THE LEVELS OF LEMBANG FAULT ACTIVITY BASED ON GEOMORPHIC INDEXES ON AROUND THE CIKAPUNDUNG WATERSHED, WEST JAVA

Lola Lintang Syalsabilla[1], Iyan Haryanto[2], and Emi Sukiyah[2]

[1]Undergraduate Program of Geological Engineering, Faculty of Geological Engineering, Universitas Padjadjaran

[2] Department of Geoscience, Faculty of Geological Engineering, Universitas Padjadjaran

Corrresponding author: lola16002@mail.unpad.ac.id; iyan.haryanto@unpad.ac.id; emi.sukiyah@unpad.ac.id

ABSTRACT

Lembang Fault is a fault in the highlands of Bandung, which has an East-West direction with a length of about 29 km. This fault greatly affects the landscape around the Cikapundung watershed, especially in the upstream. An analysis performed using the geomorphic index; Basin Shape, Mount Front Sinuosity, Asymmetry Factor, T – Index, Ratio of Valley Floor Width to Valley Height, and Relative Tectonic Activity. Based on the analysis using methods above, the level of tectonic in the Cikapundung watershed ranges from active to low. The presence of Lembang fault affects landscape, forming zone that borders the Bandung highlands and the Subang area in the north.

Keywords: Lembang fault, geomorphic indexes, tectonic,Cikapundung watershed, West Java

INTRODUCTION

Geologically, the Lembang fault is the most exciting landmark around the Bandung Highlands. The Lembang fault is one of the faults in the West Java region that has a West-East direction and has a fault-scarp that looks increasingly disappearing towards the West segment of Lembang fault. The Lembang fault is active even though its tectonic activity level has a low to intermediate.

Based on historical records, seismic activity in the Lembang fault is deficient and has a slip rate of only 1.95 to 3.45 mm per year (Daryono et al, 2019).

To determine the level of tectonic activity in an area can do with a morphometric analysis approach. According to Keller and Pinter (1996), morphometry defined as a quantitative measurement of the morphology of an area. This quantitative calculation uses geomorphic indication that can identify the tectonic characteristics of an area. With this analysis, information on the level of tectonic activity will obtain in the Lembang fault area, especially the Cikapundung watershed area (Fig. 1).

METHODOLOGY

To get the accurate analysis results, the several geomorphic indices are used to determine the level of tectonic activity in the Cikapundung watershed, namely: (1) Bs (Basin shape), (2) Vf (ratio of valley floor width to valley height), (3) Smf (Sinuosity of mount front), (4) AF (Asymmetry Factor), (5) T-Index and (6) IAT (relative tectonic activity).

Basin Shape

A high value of Bs (Basin shape) is associated with an elongated basin shape and usually associated with areas that have high tectonic activity. In contrast, a low Bs value indicates a rounded basin shape and usually associated with areas that have low tectonic activity (El Hamdouni et al., 2008). Bs Index classified into three classes, namely class 1 ($Bs \geq 4$), Class 2 ($3 \leq Bs \geq 4$), Class 3 ($Bs \leq 3$). Bs values can calculate using the following formula:

$$Bs = Bl / Bw \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Bl is the length of the basin, calculated from the highest point to the end of the basin, while Bw is the width of the basin, calculated from the widest.

The ratio of Valley Floor Width to Valley Height (Vf)

The ratio of valley floor width to valley height (Vf) is the value of the ratio between width and height of valleys in an area. The following equation calculates the value of Vf:

$$Vf = 2Vfw / (Eld\text{-}Esc) + (Erd\text{-}Esc) \ \ldots\ldots\ (2)$$

Vfw is the width of the valley floor, Erd and Eld are the elevation of the right and left of the valley, Esc is the elevation of the valley floor. A high Vf value is associated with a low lifting speed, while a low Vf value is associated with a high lifting speed.

E-ISSN : 2579 – 3136

Sinuosity of mount front (Smf)

Bull and McFadden (1977) define the sinuosity of mount front (Smf) as a comparison between the length of a mountain face (Lmf) and the length of a mountain face projection to a flat plane (Ls). Smf close to 1, is an increase in alignment near the ideal, which indicates an indication of active uplift. Enlarged sinuses reflect the water-streams or rivers that cut through mountain-plain boundary walls. Smf can calculate using the following equation:

Smf = Lmf / Ls ………………………..… (3)

Lmf is the length of the advance ridge along the bottom, and Ls is the straight length of the advance ridge.

