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THE PRIORITY OF MORPHOMETRY IN CIMANUK UPSTREAM WITH CORRELATION BASED ON LITHOLOGICAL RESPONSE

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Abstract: In this study morphometric analysis of 84 sub-watersheds upstream Cimanuk watershed, Garut, Indonesia. The study area lies at coordinates 107º42'0" E to 108º8'16" E 'and 6º56'52 "S to 7º24'0" S. Present study includes morphometric, lineaments and lithology analysis of upstream Cimanuk watershed for management watershed. The aim of this study is to find geomorphology, lineament and lithological responses in the upstream Cimanuk watershed, based on morphometric analysis. Remote Sensing technique were utilized. ASTER DEM and topographical maps have been employed to extract the drainage networks and lineaments. Geological field investigation carried out during the field work to validate geological maps. The morphometric parameters considered for analysis are stream order, stream length, bifurcation ratio, drainage density, texture ratio, form factor, shape factor, circularity ratio, elongation ratio, length of overland flow, and drainage frequency. Each sub-watershed is prioritized by assigning ranks based on the calculated compound parameter (Cp) and classified into three categories of priority; high (15 sub-watersheds, 17.86% of the total), moderate (57 sub- watersheds, 67.86% of the total), and low (12 sub- watersheds, 14.28% of the total). Structural disturbances on the drainage networks and its attributed to the lineament density value of 7,21-15,46 km/sq.km. The significant effect shows the influence of the lithology response to the study of morphometric priorities study area. High priority indicates that those watersheds are dominated lithology alluvium, tuff compared to other volcanic lithology units. The present results is useful for planning strategies in control of soil erosion and reducing the possibility of flooding downstream.

***Keywords**:* Cimanuk Watershed, Morphometric, Priority, GIS, Remote Sensing

I. INTRODUCTION

A watershed (DAS) is a natural hydrological entity from the beginning of surface runoff to flow into a river or a certain point (Vittala et al., 2004). The watershed is limited by a natural boundary in the form of an igir (ridge) leading to a point where water flow collects (outlet). The research area is bordered by a ridge where when rainwater falls in the area it will be collected and channeled from the small river to the main river called the Watershed or DAS (Asdak, 1995). In geomorphology, morphometry is a form of quantification of morphology. Morphometry is an analysis of mathematical calculations from the arrangement of the Earth's surface to its shape and dimensions (J.I. Clarke, 1966).

The value of each morphometric parameter in a watershed determines the watershed characteristics (Rai et al., 2017). Important points in this analysis include area, elevation, volume, slope, profile, and landscape texture for various characteristics of rivers and drainage basins. The morphometric analysis carried out in this study is in the form of river bifurcation ratio, drainage density, drainage frequency, form factor, shape factor, texture ratio, elongation ratio, circularity ratio and length of overland flow the stage of working on the morphometric parameters of sub-watershed selection, these nine parameter analyzes will be analyzed to determine their morphometric priority and related to the lithological.

Watershed morphometric analysis is considered as an appropriate method in understanding the relationship between various aspects of a watershed. Watershed analysis based on morphometric parameters is very important for watershed planning because it provides information on slope characteristics, topography, soil conditions, runoff water characteristics, surface water potential, and others (Chandrasekhar et al., 2015). This research covers the Cimanuk sub-watershed area and its main river. This research was conducted to understand the character of the Cimanuk watershed in conjunction with the lithological response in the area.

The lithology of the Cimanuk River Basin consists of 27 formations (Budhitrisna, 1986; Djuri, 1995), grouped into volcanic rocks, plutonic rocks, sedimentary rocks, and sediments. The lithology age varies from oldest (Oligo-Miocene) to youngest (Resen). Rocks of old age (Pre Tertiary to Tertiary) are generally sedimentary rocks in the form of alternating fine and coarse-grained material, and plutonic rocks in the form of hornblende andesite intrusion. Sedimentary rocks grouped into lithology occupy the downstream part of the upstream Cimanuk watershed, mainly exposed in the Tomo, Cadasngampar, Pamoyanan, Darmaraja, Wado, Ciherang, and Situraja areas. Rocks that are relatively younger (Plistocene) are dominated by volcanic products. These rocks are quite dominant in their distribution in the upper Cimanuk watershed. Lithology consists of volcanic breccias, lava, laharic breccias, tuffs, and loose volcanic spices.

