk channel when facing downstream. AF should be equal to 50, for a main channel that formed and continues to flow in a stable setting. Whereas, AF greater or less than 50 would decide the tilt [6]. The calculated value of AF is shown in Table.1 and the value is35.977 % indicating that the channel has shifted downstream right side of the Ijai watershed with an upliftment of eastern side.

5.5 Transverse Topography Symmetry Factor

The transverse topographic symmetry factor is a quantitative parameter with a two-dimensional vector of direction and magnitude [6]. The numerical value indicates the asymmetry of the basin while the orientation gives the direction of asymmetry (Pinter, 2005). This index helps in determining the tilt direction of a river and magnitude in relation to active tectonics [21]. A greater than Zero value is indicative of an asymmetric river basin [6]. This factor is calculated by the equation which is given below

$$T = Da \ / \ Dd$$

Where, T is the transverse topographic symmetry factor, Dais the distance from the midline of the drainage basin to the midline of active meander

Table 2. Calculated geomorphic indices of Ijai watershed

Sl. No.	Geomorphic indices	Value	Remarks
1	Basin Area (A)	183.53 km2	Total basin area
2	Basin length (L)	25.73 km	Maximum basin length
3	H_{max}	2282 m	Maximum Height
4	H_{min}	369 m	Minimum Height
5	Hypsometric integral (H i)	0.49	It shows youthful to mature basins
6	Basin elongation ratio (Eb)	0.59	Reflects elongate basin and tectonically active.
7	Drainage basin asymmetry (AF)	35.977	Tilted basin in nature
8	Transverse topography Symmetry (T)	0.421	Asymmetric in nature.
9	Valley floor width to valley height ratio (Vf)	0.053 to 0.144	Valley is V-shaped valley with streams that are actively incising and commonly associated with uplift.
10	Basin perimeter	78.17 km	Total basin perimeter.

belt, and Ddis the distance from midline of the basin to the drainage divide (Fig. 8). According to Cox [21], for perfectly symmetric basin T = 0, as the asymmetry increases, T approaches to the value of 1.

The traverse topography symmetry factor (T) for the Ijai river basin has been calculated along the tributaries Ijai and the calculated values are0.533593, 0.312321, 0.166073, 0.350125, 0.779, 0.549929, 0.18354, 0.22166, 0.386285 and 0.732189for section a, b, c, d, e, f,g, h, i and j respectively. The average values is0.421 which approaches towards 1.0 which indicates asymmetric according to the Cox [21]. Therefore, the T values for the Ijai river basin shows asymmetric in nature

5.6 Basin Elongation Ratio (Eb)

The basin elongation ratio is a quantitative morphometric parameter that deals with the shape of a river basin [22]. River basins that are undergoing active tectonism are elongated in shape [7], as an outcome of continuous thrusting and faulting in active regions [23,24]. A circular basin is indicative of an inactive setting, an oval basin depicts a slightly active basin, while an elongated basin indicates active tectonics [5]. This parameter is calculated by the following equation given by Schumm [11].

$$E_b = \frac{2\sqrt{A_b/_\pi}}{l_b}$$

Where Eb is the elongation ratio, Ab is the diameter of a circle of the same area as that of the basin, and lb is the length of the basin measured from its mouth to most distant point on the watershed. According to Chow [25], “Basin elongation ratio (Eb), over a wide range of climate and geological types, usually ranges from 0.6 for elongate and tectonically active basins to 1.0 for tectonically quiescent, oval and circular basins”. Based on these standards, Chow [26] classified “drainage basins as follows: circular (>0.9), oval (0.8-0.9), less elongate (0.7-0.8) and elongate (<0.7)”. Molin et al. [27] notice that “in active uplifting landscapes, youthful basins are commonly held to be relatively elongate”. Bull and Mc Fadden [5] considered “low values for basin elongation ratio as a proxy indicator of recent tectonic activity”. The calculated Eb value of Ijai river basin 0.59 which is less than 0.7 (Table. 2) indicating elongate basin [28-34].

6. CONCLUSION

From the results obtained after analysis of various geomorphic indices like SL/K, valley floor width to valley height ratio, hypsometric curve and integral, drainage basin asymmetry, transverse topography symmetry factor and basin elongation ratio, it is concluded that the study area is tectonically active in nature. Study of longitudinal profile largely provides valuable information to generate nature of morphotectonic of the Ijai watershed. The calculated parameters like asymmetry factor (AF = 35.977 %) and transverse topography symmetry factor (T = 0.421) help us to decipher that watershed has shifted up to the left side and the Ijai river has shifted to the right of the watershed from the datum facing downstream. The Hypsometric curve shows that the watershed is tectonically active. Also, other parameters correlate the competing force i.e., erosive power and tectonics. All the parameters studied shows the tectonic activities dominated over erosion and therefore, the Ijai watershed is tectonically active in nature.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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