Asymmetry Factor

The asymmetry factor is a way to determine the tectonic slope of a watershed unit. This method of calculation applied to large areas. According to Hare and Gardner (1985, in Keller and Pinter, 1996), Asymmetry Factor (AF) calculated using the formula below:

AF = (AR / AT) x 100 ……………….. (4)

AR is the area of the right side of the river basin (water flow downstream), while AT is the area of the river basin. According to Keller and Pinter (1996), if the value obtained AF = 50, then the area is relatively stable, meaning that the tectonic process that works is minimal. If the AF value is higher or less than 50, that means the area has a slope effect by tectonic activity.

T-Index

Morphotectonic analysis to determine the geological conditions of an area, including the watershed, can be done with a T-Index. T calculations use to detect lifts based on the asymmetry of a watershed. For watersheds that are symmetric, T = 0, and the value is greater to T = 1 according to the increasingly asymmetrical watershed (Keller and Pinter, 1996). The T index formula is:

T = Da / Dd ………………………… (5)

Da is the distance of the watershed centerline with the river line, while Dd is the distance of the watershed centerline with the sub-watershed or basins.

Relative Tectonic Activity

Several studies show the analysis of relative tectonic activity with the help of several geomorphic indices, such as Sl, Vf, Smf, HI, Af, Bs, and T (El Hamdouni et al., 2008). Each geomorphic index classified into three classes, where class 1 and class 3 show high and low tectonic activity.

The (IAT) geomorphic index value (S/n) is the average of the different four classes. Class 1 is an area with very high tectonic activity ($1 < S/n < 1.5$). Class 2 is an area with high tectonic activity ($S/n \geq 1.5$ but < 2). Class 3 is an area with moderate tectonic activity ($S/n \geq 2$ but < 2.5), and class 4 is an area with levels Low tectonic activity ($S/n \geq 2.5$) (El Hamdouni et al., 2008).

RESULT AND DISCUSSION

Basin Shape Analysis

Bs calculation performed on sub-watershed in Cikapundung Watershed has values ranging from 1.79 to 4.08. Based on El Hamdouni classification (2008), which divides Bs into three classes, the sub-watershed that have high Bs values are SD-6, sub-watershed that have medium Bs values namely SD-5, SD-9, SD-10, while the rest have low Bs values (Fig.2).

Based on the results of calculations, the Cikapundung watershed dominated by watersheds, which is quite rounded. Low seismic activity Cikapundung watershed, which is influenced by the Lembang Fault, so the form of sub-watershed that used to elongated due to high tectonic activity around the Lembang fault became rounded along with tectonic evolution which was getting lower. The southern area of the Lembang fault has a dominant elongated sub-watershed form than the Northern area. This dominant elongated because the South region has a more dominant uplift.

Analysis of Ratio of Valley Width to Valley Height

The ratio of width and height of the valley (Vf) in the Cikapundung watershed is carried out in each river order from upstream to the downstream and spread in the study area. The maximum data, the calculation area, expanded to be able to interpret the effect of the Lembang fault on the Vf value in the study area. Vf values at the study sites ranged from 0.1 to 8.7 (Fig. 3). Lithology factors can also be one of the causes of the river valley in this study area looks steep with a narrow valley width. In areas that have steep slope is the response of the valley due to vertical erosion that is much greater than horizontal erosion.

The location of the Vf calculation in the Lembang Fault area is carried out in the river valley from upstream to downstream, spreading from west to east. In some rivers

E-ISSN : 2579 – 3136

that past the Lembang Fault, it can see on the graph that the Vf value decreases as it approaches the Lembang Fault line and grows again after passing it. Based on the value of Vf in the valley around Lembang Fault that low, it interprets the existence of steep and deep valleys due to the bottom of the river. Based on the calculation results, it can conclude that the Lembang Fault structure controls the steep valleys in the study area.

