Tectonic Activity Response Based on Geomorphic Index In Pasir Muncul, Sukatani, Purwakarta Regency, West Java

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ABSTRACT

The study area administratively located in Sukatani sub-district, Purwakarta Regency, West Java. This study is aim to determine the level of tectonic activity in the study area using a quantitative geomorphological approach. The geomorphic indices that used in this research are the Mountain Front Sinusity (SMF), Ratio of valley floor width to valley height (Vf), Hipsometric Integral (HI), Drainage Basin Shape (BS), and Asymmetry Factor (AF). Then, these parameters of geomorphic index, are included in the calculation of the Relative Tectonic Activity Index (IATR) which is show the distribution of tectonic activity levels in the study area. The results of the analysis Relative Tectonic Activity Index (IATR) show that the study area is divided into 3 classes of tectonic activity, namely class 2 (high), class 3 (medium), and class 4 (low). Class 2 occupies about 19.5%of the study area with an area of 7.6 km^2 which is spread over the western part of the study area. Class 3 occupies about 79.8% of the study area with an area of 31.4 km^2 which is spread dominantly in the study area. While class 4 (low), which occupies about 0.7% of the study area with an area of 0.28 km^2 which is spread in the northern part of the research area. In general, the study area has a fairly balanced between level of tectonic activity with an erosion activity, but in the western part of the study area tended to be more dominated with tectonic activity than the erosion activity, which was indicated due to the influence of the structure in the area and caused a catastrophic ground motion in surrounding area.

Keywords : *quantitive geomorphology, morphotectonic, Relative Tectonic Activity Index*

INTRODUCTION

Java Island is one of the islands with a level of active tectonic activity in Indonesia. Java tectonics is influenced by the interaction between the Eurasian and Indo-Australian plates. The existence of these interactions produces a complex geological setting, especially in the regions of West Java and Banten (Hilmi & Haryanto, 2008). With the existence of tectonic activity, in several places formed geological structures in the form of folds, faults, joints, and a number of other geological structures (Hilmi, 2007).

The research area is located at coordinates 107° 25' 4.2" E to 107° 29' 59.6" E and -6° 36' 19.3" S to -6° 42' 24.8" S which is administratively located in the village Pasirmunjul and its surroundings, Sukatani District, Purwakarta Regency.

Based on the Geological Map of the Cianjur by Sudjatmiko (1972), in the study area has several geological structures such as the presence of faults and folds, and based on the Earth Movement Vulnerability Zone Map issued by the Center for Volcanology and Geological Hazard Mitigation (PVMBG), the study area is included in the moderate to high in the risk of land movement disasters, both of which can be a sign of tectonic activity in the study area.

Therefore, this study intends to identify the level of tectonic activity in the study area by using a geomorphic index. The geomorphic index is very useful in studying tectonic activity because it can be used to evaluate the tectonic level of a large area in a short period of time (Keller & Pinter, 2002).

RESEARCH METHOD

Some geomorphic indices can be used to analyze topography and tectonic activity. Geomorphic indices analysis is carried out by calculating the morphometric aspects. The morphometric aspects that used in this study are the Sinusity of the Mountain Face (Smf), the Ratio of Valley Width and Height (Vf), Asymmetry Factor (Af), Basin Shape (Bs), and Integral Hipsometry (HI). The morphometric aspects were processed using ArcMap 10.5 and Global Mapper 21.0 software, the values obtained were

E-ISSN : 2579 – 3136

then used in calculating the Relative Tectonic Activity Index (IATR).

Mountain Front Sinousity (Smf)

Mountain-front sinuosity is an index that reflects the balance between erosional forces that tend to cut embayments into a mountain front and tectonic forces that tend to produce a straight mountain front coincident with an active range-bounding fault (Keller & Pinter, 2002).

Smf = $\frac{Lmf}{Ls}$……………………………..

