Assessment of active tectonics in the Siwalik basin around the Subansiri river, NE India.

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Abstract. In this paper we evaluate the morphotectonics of the area around the Subansiri river in north-eastern India. Research focuses on understanding the impacts on areas experiencing active tectonic deformation. It also explains the variety of kinematics observed in the area from the Miocene to the present. The tectonics can explain some structures related to the extensional tectonics predominant in the region and the development of the minor and major morph structures driven by faults with different kinematics. We developed a morphotectonic evolutionary model for the area based on the morphotectonic analysis and geological mapping. Morphotectonic indices used to evaluate the tectonic activeness in this study are Mountain Front sinuosity Index, Valley Floor Width to Valley Height Ratio, Asymmetry Factor, Transverse Topographic Symmetry Factor, Mountain Front Steepness Index, Basin Shape Index and Stream Length Gradient Index. There are numerous lineaments present in the study area which are trending in NW-SE and NE-SW direction.

1. Introduction
The Himalayas, the Mishmi Hills, the Naga Hills and the Dhubri fault surrounds the Assam block from all sides. The Himalayan range, the world's youngest mountain range, was created when the plates of the Indian and Eurasian continents collided around 50 million years ago [25]. There have been several major tectonic events in the area. Micro-tectonic data has been gathered in several Himalayan locations during the twentieth century and used to estimate the area's activity level. The Himalayan Frontal Thrust appears to be one of the most active zones in the Himalaya, as evidenced by the upliftment of terrace deposits, the creation of steep scarps, and the upliftment of Siwaliks over recent alluvium. Because the current morphology of the mountain ranges is the outcome of both tectonic and erosional action, we can regard recent and active tectonics as the principal mechanism leading to the rock upliftment [28, 2]. Geomorphic landforms including tilted fans, fluvial terraces, unpaired terraces, aberrant drainage patterns, mountain front sinuosity, and drainage basin asymmetry are analysed in tectonic geomorphology [27, 28, 5, 6, 7, 36, 37, 33, 25, 21, 11, 12].

We are interested in understanding the morphotectonic evolution and the current state of tectonic activity. The study focuses on drainage network, topography and geomorphic appearance. Tectonic activity influences drainage patterns and river behaviour [19, 35, 38] which may be quantified as well
as qualitatively stated [18, 22]. Drainage patterns are susceptible to folding and faulting in tectonically active areas. This process accelerates river incision, asymmetries, complex drainage geometry, and river deflections [11]. Assessing earthquake risks necessitates a thorough examination of active tectonics, particularly in locations where there has been a lot of tectonic activity recently. [22]. It is difficult to identify a specific region for quantitative studies of active tectonics on a regional scale [13]. Furthermore, this study will investigate whether the tectonic activity classification developed when working in semi-arid or arid climates can be applied to the region with subtropical or tropical climates.

2. Study area
The current research area includes sections of Assam's Lakhimpur and Dhemaji district and Arunachal Pradesh's Lower Subansiri, Kamle and Lower Siang district (Figure1). The toposheet numbers 83I/2, 83I/3, 83I/6, 83E/15 and 83E/14 are used to carry out the study. We did the field investigation on the Assam-Arunachal border route sector. It covers the Lower Subansiri dam site region, the Gerukanala river section, the Dirpai nala river section, the Dakhin Rupahi hamlet in the Subansiri River downstream, and the Jiadhol River section.

![Figure 1. Location Map showing major rivers and places in the study area.](image)

3. Geology
On account of its structural characteristics and stratigraphy, the Arunachal Himalaya is categorized into two tectonic groups, which is the Frontal Fold Belt (FFB) with sediments and rocks of the Siwalik Group, that constitutes the Sub-Himalaya, and the second one is the Main Himalayan Belt (MHB) with sediments and acid magmatic rocks of the Paleoproterozoic to Middle Eocene period which forms the
Lesser and the Higher Himalaya. These two belts are divided by the Main Boundary Fault (MBF) [23]. Karunakaran and Ranga Rao (1979) of ONGCL, based on lithology, classified the Siwalik rocks in Arunachal Pradesh into three units (Table 1) (Figure 2).