Analysis of Sinuosity of mount front

The Smf calculation carried out at the Cikapundung watershed, which scattered at the study site. The Smf value is a reflection of the balance between the erosive forces that cut along the ridges of the face mountains and the tectonic forces that produce the mount-front. This mount-front relates to a series of active fault zones (Keller & Pinter, 1996). Based on the results of Smf calculations, the Cikapundung watershed area dominated by active tectonic activity. Smf values in the study area ranged from 1.05 to 2.26 (Fig. 4, Table 1). The smallest Smf value is at SD-1, where there is a Lembang Fault in the sub-watershed. Based on the dominance of the level of active tectonic activity, it can conclude that the study area already experienced a reasonably widespread deformation.

Asymmetry Factor Analysis

Calculation of AF on the Cikapundung watershed use to determine the tectonic slope that is developing in the area. According to Keller and Pinter (1996), if the value obtained by AF = 50, then the area is relatively stable, meaning that the tectonic process that works is minimal. If the AF value is higher or less than 50, then a tectonic slope occurs. Based on the results of calculations, it can conclude that all the sub-watershed in the Cikapundung watershed have experienced a slope due to tectonic movements.

AF values range from 14 to 69 (Fig. 5). AF values effected by uplift dominated by sub-watershed in the South area. That is because a higher uplift has effected the South area than the North area.

Analysis of T-Index

The T index calculation finished on all sub-watershed. If there is no tectonic activity, the main river will flow into two equal sub-watershed, and the T index value is 0. The main river used for the calculation of the T index is the 4th order rivers (SD-1, SD-2, SD-3, SD-4, and SD-9) and the 2nd order rivers (SD-5, SD-6, SD-7, SD-8, SD-10). Based on the calculation of the T index, which ranges from 0.18 to 0.8, the sub-watershed, which has high tectonic activity, are sub-watershed four and the sub-watershed, which has the smallest tectonic activity is sub-watershed 3 (Fig. 6).

Analysis of Relative Tectonic Activity

Based on IAT, the Cikapundung watershed divided into three levels of relative tectonic activity, namely level 2, which is the level of active tectonic activity, level 3, which is a level of moderate tectonic activity, and level 4 which is a level of low tectonic activity (Fig 7). In the west of the study area has a higher tectonic level than the east area.
Also, based on earthquake data from the research of Rasmid and colleagues in 2011, in the Lembang Fault, there were about a dozen small earthquakes that occurred with depths ranging from 2 to 30 km (Rasmid, 2014). The earthquake that occurred in the Lembang fault had a dominant location in the Western block, which is around the Gunung Batu, Bosscha, Cihideung, and Ngamprah (Rasmid & Ramdan, 2014). While the earthquake that occurred in the Eastern block, namely the Maribaya. So based on the above analysis, it can be concluded that the level of tectonic activity in the West Block of the Lembang fault (the west of Cikapundung River) is higher than the East Block.

ACKNOWLEDGMENTS

The authors would like to thank all those who supported, so that this article can be published in scientific journals.

CONCLUSION

Based on geomorphic indexes analysis such as basin shape, Vf, Smf, AF, T-Index, IAT (relative tectonic activity), and earthquake data based on previous studies, the morphology along the Lembang fault. Especially the Cikapundung watershed shows that the area included active tectonics, which is the dominant low to middle.