Where :
Smf : Mountain Front Sinousity
Lmf : Length of the mountain front
Ls : Straight-line length of the mountain front

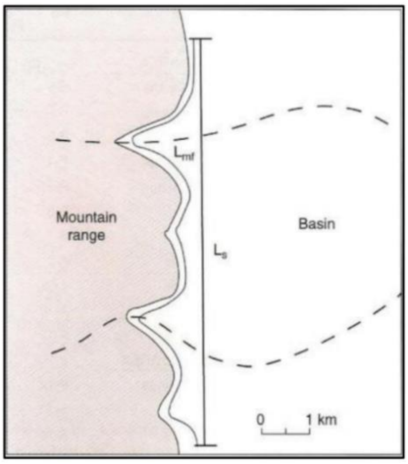

Figure 1.
Smf Illustration (Keller & Pinter, 2002)

The calculation results are then grouped based on the class of tectonic activity referring to the classification of Elhamdouni, et al (2008) as shown in Table 1. Mountain fronts associated with active tectonics and uplift are relatively straight, with low values of Smf. If the rate of uplift is reduced or ceases, then erosional processes will carve a more irregular mountain front, and Smf will increase (Keller & Pinter, 2002).

Table 1. Classification of Smf (Elhamdouni et al, 2008)

Nilai	Klasifikasi
Smf < 1,1	Class 1 (High tectonic activity)
1,1 ≤ Smf ≤ 1,5	Class 2 (Moderate tectonic activity)
Smf > 1,5	Class 3 (High tectonic activity)

Ratio of Valey Floor Width to Valley Height (VF)

Vf is an index used to determine the level of uplift in a place. Analysis The ratio of the width and height of the valley (vf) is used to measure the formation and development of a valley in relation to tectonic activity. This index will distinguish between the "U" shape of the valley and the "V" shape of the valley (El Hamdouni et al, 2008)

Vf = $\frac{2Vfw}{(Eld-Esc)+(Erd-Esc)}$………………..

Where :
Vf : Ratio of Valey Floor Width to Valley Height
Vfw : Width of the valley floor
Eld : Elevation of the left side of valley
Erd : Elevation of the right side of valley
Esc : Elevation of valley floor

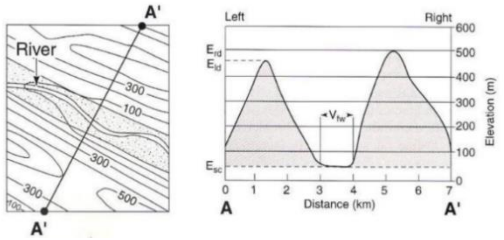

Figure 2.
Vf Illustration (Keller & Pinter, 2002)

Valleys with a "U" shape will generally have high Vf values. A high vf value generally indicates a low uplift speed so that the river will tend to cut through the valley floor so that the formation of the valley will widen or form a U. Meanwhile, a low Vf value indicates that active tectonics plays a role in the formation and development of a valley and is associated with high uplift (Keller dan Pinter, 2002).

Table 2. Classification of Vf Index (Elhamdouni et all, 2008)

Nilai	Klasifikasi
Vf < 0,5	Class 1 (High tectonic activity)

E-ISSN : 2579 – 3136

0,5 ≤ Vf ≤ 1,0	Class 2 (Moderate tectonic activity)
Vf > 1,0	Class 3 (Low tectonic activity)

Asymmetric Factor (Af)

AF index is used to detect tectonic tilting to flow at drainage basin (Keller & Pinter, 2002). The asymmetry factor is an index that is sensitive to changes in tectonic tilting in a basin (El Hamdouni et al, 2008). The asymmetry factor value can explain the area affected by tectonic-tilting in a watershed.

Af = $\frac{Ar}{At} x100$...............................

Where :
Af : Asymmetric Factor
Ar : the area of the basin to the right (facing downstream of the trunk stream)
At : Total area of the darinage basin (Km2)

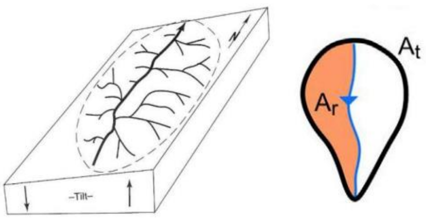

Figure 3.
Af Illustration (Keller & Pinter, 2002) (left), (Putra & Chenrai, 2022)(right)

If an asymmetry factor value close to 50 indicates that the area is relatively stable, which means that the tectonic processes are very small. However, if the AF value is greater or smaller (away from) 50 then it indicates a slope due to active tectonics or from differential erosion as a result of the control of lithological structures such as river flow which tends to lead to bedding areas from time to time (El Hamdouni et al, 2008).

