MORPHOMETRY AND MORPHOTECTONIC OF CIANTEN AND CISAAT WATERSHED ON QUATERNARY VOLCANIC TERRAIN, GARUT, WEST JAVA

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ABSTRACT

The research area is located in the Baluburlimbangan, Garut regency, West Java Province. Geographically, the research area is located at 107° 52' 23.32" E - 107° 59' 30.04" E and 6° 57 '28.21" S - 7° 3' 39.23" S. Research object comprise Cianten and Cisaat watershed which will be compared based on morphometric and morphotectonic parameters. Observations carried out directly in the field and data analysis carried out in the studio. Research result shows that research area can be classified into medium – weak active tectonic area. It is proved by bifurcation ratio (R_b), drainage density (D_d), and sinuosity of mountain front (Smf). Active tectonic condition is also indicated by geology structure formed in research area such lineament of ridge and valley, and drainage pattern.

Keywords: *Cianten, Cisaat, morphometry, morphotectonic, watershed*

INTRODUCTION

Watershed has an important role in the development of science, especially in relation to geological process. Indonesia archipelago is one of the most active tectonic area due to several tectonic activities such as subduction, collision, volcanic eruption, and others. Tectonic activity has created an attraction for the earth science experts who conduct activities in Indonesia (Simandjuntak, 2004). Java is one of the most active tectonic area in the Indonesia. Cisaat and Cianten watershed are the research area (Figure 1) will be distinguished based on several geological factors. Also, there is a need for further analysis in these two watersheds that include both qualitative and quantitative.

RESEARCH METHODS

The research objects are the morphometry and morphotectonic characteristics of the Cianten and Cisaat sub-watershed include drainage patterns, watershed dimensions (area, length, width, and shape), river order, bifurcation ratio (R_b), drainage density (D_d), and sinuosity of mountain front (Smf), ridge and valley lineaments. This research uses Regional Geological Map of Bandung (Silitonga, 1973) and Garut-Pemeungpeuk (Alzwar et al., 1992), Map Info, and Microsoft Excel software.

This research is divided into several stages, namely preparation, field work, data collection, data processing, and report writing. The data processing involves various kinds of variables from the data collection. Morphometry and morphotectonic variables can be obtained from DEM analysis, topographic map, and geological map. Characteristics and variables of morphometry and morphotectonic can be obtained from the data processing.

The drainage pattern can reflect the geological conditions of the research area. Determination of drainage pattern in Cianten and Cisaat watershed, determined by classification of drainage pattern according to Howard (1967) (Figure 2).