Table 1: Stratigraphic succession of the Siwalik.

| Age                  | Lithotype                                                                 |
|----------------------|---------------------------------------------------------------------------|
| Recent to Sub-Recent | Alluvium and older deposits                                               |
| Plio- Pleistocene    | Kimin Formation: soft sandstone, shales, siltstone and conglomerates, etc.|
| Middle to Upper Miocene | Subansiri Formation: coarse to medium grained, massive to poorly bedded, pebbly micaceous soft friable sandstone, shale with coal streaks. |
| Middle to Lower Miocene | Dafla Formation: fine to medium grained silty Sandstone, shale, claystones, mudstone and carbonaceous shale. |

Figure 2. Geological map showing major thrust and lithologies present in the study area

We studied sections of Subansiri Dam, Gerukanala Section, Dirpai River Section, Jiadhol River Section, and the Paharpur area of landslides and the Dakhin Rupahi Village. The dam site at Subansiri has a section of road that runs along the Siwaliks. The lithology consists of alternate bands of sandstone
and conglomerate. The high-level river terraces in this area lie unconformably above the rocks of the Siwalik group. These sections are characterized by several small-scale faults (Figure 3).

![Figure 3. Small scale fault nearby Subansiri River.](image)

There are alternate bands of sandstone and boulder beds exposed in the Gerukanala section. The Gerukanala is one of the tributaries of the Subansiri River. The sandstone present is greyish in colour and has friable characteristics and belongs to the Kimin Formation of the Siwalik Group. High-level river terrace deposits with a horizontal disposition overlie this deposit (Figure 4). It is evident that the conglomerate bands are brecciated, which is indicative of a thrust zone marked by the designation HFT-1 on the geological map (Figure 5). Several unconformities (Figure 6), minor faults and a fault surface (Figure 7) are exposed in the Gerukanala river bank. HFT-1 is the name given to the entire fault zone that separates the Subansiri and Kimin formations.

![Figure 4. Kimin Formation overlain by terrace deposit.](image)  
![Figure 5. Crushed pebble on the Gerukanala river section](image)
There are terrace deposits 5.3 meters thick in the Dirpai nala river section. It is one of the tributaries of the Subansiri River. In the base of the terrace deposit, boulders, cobbles, and pebbles have been deposited, which are overlain by the cross-bedded sand unit. There are low hills towards the north and a flat, featureless plain towards the south, which are part of the Subansiri floodplain. The abrupt topographical change in the region is evidence of the presence of the thrust (Figure 8), marked as HFT-2 on the geological map.

A terrace deposit can be found in the Jiadhol River section at its mouth. It is also the tributary of the Subansiri River. It is known as Kumotiya River in Assam from Gogamukh. A zone of brecciate and shear sandstone exists north of the terrace deposit, indicating the presence of HFT-1 (Figure 9). The rocks of the Subansiri Formation are found north of the thrust zone. The Kimin sandstones are exposed in a landslide zone at Sayengia and Paharpur, west of the Jiadhol River section (Figure 10). Sandstone, siltstone, and shale make up the lithology, interspersed with a conglomerate substrate. The clasts in the conglomerate strata are mostly quartzite, with sandstone boulders as subordinates.

The Kimin Formation is unconformably overlain by river terraces where we find channel fill deposits (Figure 11). The presence of sandstone boulders within the Kimin Formation indicates that the Dafla and Subansiri Formations were uplifted and became the source during the deposition of the Kimin
Formation (Figure 12). The topography abruptly changes to featureless plains to the south of this exposure, indicating the presence of HFT-2 nearby.

Older alluvium and recent deposits can be found near Dakhin Rupahi village, along the Subansiri Riverbank. The bank stratigraphy comprises lithified conglomeratic bed at the base followed by a yellowish-brown colour older alluvium, which is overlain by recent deposits of Subansiri River. The recent deposit consists of fine-grain sand, overlain by a silt layer of around 20 cm thickness. Downstream of this location, the recent deposit near the riverbank has been eroded and exposed older alluvium. Here, over the older alluvium, we find lots of upright tree trunks, which indicates the presence of a forest buried under recent deposits (Figure 13). The forest submerged under the flood during the 1950 great Assam earthquake, as per the information provided by the area’s residents. The great Assam earthquake of 1950 caused great destruction, a dam formed by landslides eventually burst and caused the great flood in the Subansiri river [17, 34]. The historic flood of 1950 contributed so much sediment that it deposited up to 1 m of coarser sediment comprising pebbles and coarse sand over the earlier flood plain alluvium, as can be seen in Chauldoa ghat, Assam [17].
4. Materials and Methodology
Through the use of various morphotectonic indices, the paper examines the area’s active tectonic activity. Morphotectonic indices taken for the study are Mountain Front Sinuosity Index (Smf), Valley Floor Width to Valley Height Ratio (Vf), Asymmetry Factor (Af), Transverse Topographic Symmetry Factor (T), Mountain Front Steepness Index (S), Basin Shape Index (Bs), Stream Length Gradient Index (SL) and Relative Tectonic Activity Index (lat). We calculated the morphotectonic indices for four mountain fronts and 32 watersheds within the study area (Figure 15). The study uses topographic maps by carrying out extensive field surveys and laboratory work. The general methodology applied in the study is given in the flow chart (Figure 14). Exposed rock outcrops are studied during field investigation using geological field tools such as Brunton Compass, hammer and GPS. Laboratory investigation involves geological maps preparation, map digitization and morphotectonic index calculation. ASTER-GDEM of 30m resolution is used to obtain the elevation data required during the preparation of geological profiles, cross-sections and morphotectonic indices calculation.