Table 3. Classification of Af Index (Elhamdouni et all, 2008)

Nilai	Klasifikasi
│AF - 50│ > 15	Class 1 (High tectonic activity)
│AF - 50│:7-15	Class 2 (Moderate tectonic activity)
│AF - 50│ < 7	Class 3 (Low tectonic activity)

Basin shape (BS)

BS index is used to determine the relationship between the length of a basin measured from the longest point and the width of the basin measured from the widest point. High values of Bs are associated with elongated basins, generally associated with relatively higher tectonic activity. Low values of Bs indicate a more circular-shaped basin, generally associated with low tectonic activity (El Hamdouni et al, 2008).

Bs = $\frac{Bl}{Bw}$......................................

Where :
Bs : Basin Shape
Bl : length of a basin measured from the longest point
Bw : width of the basin measured from the widest point

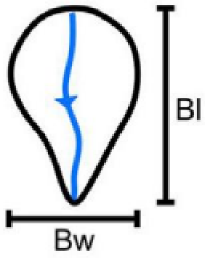

Figure 4.
BS Illustration (Putra & Chenrai, 2022)

Table 4. Classification of BS Index (Elhamdouni et all, 2008)

Nilai	Klasifikasi
Bs ≥ 4	Class 1 (High tectonic activity)
3 ≤ Bs < 4	Class 2 (Moderate tectonic activity)
Bs < 3	Class 3 (Low tectonic activity)

Hysometric Integral (HI)

The hypsometric integral is an index that describes the distribution of elevation of a given area of a landscape (Strahler, 1952 dalam Elhamdouni dkk, 2008). The Integral Hipsometric Index explains the relationship between elevation elevations in an area and their relationship to tectonics.

E-ISSN : 2579 – 3136

HI = $\frac{Hmean - Hmin}{Hmax - Hmin}$..........................

Where :
HI : Hysometric Integral
Hmean : Average elevasi
Hmax : Maximum elevation
Hmin : Minimum Elevation

Figure 5.
HI Illustration (Putra & Chenrai, 2022)

The average height is obtained from the average height of 50 points taken randomly in the watershed. High HI value indicates that there is not much land that has been eroded and indicates that the land is relatively young and allows it to be generated by active tectonics. Meanwhile, low HI values are associated with relatively older land ages that have been eroded and little active tectonic influence in recent times (Elhamdouni et al, 2008).

Table 5. Classification of HI Index (Elhamdouni et all, 2008)

Nilai	Klasifikasi
HI > 0,5	Class 1 (High tectonic activity)
0,4 ≤ HI ≤ 0,5	Class 2 (Moderate tectonic activity)
HI < 0,4	Class 3 (Low tectonic activity)

RESULT AND DISCUSSION

Mountain Front Sinousity (Smf)

Based on the calculation results, the Smf values in the study area ranged from 1.058 to 1.833 (table 6).

Table 6. Smf values of study area

Sub-basin	Smf	Class
SD - 01	1.162	2
SD - 03	1.35	2
SD - 05	1.833	3
SD - 08	1.36	2
SD - 09	1.402	2
SD - 10	1.285	2
SD - 11	1.134	2
SD - 12	1.142	2
SD - 13	1.058	1
SD - 14	1.257	2
SD - 21	1.069	1
SD - 25	1.141	2
SD - 26	1.178	2
SD - 27	1.178	2
SD - 30	1.226	2

In the study area (Figure 6), there are 2 sub-basin that are included in the category of tectonic class 1 (high), 12 sub-basin are included in the category of tectonic class 2 (medium), and 1 sub-basin is included in the category of tectonic class 3 (low). Based on the Smf map, the study area is dominated by class 2 (medium) which indicates that uplift has occurred in the study area which then experienced a decrease in tectonic velocity resulting in an erosion process that has cut the ridge face irregularly.