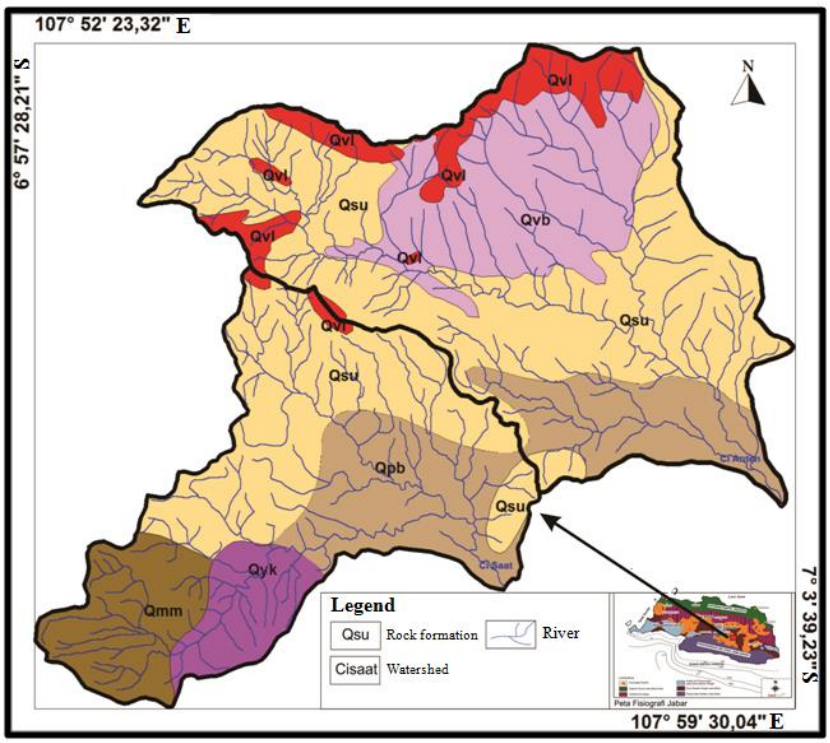

Figure 1. The research area

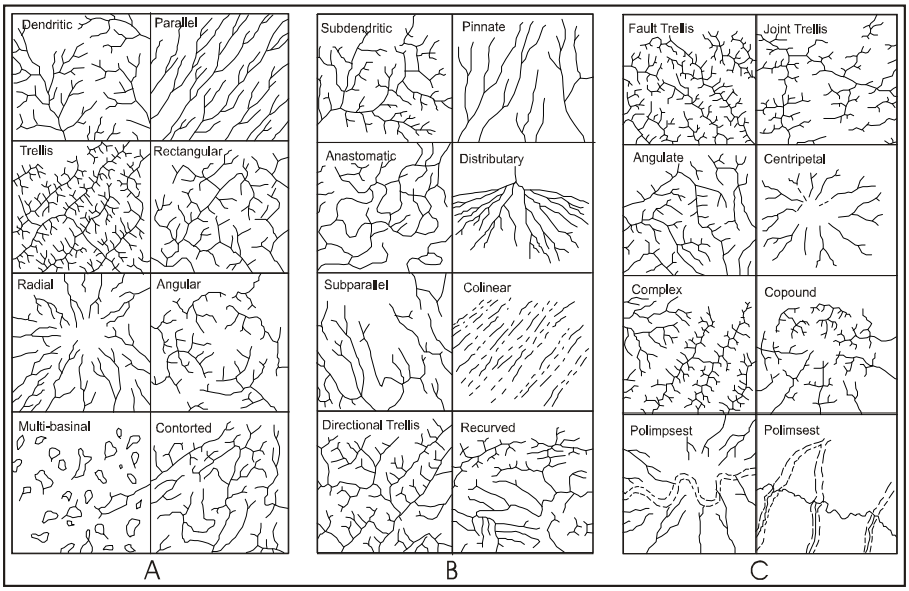

Figure 2. Basic drainage pattern (A) and Modified drainage pattern (B and C)

The watershed dimensions that cover the area, length, and width of the watershed and sub watershed can be calculated using the formula (Priyono and Savitri, 1997; in Hidayah, 2008) as follows:

$$A = w \times Lb$$

A is the area of the watershed (km^2), w is the width of the watershed (km), Lb is main river length (km).

The determination of sub-watershed shape of Cianten and Cisaat river is done by comparing with the shape of the watershed according to Ramdan (2006) (Figure 3). Determination of river order in research area can be done based on Strahler method (1952) (Figure 4).

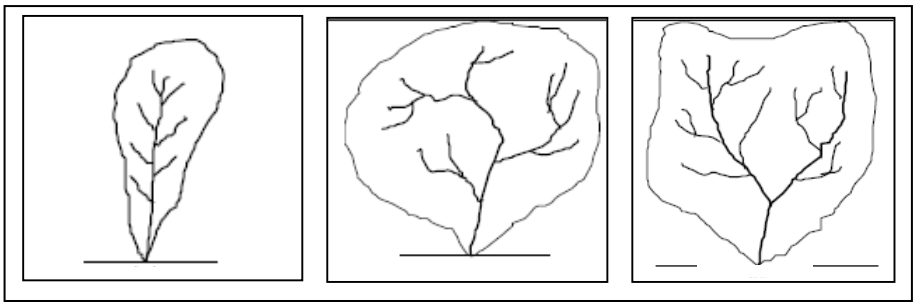

Figure 3. Variation of watershed shape

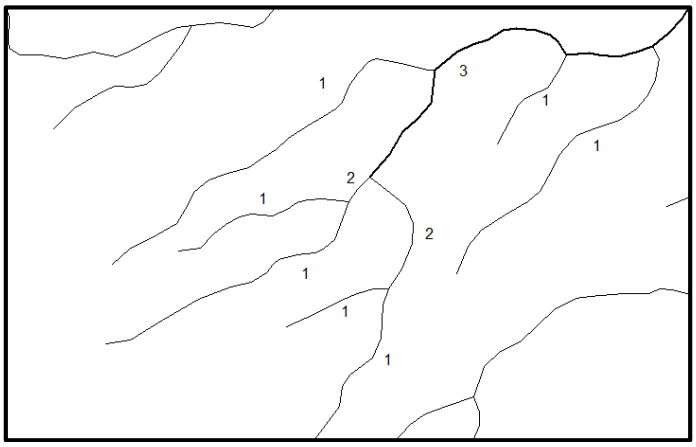

Figure 4. Strahler method of river order determination

The number of segments in an order with the number of segments in the next higher order will be found its index number which states the bifurcation ratio (Rb), can be calculated by the following formula:

$$\mathbf{R_b} = N_i / N_{i+1}$$

Rb is the ratio of the river branch or bifurcation ratio, Ni is the number of river segments in an i order, Ni+1 is the number of river segments in the i+1 order. Verstappen (1983) states that if a watershed has a ratio of river branch or bifurcation ratio (Rb) of less than 3 or more than 5, it can be indicated that the watershed has been deformed due to tectonic influence.

Drainage density (Dd) is a number indicating the total length of the river of a catchment divided by the area of drainage. It can be calculated using the formula:

$$\mathbf{D_d} = \frac{L}{A}$$

Dd is the river density index, L is the total length of all river segments (km), A is the watershed area (km^2).

Morphotectonic analysis is related to sinuosity of mountain front (Smf), lineament of the ridge and valley and structural analysis. Analysis of lineament of the ridge and valley is done to determine the direction of lineaments of the ridge or valley which is useful for comparison with the direction of the river flow.

Sinuosity of mountain front (Smf) is an index that reflects the balance between the erosion strength which has a tendency to cut along the curve of the mountain range and the tectonic that produce ridges directly and coincides with the active fault zone reflecting active tectonics. The value of Smf can be calculated using the formula (Keller and Pinter, 1996):

$$\mathbf{Smf = Lmf / Ls}$$

Lmf is length of mountain front along the valley, Ls is the length of straight mountain front.

Table 1. Classification of tectonic activities based on sinuosity of mountain front (Doornkamp, 1986)

Class	Smf	Tectonic Activity	Notes
1	1.2-1.6	Active Tectonic	Associated with alluvial fan landform, elongated-shape watershed, narrow valley floor, a steep slope.
2	1.8-3.4	Weak to Moderate Tectonic	Associated with alluvial fan landscape, watershed extends, steep slope, the valley floow is wider than the flood plain
3	2.0-7.0	Inactive Tectonic	Associated with the mount-front landform pediment and embayments, only a steep slope on rock layers resistant, valley widened and integrated.

Geological structure analysis can be done by using topographic and regional geological map. The geological structure is also supported from the analysis of lineament of the ridge, sinuosity of mountain front (smf), and field data.

RESULT AND DISCUSSION

Based on the drainage pattern analysis, the research area has four drainage patterns, namely subdendritic, trellis, parallel, and subparallel drainage pattern. Where the subdendritic and trellis drainage patterns can be found in Cianten watershed whereas the parallel and subparallel drainage patterns can be found in Cisaat watershed.

There are 20 Cianten Sub-watersheds and 12 Cisaat sub-watersheds in the research area. Cianten watershed area has 44.9 km^2 area with the maximum length of the main river is 14.97 km, so that its maximum width is 2.99 km. Cisaat watershed has 30.41 km^2 area with maximum length of the main river is 12.06 km, so that its maximum width is 2.52 km. Cianten sub-watershed has its width ranged from 0.25 km^2 (S16) - 13.17 km^2 (S15) with a total sub area of 36.92 km^2 and has an average area of 1.85 km^2 while the Cisaat sub-watershed has its width ranged from between 0.29 km^2 (R7) - 10.49 km^2 (R11) with a total area of 24.17 km^2 of basin and has an average area of 2.01 km^2. From those data, it can be concluded that the average water catchment of each Cianten sub watershed is smaller than the Cisaat sub watershed. But it can be seen from the total area of the sub-watershed, that Cianten sub-watershed total area is larger than the total area of Cisaat sub-watershed. It is because there are more Cianten sub-watershed than the Cisaat. Calculation of drainage density (Dd) can be obtained through this sub watershed area.