![Figure 14: Methodology flow chart of the study.](image)

![Figure 15. Drainage basin/watershed and Segments of the mountain front.](image)
5. Morphotectonic indices and results

5.1. Mountain front sinuosity index

Many mountains are characterised by straight or curved fronts due to a constant struggle between active tectonic pressure and erosion. Tectonic activity produces a majority of straight mountain fronts; these faults can be evaluated to derive basic information about the tectonic activity and long-term deformation [39]. Mountain front Sinuosity Index (Smf) measures how much erosional modification has taken place on tectonic structural features or topographic escarpments bounded by fault [4, 6, 7, 22, 31, 34, 39].

It is described as the ratio between Lmf and Ls where Lmf is the length between two points of the mountain front along its base where there is a change in slope from hills to plain, and Ls is the straight length between the two ends of mountain front [6, 7] and is expressed in the formula:

$$\text{Smf} = \frac{\text{Lmf}}{\text{Ls}}$$

The Smf index in this study is measured at four fronts A A’, B B’, C C’ and D D’. These fronts are separated by Dulang River, Subansiri River, Gerukanala, Dirpai river and Jiadhol river. The obtained Smf values are analysed and shown in Table 3 as per the ranges given by various authors. The ranges given by different authors are presented in Table 2.

Table 2: Tectonic activity classes and their ranges given by different authors.

| Authors                | Tectonic classes | Smf ranges    | Vf ranges |
|------------------------|------------------|---------------|-----------|
| Bull & McFadden (1977) | 1                | 1.0 to 1.6    | 0.05-0.9  |
|                        | 2                | 1.4 to 3.0    | 0.5- 2.0  |
|                        | 3                | 1.5 to >5     | >2.0      |
| Rockwell et al. (1984) | active fronts    | 1.01- 1.34    | 0.43-1.91 |
|                        | less active fronts | 1.57- 2.72    |           |
| Silva et al. (2003)    | 1                | 1.17- 1.53    | <0.5      |
|                        | 2                | 1.8- 2.30     | 0.3-0.8   |
|                        | 3                | 2.8- 3.5      | >0.7(mostly 0.8-1.2) |

Table 3: The Mountain front sinuosity values and their tectonic activity class.

| Front | Smf (avg) | Tectonic activity class |
|-------|-----------|-------------------------|
|       |           | Bull and McFadden (1977) | Silva (2003) | Rockwell (1984) |
| A A’  | 1.381     | 1                       | 1            | 1               |
| B B’  | 1.382     | 1                       | 1            | 1               |
| C C’  | 2.066     | 2                       | 2            | 2               |
| D D’  | 1.975     | 2                       | 2            | 2               |

The mountain front analysis shows front A A’, B B’ as active and C C’, D D’ as less active. None of the segments came out as inactive. The ranges given by all the mentioned authors suitably indicates the area’s tectonic activeness.

5.2. Valley Floor Width to Valley Height Ratio ($V_f$)

The Vf Index is calculated at the valleys at some distance upstream from the mountain front. It can be counted as an essential stability indicator. It signifies the dissimilarity between valleys with V and U shapes. The V-shape valleys indicate high tectonic activity and show active uplift, whereas U-shape
Valleys are broad-floored due to prominent erosion in the lateral sides up to the adjoining hillslopes, and it displays low tectonic activity. Vf with high value is related to U shape valley and low uplift rates, while low Vf values represent deep V-shaped valleys with actively incising streams linked with uplift [4, 6, 7, 8, 21, 30, 32, 37]. The Vf index is expressed by the formula [7],

\[ V_f = \frac{2V_{fw}}{(E_{ld} - E_{sc}) + (E_{rd} - E_{sc})} \]

Where V_{fw} is the valley floor width measurement, elevation of the left and right valley divide is E_{ld} and E_{rd} and E_{sc} is the valley floor elevation.