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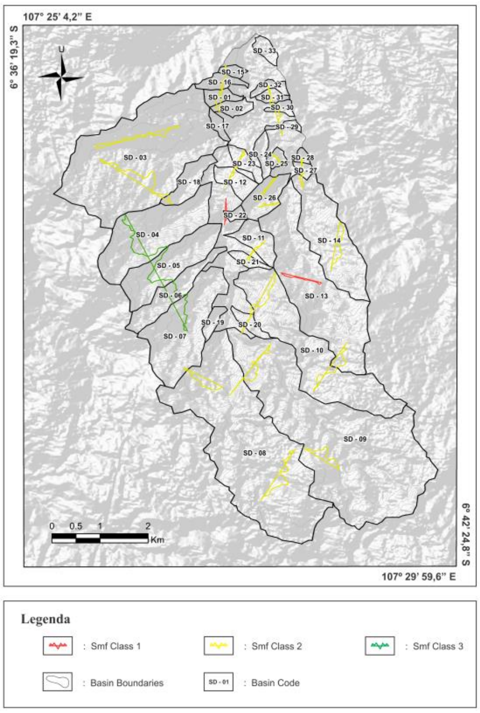

Figure 6.
Smf Map of study area

Ratio of Valey Floor Width to Valley (VF)

The calculation of the Vf value in the study area was carried out at 382 points which were spread evenly in each sub-basin of the study area. Based on the calculation results, it was found that Vf values varied in the study area is between 0.245 and 2.492 (table 7).

Table 7. Vf values of study area

Sub-basin	Vf	Class
SD - 01	0.953	2
SD - 02	0.88	2
SD - 03	0.499	1
SD - 04	0.492	1
SD - 05	0.47	1
SD - 06	0.898	2
SD - 07	0.496	1
SD - 08	0.934	2
SD - 09	1.186	3
SD - 10	1.328	3
SD - 11	0.879	2
SD - 12	0.879	2
SD - 13	1.09	3
SD - 14	1.346	3
SD - 15	2.462	3
SD - 16	1.659	3
SD - 17	1.765	3
SD - 18	0.749	2
SD - 19	0.499	1
SD - 20	0.457	1
SD - 21	0.435	1
SD - 22	0.463	1
SD - 23	1.132	3
SD - 24	0.742	2
SD - 25	0.842	2
SD - 26	0.505	2
SD - 27	0.506	2
SD - 28	0.588	2
SD - 29	2.421	3
SD - 30	1.531	3
SD - 31	2.492	3
SD - 32	1.593	3
SD - 33	0.77	2

Based on the map of the calculation of the Vf index in the study area (Figure 7), there are 8 sub-basin in the study area which are included in class 1. Class 1 sub-basin values are scattered in the western part of the study area which indicates that there is an uplift effect which tends to be dominant compared to the effect of erosion in the area. the. While 13 sub-basin are included in class 2 which are scattered in the southern part of the study area which indicates an increased erosion rate and offsets the uplift rate. Then 12 other sub-basin belonging to class 3 which are scattered in the eastern part of the study area indicate that the erosion rate is more dominant than the uplift rate that occurs.

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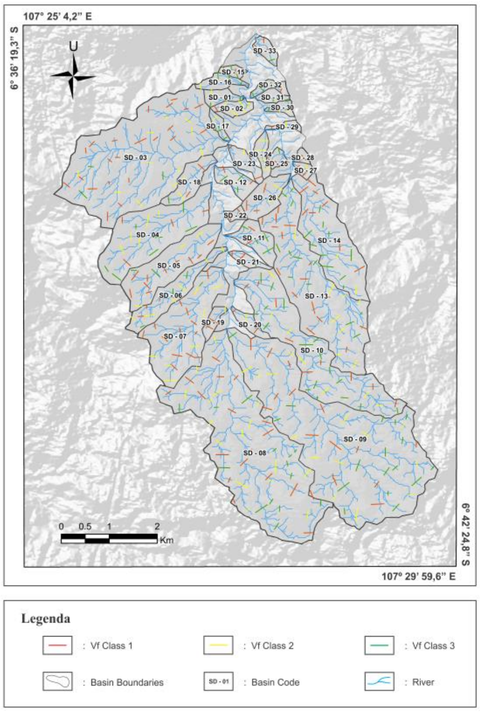

Figure 7.
Vf Map of study area

Asymetri Factor (Af)

Based on the calculation results, the Af values varied in the study area, namely between 14.649 and 80.160 (table 8).