Geologically, the scale of catchment area can be known through this area calculation. The larger area of a watershed or sub-watershed, the greater its ability to catch water falling and passing through the watershed or sub-watershed.

Watershed shape determination can be done by comparing between the model of watershed area of research and the form of watershed Sosrodarsono and Takeda (1987) and Ramdan (2006). Cianten watershed has 15 sub-watersheds of bird-feather shape, 2 sub-watersheds of sub parallel shape, and 3 sub-watersheds of complex shape. Cisaat watershed has 8 sub-watersheds bird-feather shape, 4 sub-watersheds of parallel shape. It can be concluded that the Cianten and Cisaat watershed is dominated by sub-watersheds with bird-feather shape. A bird-feather shape has a characteristic of relatively small flood discharge compared to other sub-watersheds. It happens because the water concentration is more longer contained in the elongated shaped watershed or sub-watershed compared to elongated or circular shaped watershed or sub watershed (Asdak, 1995).

The Cianten sub-watershed has a range from 1^{st} order to 5^{th} order with a total of 218 river segments with the total number of river segment as a whole reaching 134.73 km. In the Cisaat sub-watershed has a range from the 1^{st} to 4^{th} order with the total segment of the river as much as 162 segments with the total number of river segment as a whole reaching 101.05 km. The value of the number of river segments in a sub-watershed is directly proportional to the number of river segments present within the sub-watershed itself. The greater the number of river segments indicates the number of branches in a sub-watershed. So it can be concluded that branching in Cianten watershed more than Cisaat

watershed, river order in Cianten watershed is larger than that of Cisaat watershed and total length of Cianten watershed is bigger than Cisaat watershed. From the processed data can also be distinguished the branching of each river order in both watersheds. Where in Cianten watershed with the largest segment number of 1st order segment is found in S15 sub-watershed which are 26 segments, 2nd order in S15 with 15 segments, 3rd order in sub-watershed S11 with 9 segments, and 4th order on S15 sub-watershed with 6 segments. While in Cisaat watershed, the largest order segment was found in R11 sub-watershed, which are 32 segments, 2nd order in R11 with 18 segments, and 3rd order in sub-watershed R11 with 12 segments. While from the total number of segments in the sub watersheds of both watersheds, the largest segment is found in sub watershed R11 of Cisaat watershed which is 62 river segments while S15 sub watershed Cianten only has 51 river segments. From the total segment, it can be concluded that the sub-watersheds of both watersheds with the largest branches are in Cisaat watershed which is sub watershed R11. The ratio of river branch in Cianten watershed with the smallest Rb value is of the order of 4-5 which is 1 and the largest Rb value is in the order of 2-3 which is 3.83, while in the Cisaat watershed with the smallest Rb value is the order 1-2 which is 1.67 and the largest Rb value is in the order of 2-3 which is 2.45. Determination of river branch ratio in each sub watershed in Cianten watershed and Cisaat watershed also use the equation as above. The result of comparison from both watershed have calculation result of Rb value that shows not too different, in Cianten watershed has a total of 39.33 and average Rb value of 1.97 whereas in Cisaat watershed has a total of 18.99 and an average Rb value of 1.58. The calculation results in terms of numbers have significantly different value but the value of Rb has a range that is not too far, it shows that between the Cianten watershed with Cisaat watershed genetically does not have a significant difference. It is seen from each sub watershed in both watersheds that in Cianten watershed the smallest Rb value is found in sub watershed S13, S14 and S17 is 1.5 and in Cisaat watershed the smallest Rb value is found in sub DAS R9 1,17. Cianten watershed with the largest Rb value is found in the S19 subwatershed which is 3.2 and the largest in Cisaat watershed is in the R2, R4 and R7 sub watersheds which is 2. It is seen from the Rb value that Cianten watershed has Rb value in the range of 3-5 on the S19 sub-watershed which is 3.2 whereas in the Cisaat watershed there is not even a subwatershed that included in the range of 3-5. This shows that in Cianten watershed there are sub watersheds that are not exposed to deformation whereas in Cisaat watershed all sub watersheds have been affected by deformation. Although the Rb value of the S9 subwatershed is included in range of 3-5 does not mean that the Cianten watershed is not subject to deformation because interpretation is based on the average or dominant value of each subwatershed.