The Vf index is calculated at twelve locations in the respective mountain fronts segments. Two transect distances are taken to determine the valley profiles, one at 250 meters [34] and another at 1 km upstream of the mountain fronts [7]. The calculation results at two different transect distances can be analyzed and compared in terms of upliftment, incision, and erosion.

For the valley transect profile taken at 250m upstream in the river from the mountain front. The Vf class at front A A’ is moderately active, highly active at front B B’, C C’ and D D’. Similarly, we calculated the Vf index for the Subansiri River, and the result infers that it is a class 3 U type valley indicating moderate tectonic activity. The Vf index measured for Jiadhol river indicates V shaped valley and high tectonic activity class. For the valley transect profile taken at 1km upstream in the river from the mountain front. The Vf class at front A A’, B B’, C C’ and D D’ is highly active. It is a class 1, V type valley for the Subansiri River and Jiadhol River, indicating high tectonic activity.

5.3. Asymmetry Factor
The watershed development in a tectonically active terrain is affected by the ongoing active deformation. Streams in the watershed follow distinct patterns and geometries that can be qualitatively and quantitatively described [18, 22]. To identify tectonic tilting transverse to flow at watersheds and larger scales, the asymmetry factor was originated [18, 22]. As with most morphotectonic indices, the Af is most effective where the same lithology underlies all the watersheds. This method assumes that asymmetry doesn’t occur due to lithologic formations such as dipping sedimentary layers or the climate in a region [22]. The formula obtains the Asymmetry Factor (AF) of a watershed, AF = 100 (Ar /At), Where, At denotes the total watershed area and area of the watershed to the right (facing downstream) of the trunk stream is Ar.

![Figure 16. Asymmetry map of the study area.](image)
The Af values for the watersheds range from 1.11 to 30. We have used the absolute Af values to determine the degree of asymmetry for each watershed. The absolute Af are categorized into four classes: symmetric watershed where Af is less than 5, gently asymmetric watershed where Af ranges between 5 to 10, moderately asymmetric watersheds where Af ranges between 0 to 15 and strongly asymmetric watersheds where Af is greater than 15 [27]. Many watersheds have Af values greater or less than 50, which indicates tilt in those watersheds due to tectonic activity. There is prominent tilting in the E, NE and SW directions. Out of 32 watersheds selected for the study, 10 watersheds are strongly asymmetric, 8 is moderately asymmetric, 8 is gently asymmetric, and the rest 6 are symmetric watersheds (Figure 16). It can be concluded that Af shows the area to be tectonically active.

5.4. Transverse Topographic Symmetry Factor (T)

T evaluates asymmetry and determines the tilting direction based on the deviation from the watershed midline of the trunk stream. It is computed with the formula \( T = \frac{D_a}{D_d} \), Where \( D_d \) is the distance taken from the watershed midline to the watershed divide and \( D_a \) is the distance taken from the watershed midline to the midline of the stream. The T values show the shifting at a right angle to the watershed axis. In other words, it is a vector whose direction and magnitude ranges from zero to one, corresponding to the perfect asymmetric watershed [8, 11, 12, 22].

The T value ranges from 0.05 to 0.99, showing highly active tectonic activity. With increasing T values, the watershed becomes increasingly asymmetric. Changes in slope caused by tilting of the watershed in a particular direction cause the stream to shift in that direction and the length of the tributaries to increase. As we observe the trend of the streams in all the watersheds, the main channel in each watershed follows an E, NE and SW direction.

5.5. Basin Shape Index

An index of basin shape (Bs) may indicate the horizontal projection of a basin or watershed [9, 30]. It is calculated with the formula \( B_s = \frac{B_l}{B_w} \), Where \( B_l \) is the length between the highest point to the mouth of the watershed, and the width of a watershed at its widest point is \( B_w \). In tectonically active areas, watersheds are elongated in shape and perpendicular to the topographic slope [7, 30]. So, it is possible to find the rate of active tectonics through Bs.

It is found in the study that most of the watersheds in the region are circular. Four watersheds are semicircular, one is elongated, and all the rest are circular. In this region, the Bs index is not indicating tectonic activity. So, it can be concluded that the Bs index is not applicable to find the tectonic activeness in the Eastern Himalaya because of its weak and friable lithology and high precipitation level.