Table 8. Af values of study area

Sub-basin	AF	Class
SD 1	37.906	2
SD 2	72.432	1
SD 3	52.172	3
SD 4	49.552	3
SD 5	42.85	2
SD 6	45.493	3
SD 7	38.83	2
SD 8	50.141	3
SD 9	58.656	2
SD 10	49.797	3
SD 11	65.194	1
SD 12	14.65	1
SD 13	42.381	2
SD 14	80.16	1
SD 15	60.199	2
SD 16	32.873	1
SD 17	47.064	3
SD 18	43.285	3
SD 19	48.495	3
SD 20	26.542	1
SD 21	45.322	3
SD 22	34.346	1
SD 23	58.342	2
SD 24	38.765	2
SD 25	24.942	1
SD 26	46.206	3
SD 27	70.306	1
SD 28	67.632	1
SD 29	62.904	2
SD 30	50.771	3
SD 31	63.693	2
SD 32	62.751	2
SD 33	50.39	3

Based on the map of the Af index in the study area (Figure 8), there are 10 sub-basin included in class 1 which indicates asymmetrical basin, 11 sub-basin are included in class 2 which indicates a slightly symmetrical (less tilting) basin, and 12 sub-basin are included in the in class 3 which indicates a relatively stable basin.

In the study area, the distribution of AF classes was random and did not reflect the dominant tilting area. However, based on the direction tilting of the basin, in the western part of the study area is tend to have a tilting direction towards the southeast which can be interpreted as there is a more dominant uplift occurring in the western part of the study area.

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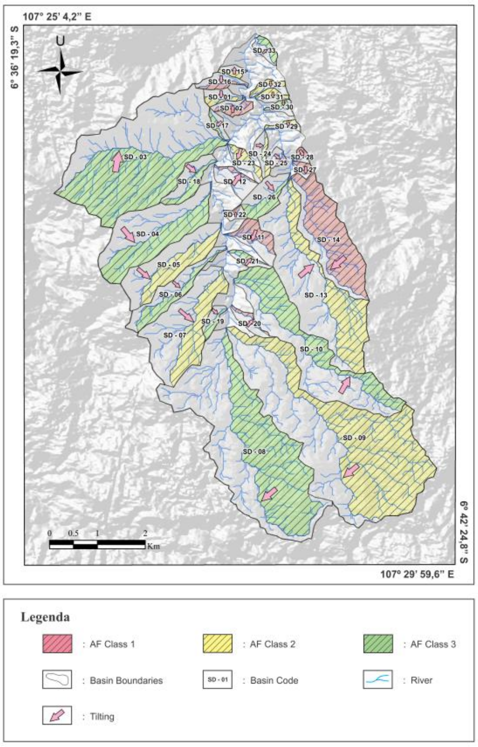

Figure 8.
Af Map of study area

Basin shape (BS)

Based on the calculation results, the BS index values were varied in the study area is between 1.117 and 5.753 (table 9).

Table 9. BS values of study area

Sub-basin	BS	Class
SD 1	2.094	3
SD 2	1.977	3
SD 3	1.856	3
SD 4	3.082	2
SD 5	3.348	2
SD 6	5.753	1
SD 7	1.86	3
SD 8	2.396	3
SD 9	1.987	3
SD 10	4.188	1
SD 11	2.152	3
SD 12	2.047	3
SD 13	2.77	3
SD 14	2.999	3
SD 15	2.285	3
SD 16	3.057	2
SD 17	3.004	2
SD 18	2.719	3
SD 19	3.378	2
SD 20	3.702	2
SD 21	4.182	1
SD 22	1.366	3
SD 23	3.099	2
SD 24	3.573	2
SD 25	1.117	3
SD 26	2.157	3
SD 27	1.535	3
SD 28	1.227	3
SD 29	3.289	2
SD 30	2.025	3
SD 31	2.276	3
SD 32	2.711	3
SD 33	2.035	3

Based on the map of the BS index calculation results (Figure 9), in the study area there are 3 sub-basin that are included in class 1, 9 sub-basin that are included in class 2, and 21 sub-basin that are included in class 3. Therefore, the research area tends to be dominated by class 3 which indicates that the study area tends to have a circular Sub-basin which indicates that the area tends to be more dominantly affected by erosion and experiences a cessation or reduction in tectonic activity from time to time.