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E-ISSN : 2579 – 3136

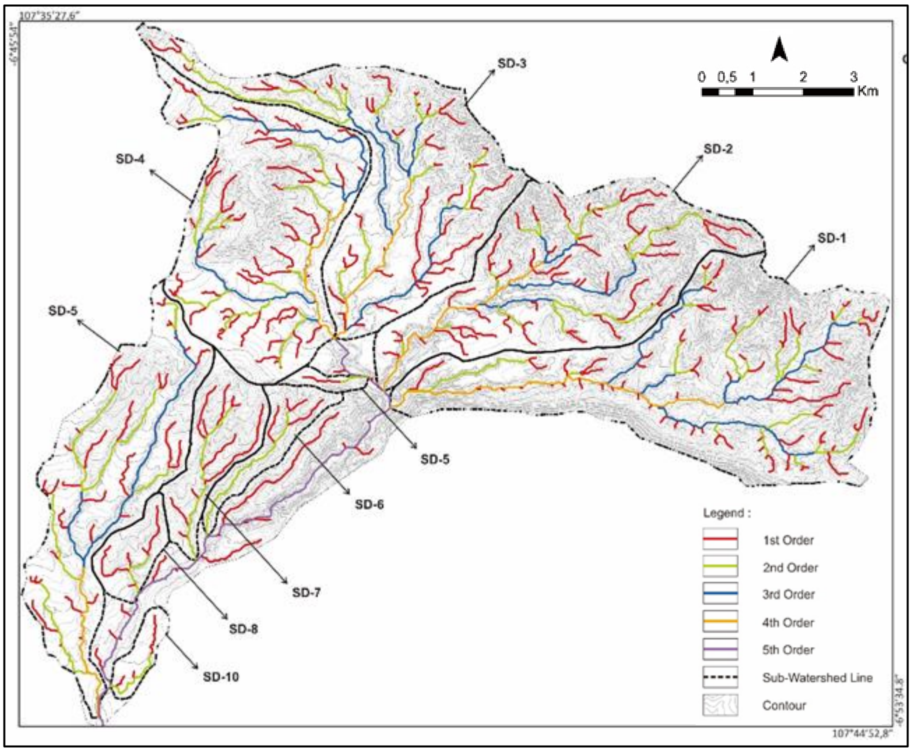

Fig. 1. The distribution map of sub watersehed and stream order in Cikapundung watershed