5.6. Mountain Front Steepness Index

By examining the slope in the frontal portion of the mountains, the Mountain Front Steepness Index (Ms) detects the transition in topography in frontal regions of mountainous ranges from hill to plain. The cross-section of the mountain front produced from a DEM is used to calculate this index. A tectonically active mountain front will have a steeper mountain front than a less active one if the region’s lithology, climate, and vegetation are all consistent. Ms is defined as \( Ms = \frac{Y}{X} \), Where the vertical distance between the hill’s highest elevation points and the point where the slope breaks are \( Y \) and the horizontal distance between the hill and the plain where remarkable slope changes occur is denoted by \( X \).

The mountain front steepness index is calculated in this study by obtaining perpendicular cross-sections of the mountain fronts A A’, B B’, and D D’. The Ms value for the front A A’, B B’, and D D’ is 0.31, 0.42 and 0.23. The Ms values indicate that segment D D’ is more active than the other two segments.

5.7. The Stream Length-Gradient Index (SL)

The Stream Length-Gradient index can be used to evaluate any divergence in river longitudinal profile stability caused by tectonic, climatic, or lithological factors. [17]. Hack (1973) defined the stream length gradient index as \( SL = (\Delta H / \Delta L) \). L Where \( \Delta H \) is the elevation change, \( \Delta L \) is the length of the reach,
the ratio of $\Delta H/\Delta L$ is the channel slope, and the channel length between the midpoints of the reach to the divide is $L$. Because the SL index is sensitive to variations in channel slope, it may be used to assess the link between the tectonic activity, rock resistance, topography, and stream length. [3, 17, 22, 40]. The required parameters for calculating the SL index are obtained from topographic maps. [3, 17, 22].

Figure 17: Following Graph showing relation between Slope and SL index of a watershed. (Slope in the graph is represented in brown line and SL index in blue line)

Figure 18: Map showing S L points in the area.
For watersheds of third or higher-order, the SL index is measured. The SL graphs are made by plotting the SL values against L, and the longitudinal profile is prepared by plotting elevation against distance from the source to the point of measurement in the river profile (Figure 17). From the overlay of the SL index with the longitudinal profile, it is observed that the anomalous value of the SL index lies close to the break in slope in the longitudinal profile. When these anomalous points are marked in the geological map (Figure 18), many SL points are noted to fall right over the fault or lined parallel to the major faults in the vicinity. It can therefore be said that all of the primary faults in the study region are active.

5.8. Relative tectonic activity index (Iat):
We use the approach described by [13] to calculate an index that represents relative tectonic activity over a specific region in this study. The different indices are grouped into three categories, with class one indicating high activity and class four indicating low activity (Table 4). Iat is calculated by taking the average of tectonic activity classes of different morphotectonic indices (S/n). It is divided into four classes to determine the degree of tectonic activity where class 1 denotes very high tectonic activity (between 1 to 1.5), class 2 denotes high tectonic activity (S/n> 1.5 but < 2), class 3 denotes moderate tectonic activity (S/n>2 but < 2.5), and class 4 denotes low active tectonics (S/n> 2.5).

| Class | Smf | Vf | S.L. | Af | Bs |
|-------|-----|----|------|----|----|
| 1     | < 1.1 | <0.5 | >/500 | Af>/65 or <35 | >4 |
| 2     | 1.1- 1.5 | 0.5-1 | 300< | 35<Af<43 or 57<Af<65 | 3-4 |
| 3     | >1.5 | >300 | <300 | 43<Af<57 | <3 |

Iat values in the study area are mainly class 2 and class 3. The data indicates that the area is experiencing high and moderate tectonic activity.

6. Lineament Analysis:
Fractures, jointing, and other linear geological processes that occur everywhere from the terrain surface to potentially large depths are shown as lineament on the terrain surface. [13]. Lineament is a straight or slightly curving feature topographically manifested as depression, aligned depression or ridge. It is more intense in tectonically active zones than in tectonically quiescent zones. An important factor in the lineament study is the trend of the lineament. If the trend of the lineaments is correctly plotted on the Rose diagram, it can provide information about the principal stress and deformation direction of an area. The trend of the lineaments near the study area is determined and plotted on the Rose diagram to determine the stress directions. Analyses of lineaments in areas with poor exposures and dense vegetation can often reveal evidence of tectonic activity. The major lineaments of the study area are traced from the toposheet and AsterDEM 30m resolution. The map showing the locations of these lineaments is shown in Figure 19.