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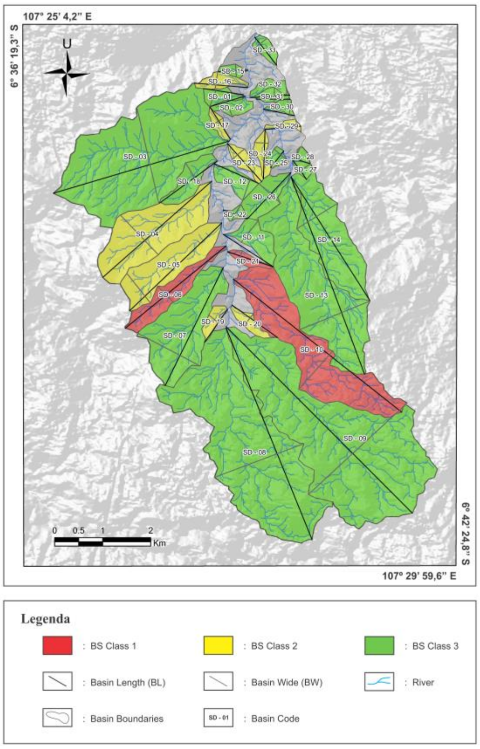

Figure 9.
BS Map of study area

Hysometri Integral (HI)

Based on the calculation results, the HI index values were varied in the study area is between 1.117 and 5.753 (Table 10).

Table 10. HI values of study area

Sub-basin	HI	Class
SD - 01	0.508	1
SD - 02	0.489	2
SD - 03	0.505	1
SD - 04	0.512	1
SD - 05	0.501	1
SD - 06	0.507	1
SD - 07	0.502	1
SD - 08	0.522	1
SD - 09	0.515	1
SD - 10	0.523	1
SD - 11	0.5003	1
SD - 12	0.499	2
SD - 13	0.506	1
SD - 14	0.489	2
SD - 15	0.489	2
SD - 16	0.499	2
SD - 17	0.501	1
SD - 18	0.5007	1
SD - 19	0.502	1
SD - 20	0.476	2
SD - 21	0.4998	2
SD - 22	0.493	2
SD - 23	0.468	2
SD - 24	0.499	2
SD - 25	0.492	2
SD - 26	0.504	1
SD - 27	0.499	2
SD - 28	0.498	2
SD - 29	0.474	2
SD - 30	0.5002	1
SD - 31	0.504	1
SD - 32	0.509	1
SD - 33	0.477	2

Based on the HI index calculation map (Figure 10), there are 18 sub-basin that are included in class 1, and 15 sub-basin that are included in class 2. Based on that, the study area tends to be dominated by class 1 which is spread dominantly in the research area where this indicates that The study area tends not to have much eroded land area and also indicates that the land in the study area is relatively young.

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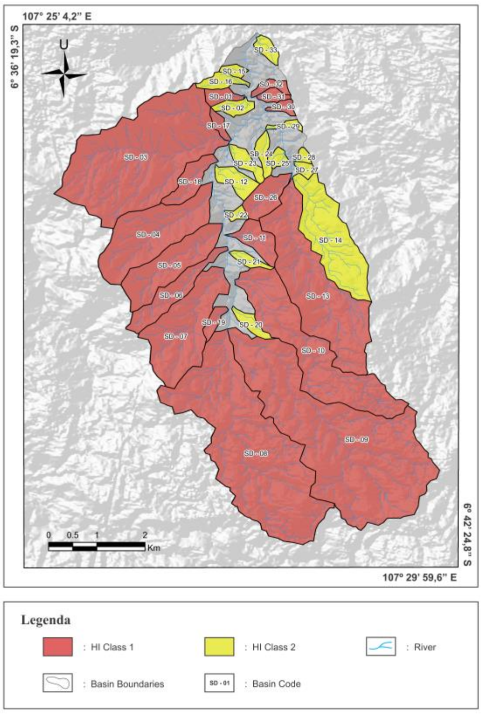

Figure 10.
HI Map of study area

RELATIVE TECTONIC ACTIVITY INDEX

Based on the calculation results of geomorphic indices, the Relative Tectonic Activity values were calculated (Table 11).