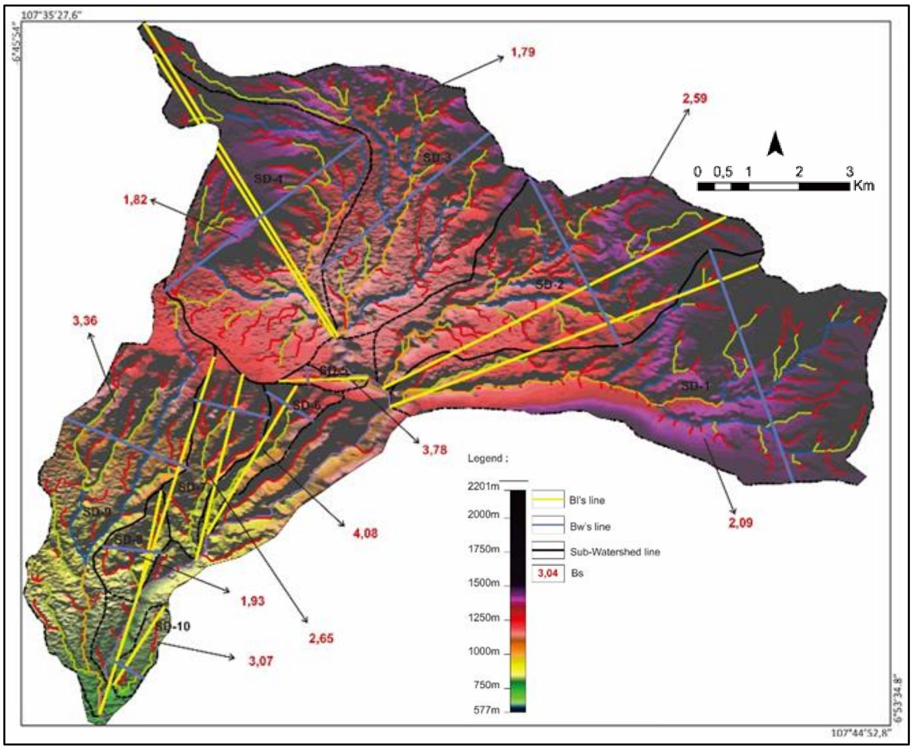

Fig 2. The distribution map of basin shape values

E-ISSN : 2579 – 3136

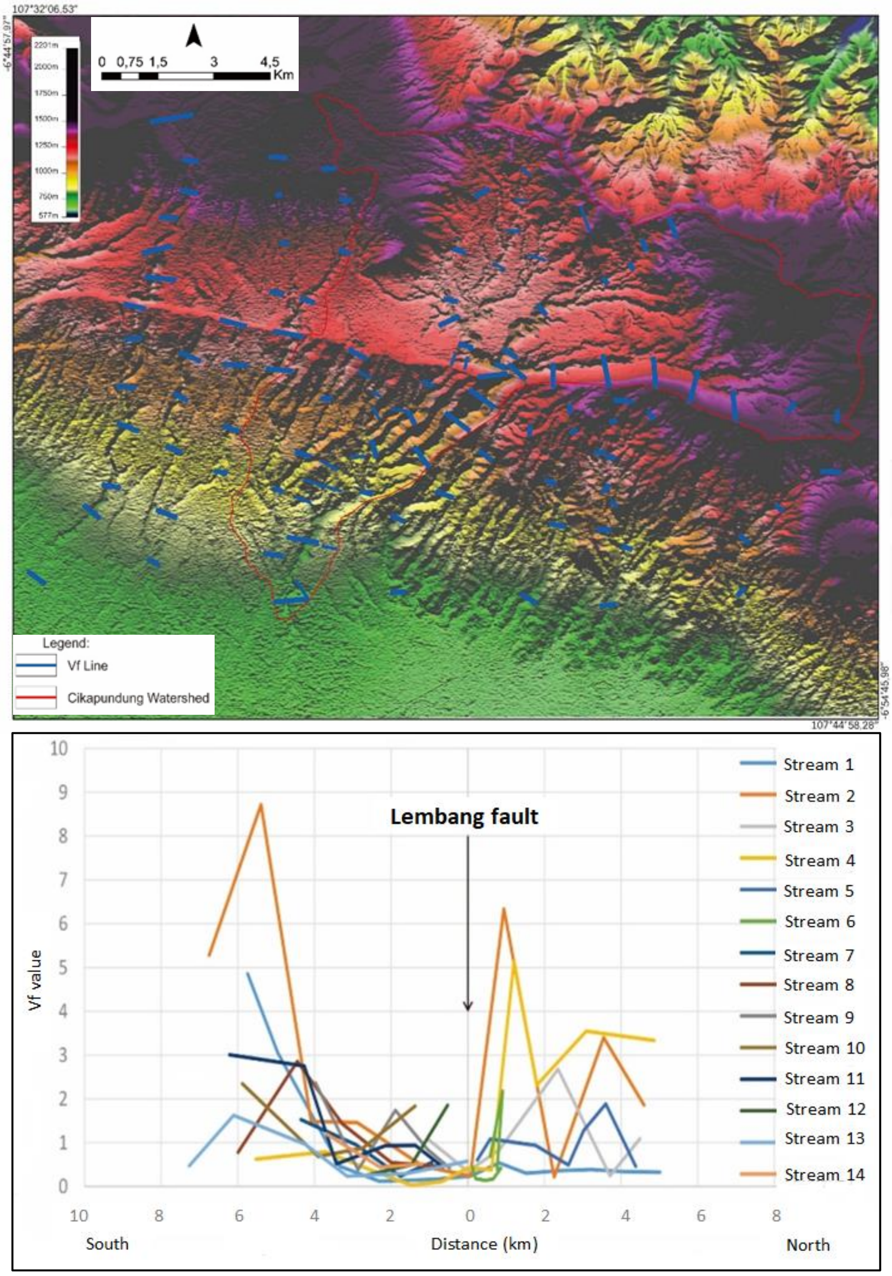

Fig. 3. Distribution of Vf values in the Cikapundung watershed based on the distance to the Lembang fault

E-ISSN : 2579 – 3136

Table 1. The result of Smf analysis in Cikapundung watershed

Sub Watershed	Smf	Level of tectonic activity (Bull & Mc Fadden, 1977)	Deformation Rate
SD-1	1.05	Active	High deformation
	1.22	Active	High deformation
SD-2	1.68	Active	High deformation
	1.29	Active	High deformation
	1.44	Active	High deformation
SD-3	1.31	Active	High deformation
	2.03	Moderate	Medium deformation
	1.94	Moderate	Medium deformation
SD-4	1.41	Active	High deformation
	1.31	Active	High deformation
SD-6	1.31	Active	High deformation
	1.19	Active	High deformation
SD-7	2.26	Moderate	Medium deformation
	1.16	Active	High deformation
SD-8	1.45	Active	High deformation
SD-9	1.22	Active	High deformation
	1.07	Active	High deformation
	1.44	Active	High deformation