This geological identification based on the Rb value of less than 3 indicates that the Cianten and Cisaat watersheds in the research area have been deformed and have many river branches formed by the tectonic effects that develop in the area (Strahler, 1964 in Verstappen, 1983). This is also supported by the lineaments on DEM and river anomaly as well as descriptive analysis in the field.

Based on the value of drainage density it is shown that Cianten watershed and Cisaat watershed has a value of density that is not too much different which are 3 and 3.32 from the above calculation, both watersheds are classified as medium density (Sukiyah, 2009). Drainage density levels are indicating that in general the river in both watersheds have hard resistance rocks. Based on the equation above, the drainage density value in each sub watershed of both watersheds can also be calculated. In the sub watershed Cianten has a drainage density of 3 and the Cisaat Sub watershed has a density of 3.32. It is seen from Rb value of each sub watershed that sub watershed in Cianten watershed has 2 textures that is coarse and medium where coarse texture is in sub watershed S5, S6, and S 15 with value which is in the range of 1,380-2,759. In the Cisaat watershed the coarse texture is located in the R6 sub watershed. The result of the calculation of the drainage density value shows that the sub watershed in Cianten watershed has a drainage density (Dd) with values ranging from 2.54 to 4.38 with an average of 3.46 whereas the sub watersheds in Cisaat watershed have drainage density (Dd) ranging from 2.33 to 5.88 with an average of 3.93. The average Rb value of the two largest catchments is owned by Cisaat watershed. The calculation results of the average drainage density in the two watersheds shows values that is not too much different which is in the range value of 2.760-4.139. It can be concluded that the overall value of sub watersheds in both watersheds are categorized as medium, although on some subwatersheds of both watershed are included in the coarse texture but this conclusion is based from its dominant or average value. The medium category of Dd shows that the condition of the river has a medium resistance rock, so the distance between the streams is slightly tenuous.

Table 2. Smf calculation in research area

Watershed	Lmf (m)	Ls (m)	Smf
Cianten	4.553	3.293	1,38
	8.779	4.368	2,01
	3.595	2.234	1,61
	8.460	3.950	2,14
Cisaat	4.043	3.324	1,22
	4.757	3.694	1,29
	5.773	2.766	2,09

Based on above smf results, it can be seen that the value of smf in the research area ranged between 1.38 - 2.14 on the Cianten watershed and 1.22 - 2.09 on the Cisaat watershed. It indicates that the Cianten and Cisaat watershed are classified into medium to weak active tectonic.

The result of ridge lineaments analysis on Cisaat watershed shows there are 14 lineaments with length between 487 to 2,462 meters and has the dominant direction of north-west direction with azimuth 60° - 168° based on the ridge lineament data that has been processed using rossette diagram. The result of the analysis of the valley lineament pattern in the Cisaat watershed shows there are as many as 19 alignment with a length of between 394 meters to 3,456 meters and has a dominant direction of north-west direction with azimuth 67° - 229° based on the data of straightness pattern that has been processed by using rosette diagram. The pattern of lineament of the ridge and valley can be concluded that the dominant alignment in the research area has a northwest-southeast direction with azimuth between 60°-229°.

CONCLUSION

Morphometry and morphotectonic can be used to determine Cianten and Cisaat watershed characteristics. The drainage pattern in the Cianten watershed is subdendritic and trellis pattern with dominated by bird-feathers shape sub-watersheds. The drainage pattern in Cisaat watershed is parallel and subparallel patterns with dominated by bird-feather shape sub-watershed. It can be concluded that geological structure activity influences the drainage pattern in Cisaat and Cianten watershed. In the research area, the Cianten sub-watershed has an average Rb value of 1.97 whereas the Cisaat sub-watershed has an average Rb of 1.58. It shows that both watersheds have been deformed due to tectonic activity. Cianten sub-watershed has drainage density (Dd) with a value ranging from 2.54 - 4.38 with an average of 3.46, while the Cisaat sub-watershed has a drainage density (Dd) value ranging from 2.33 to 5.88 with average 3.93. Both of Cianten and Cisaat sub-watershed are classified into medium category that indicating the condition of the river has a medium resistance rock. The Cianten watershed has smf value ranging from 1.38 - 2.14 and Cisaat watershed has smf value ranging from 1.22 - 2.09. It can be concluded that both watersheds have medium to weak tectonic activity.

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