Table 11. IAT values of study area

Sub-basin	Geomorphic Index					IAT	Class
	Vf	Af	HI	BS	Smf		
SD 1	2	2	1	3	2	2	3
SD 2	2	1	2	3	-	2	3
SD 3	1	3	1	3	2	2	3
SD 4	1	3	1	2	-	1.75	2
SD 5	1	2	1	2	3	1.8	2
SD 6	2	3	1	1	-	1.75	2
SD 7	1	2	1	3	-	1.75	2
SD 8	2	3	1	3	2	2.2	3
SD 9	3	2	1	3	2	2.2	3
SD 10	3	3	1	1	2	2	3
SD 11	2	1	1	3	2	1.8	2
SD 12	2	1	2	3	2	2	3
SD 13	3	2	1	3	1	2	3
SD 14	3	1	2	3	2	2.2	3
SD 15	3	2	2	3	-	2.5	4
SD 16	3	1	2	2	-	2	3
SD 17	3	3	1	2	-	2.25	3
SD 18	2	3	1	3	-	2.25	3
SD 19	1	3	1	2	-	1.75	2
SD 20	1	1	2	2	-	1.5	2
SD 21	1	3	2	1	1	1.6	2
SD 22	1	1	2	3	-	1.75	2
SD 23	3	2	2	2	-	2.25	3
SD 24	2	2	2	2	-	2	3
SD 25	2	1	2	3	2	2	3
SD 26	2	3	1	3	2	2.2	3
SD 27	2	1	2	3	2	2	3
SD 28	2	1	2	3	-	2	3
SD 29	3	2	2	2	-	2.25	3
SD 30	3	3	1	3	2	2.4	3
SD 31	3	2	1	3	-	2.25	3
SD 32	3	2	1	3	-	2.25	3
SD 33	2	3	2	3	-	2.5	4

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Based on the map of the calculation of the Relative Tectonic Activity in 33 sub-basin (Figure 11) with an area of study area ranging from 43 km^2, the study area has 3 classes of tectonic activity, namely class 2 which reflects a high level of tectonic activity, class 3 which reflects medium level of tectonic activity and class 4 which reflects a low level of tectonic activity. In the study area, class 3 is the dominant class one with a distribution from north to south of the study area which occupies 79.8% of the total area of the study with an area of 31.4 km^2, while class 4 is spread in the northern part of the study which occupies 0.72%. research area with an area of 0.28 km^2, and class 2 spread in the western part of the study area occupying 19.5% of the study area with an area of 7.6 km^2.

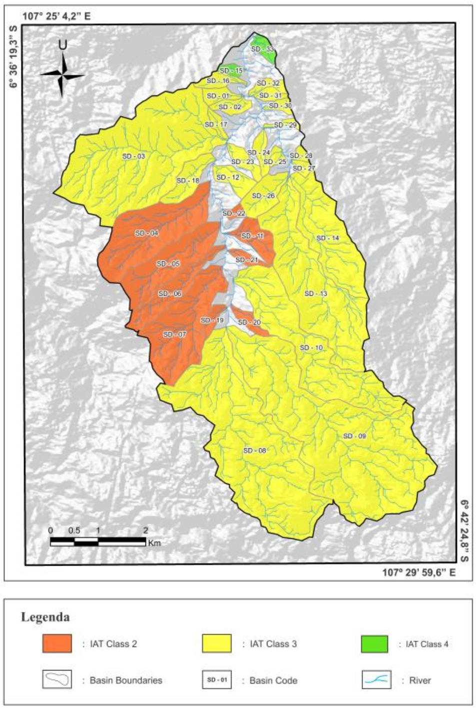

Figure 11.
Relative Tectonic Activity Map of study area

CONCLUSION

Analysis of the level of tectonic activity in the study area was carried out using 5 geomorphic index parameters namely, Smf, AF, HI, Bs, Vf. Based on the calculation of the Geomorphic Index which is summarized in the Relative Tectonic Activity Level Index (IATR), it is known that in the western part of the study area, tectonic influences tend to be more dominant than the erosional effects that occur. In contrast, in the northern part of the study area, the level of erosion is relatively more dominant than the level of tectonic activity.

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