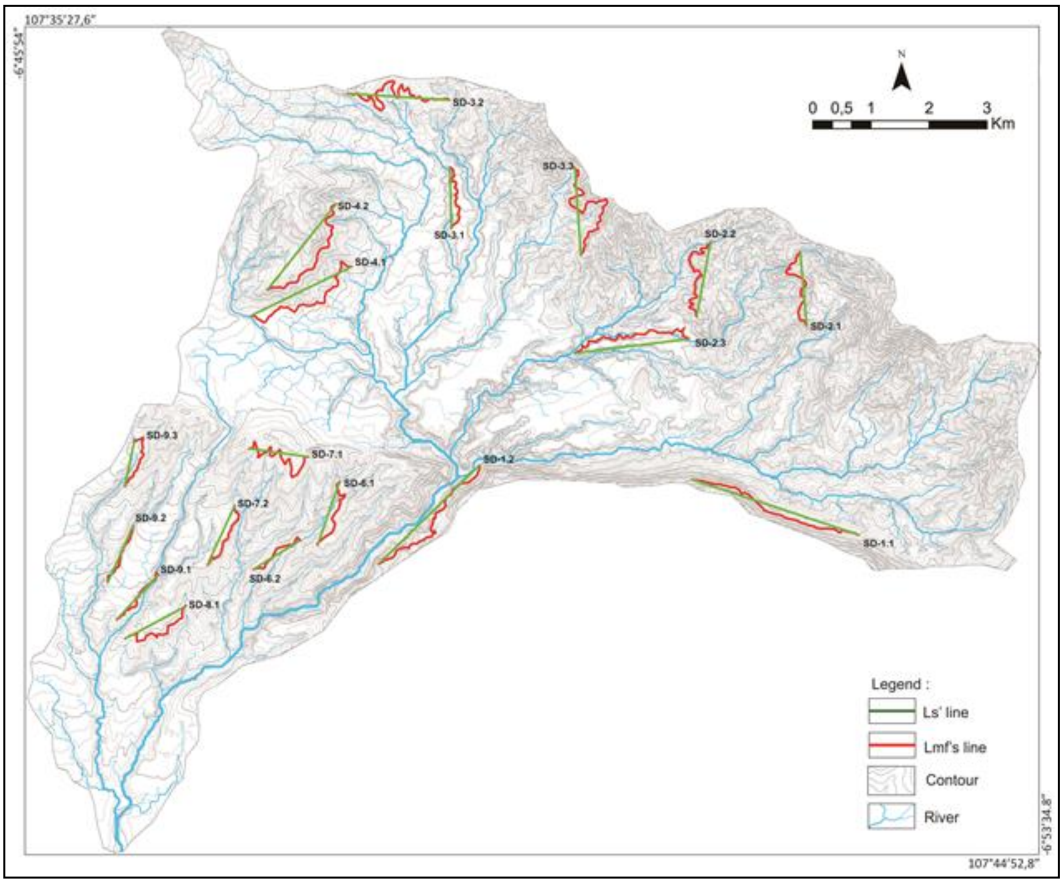

Fig. 4. The distribution map of Smf values

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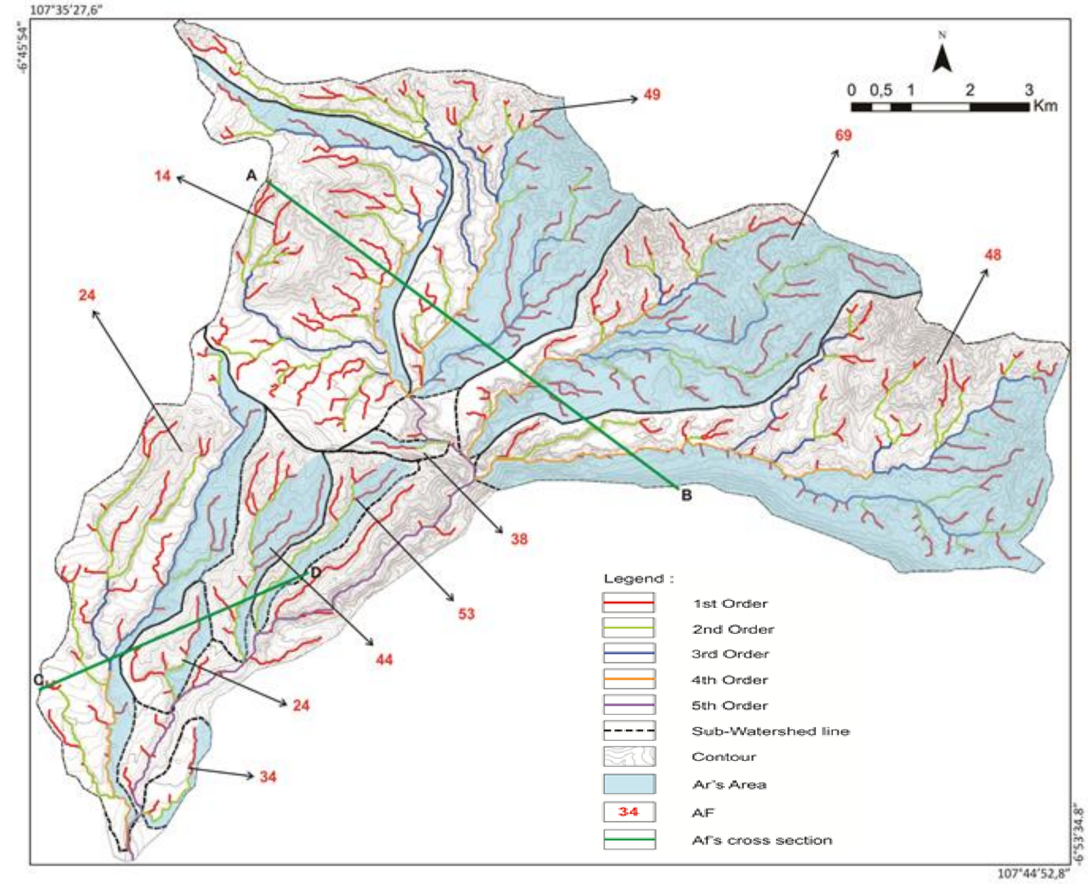