According to the Rose plot created with Rozeta Software, the predominant trend of lineaments in all three segments is in the NW-SE and NE-SW directions, similar to the region's major thrust and cross faults. (Figure 20).
7. Morphotectonic evolution of the area

Along the whole length of the Himalayan strike, there are four critical structural breaks [24] that contribute to the Himalayan Mountain belt's tectonic setting. They are MFT, MBT, MCT and ITS (Indus Tsangpo suture).

The moderate to steep northerly dipping Main boundary thrust (MBT) separates the Lesser Himalaya's sedimentary strata from the Sub Himalaya. The Himalayan frontal thrust is the southern limit of the Himalayan orogeny. The Siwaliks are Late Tertiary sediments found over the whole length of the Himalayan foothills and deposited between the MBT and MFT. The most common lithology in the Sub Himalaya is sandstone.
In the study area, the overriding of thrust sheets due to intense compression probably occurred during the early Miocene, which resulted in the formation of a foredeep. In this foredeep basin, the Siwalik sediments are deposited (Figure 21). There is continuous North-South compression in the Himalayan frontal part, which has led to the development of several thrusts. Due to the constant compression during this orogeny, thrusts propagated southward into the basin and uplifted some portion of the foreland basin. The ongoing tectonic deformation has resulted in the southward propagation of numerous branching faults that belong to the fault system like MBT and HFT. The branching faults are the manifestation of an imbricate thrust fault in the region. The development of the thrust system is aided by basal detachment. MBT may be originated in the early Eocene age and separated the Gondwana group of rock from the Siwaliks. HFT is a prominent branching fault in the study area.

![Figure 21. Development of the Siwalik basin.](image1)

The HFT-1 in the study area probably originated in the late Pliocene when the foreland basin compressed intensely. With the development of HFT-1, part of the Siwalik basin containing Dafla and Subansiri formation uplifted. It resulted in the southward migration of the foredeep. In this foredeep, Kimin Formation got deposited along with some alluvium (Figure 22). HFT-1 uplifted the middle Siwalik rocks and led to the development of the Outer Himalaya Ranges. Further movement along the frontal fault led to the deformation of the Kimin Formation, and they thrusted over recent alluvium (Figure 23). This episode involved the activation of another fault, which branched out of HFT-1 and was named HFT-2.

![Figure 22. Upliftment of Dafla and Subansiri Formation and development of Kimin basin.](image2)

![Figure 23. Upliftment of Kimin Formation and Development of foreland basin where alluvium is deposited.](image3)
In the study area, we observe significant differences in the lithology present in the right and left banks of the Subansiri river. The dip direction, dip amount, tilting of the bed, fold axis of the beds vary for both the river bank. The dipping of beds on the left bank is towards the SW and NE, whereas on the right bank, it is towards the W and S. Fold axis orientation is also different in both the bank. The right bank’s folding is more intense than the left banks, indicating the presence of differential compression in the area. It is probably because of the difference in resistance for thrust movement in both the banks. These field evidence indicate the occurrence of a cross fault across the Dulung River in the study area. HFT-2 has been displaced by this cross fault, which indicates its age is late Pleistocene to post Pleistocene in age. The evolutionary model is prepared for the study area and shown in Figure 24.

Figure 24. Block diagram shows the evolutionary model of the study area.

8. Conclusion
From studying seven morphotectonic indices, it can be said that the area is tectonically active and continuously undergoing tectonic deformation. The anomalous points identified by Stream Length Gradient Index falls along or near the MBT and HFT showing active tectonics. Therefore, we can say that these thrusts are still active. The relative tectonic index is calculated, and the parameters are classified into four classes. It indicates that the area is high to moderately active. In the following discussion, the ranges of every single morphotectonic parameter are defined on the basis of research conducted in the arid and semiarid regions. Considering the geographical location of the study area, which is subtropical-tropical climate zone, it receives very high precipitation (2000mm to 5000mm) annually, so rivers have a higher erosive power. The eastern Himalaya's frontal portion consists primarily of rock from the Siwalik Group, which is weak and friable. It is easy for these rocks to erode. This may be why the drainage basins attain a circular shape rapidly. Hence, the range for the Basin shape Index indicating tectonic classes for Eastern Himalaya needs to be revised. The lineament study shows that most features align parallel to MBT and HFT or the cross-fault in the study area. As a result, tectonics is crucial in the evolution of lineaments in the research domain. An evolutionary model of the study area is introduced to understand its tectonic evolution. It is observed that there is a development of splays from HFT, which is HFT 1, HFT 2 and HFT 3. So, it can be concluded that the Himalayan Mountain front could be in a state of southward expansion.

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