Fig. 5. The distribution map of Asymmetry Factor values

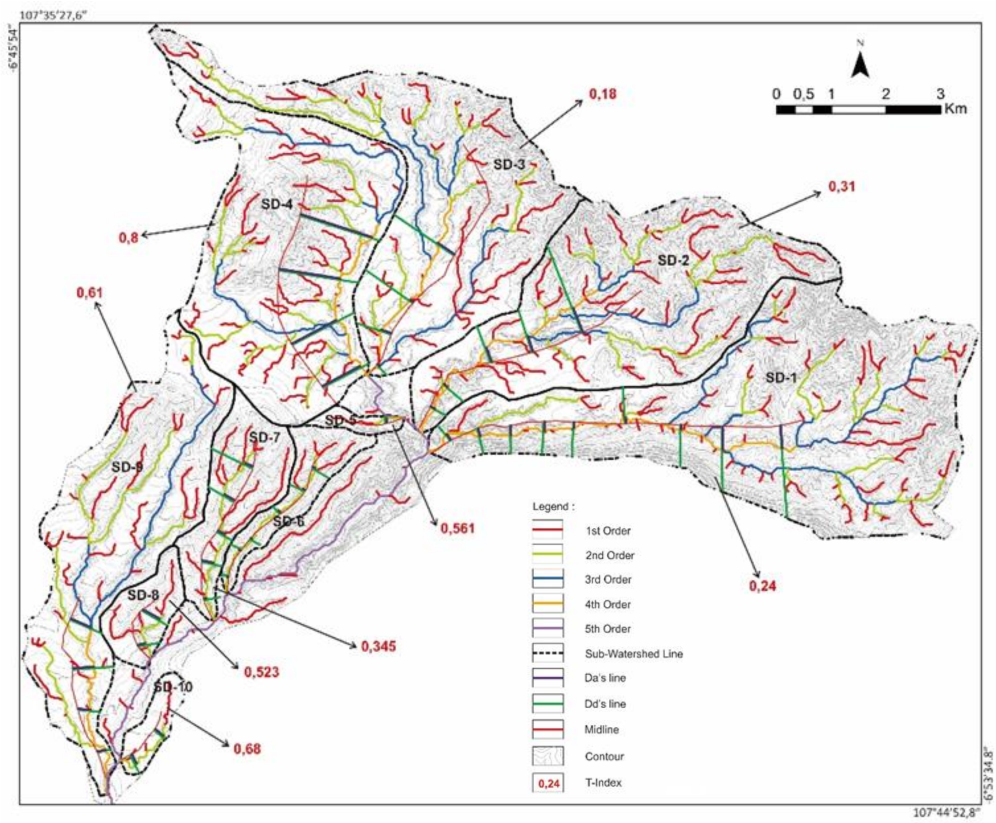

Fig. 6. The distribution map of T-Index values

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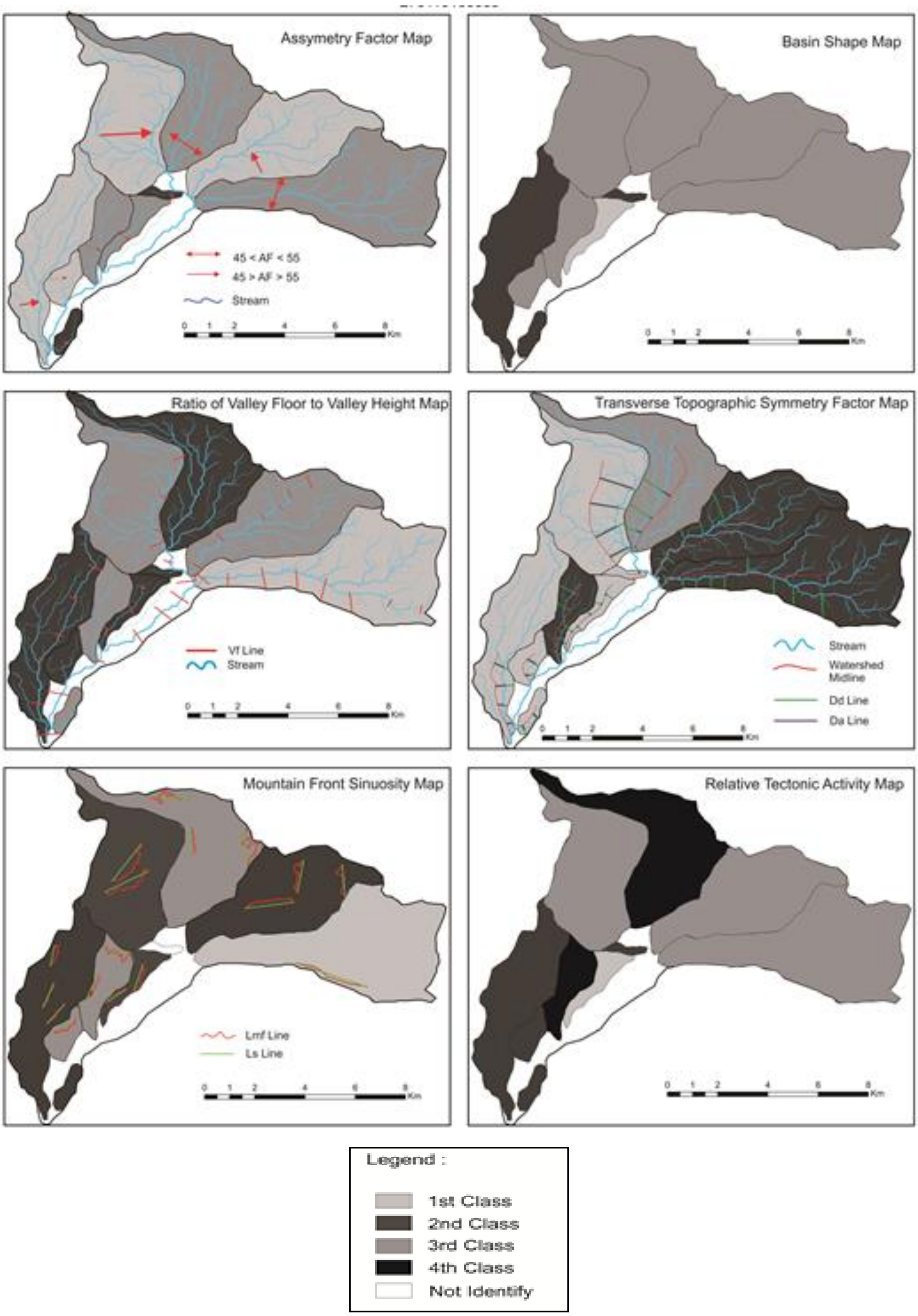

Fig 7. The morphotectonic map of Cikapundung watershed

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