Hard volcanic rocks occupy the relatively steep ridge morphology, mountain slopes and hills (Sulaksana, 2018). Meanwhile, relatively soft volcanic rocks (fine clastic material) generally occupy the plain morphology and gently sloping hills. The distribution of this lithology is in the South, Central and West parts. Young lithology (Holocene-Resen) is dominated by loose spices of volcanic products and sediments. Loose spices are a product of young volcanoes and some are still active (Mount Papandayan). Deposits are in the form of alluvium, coluvium, and lake sediment. A small portion, namely alluvium deposits, occupies major river valleys, especially Cimanuk River, with relative morphological data.

II. METHODS

The research method in this research is studio analysis using topography in the form of a watershed used in this research. Research with studio analysis, field data, begins with analysis studio using ArcGIS software to obtain quantitative values. The drainage network of Cimanuk watershed and 84 (eighty-four) third order sub-watersheds was generated namely DTA01 to DTA84. Watershed morphometric can be interpreted as a quantitative value in the river network (Van Zuidam, 1985). Morphometric calculations are in the form of river bifurcation ratio (Rb), Drainage Density (Dd), Circularity ratio (Rc) and Elongation ratio (Re) and Length of Overland Flow (Lof).

The stage of working on morphometric parameters for sub-watershed selection, classification of parameter values to classify the area that has been studied. The morphometric parameters used include: Apart from variable measurement and field observations, research is also carried out in studio and field analysis. Some of the morphometric variables can be obtained through interpretation of the topographic maps. Data analysis was carried out quantitatively, including the average value and range of values, to obtain morphometric priority values and to determine the type of lithology that developed in the rock priorities in the upper Cimanuk watershed.

Formation and development of the watershed can give information of morphometric characteristics because all hydrological and geomorphic processes occur within the watershed (Singh, 1992 in Bharadwaj et. al., 2014). Prioritization rating of eighty-four sub-watershed of upper Cimanuk watershed is carried out through ranking the computed morphological parameters. The lowest compound parameter value of sub-watershed is given the highest priority.

III. Result

The morphometric parameters of the Cimanuk watershed and its sub-watersheds have been analysed and detailed in the following:

3.1 Watershed Forms

The shape of a watershed affects the river flow hydrograph and peak runoffs. The shape of the drainage area that forms bird feathers indicates that the flood discharge will be relatively small because the flood travels from the tributaries are different in time. Meanwhile, the radial shape of the catchment area indicates that the flood discharge will be relatively large at the meeting point of the tributaries.

The form of parallel watersheds, namely flooding can occur at the meeting point of tributaries. The sub-watershed in the research area dominated by shaped bird feathers for 52 sub-watersheds (61.90% of the total), while the shape of the radial for 17 sub-watersheds (20% of the total).

3.2 Bifurcation Ratio (Rb)

Rb value is not same for all order and geological and lithological development of the drainage basin are the reason for these variations (Strahler, 1964; Verstappen, 1983). The bifurcation ratio (Rb) is a dimensionless property and it normally ranges from 3.0 to 5.0. The Rb with values less than three or more than five, indicating deformation (Verstappen, 1983). The lower values of Rb shows drainage pattern has not been distorted because of the geological or structural control (Schumm, 1956; Chopra et al., 2005). The Rb of the upper Cimanuk watershed as calculated varied from 1,04 to 4.63.

There are 73 sub-watersheds (80% of the total sub-watersheds) are indication deformating with Rb value less than three, it indicates structurally controlled and 11 sub-watersheds with Rb values ranging between 3.0 to 5.0, reflect that geological structures do not influence the drainage pattern. The sub-watersheds that are indicated to have been deformed are scattered throughout the lithology in the study area. This indicates that the study area has mostly been deformed as a result of the influence of tectonic activity according to the classification of Strahler (1964). The highest Rb value among all the sub-watersheds is 4.63 for the sub-watesheds DTA12, DTA49, and DTA84 while DTA27 has the lowest Rb value (1.04).

3.3 Drainage Density (Dd)

Drainage density is an expression to indicate the closeness of spacing of channels. It shows landscape analysis, runoff potential, infiltration rate, climate condition, and vegetation cover (Horton,1932). The low Dd indicates the area of highly resistant permeable subsoil material under dense vegetation and low relief. High Dd value indicates impermeable rocks and sparse vegetation and hilly region. The results of the calculation of drainage density (Dd) from 84 sub-watersheds in the study area have a value range from 1.59 for sub-watershed DTA66 to 5.12 km/sq. km for sub-watershed DTA11. (Sukiyah, 2009) divides the landscape texture classification into 6 texture classifications i.e, very fine, fine, slightly medium, medium, coarse and very coarse.

The average value of the overall network density in the study area is 3.33 km/sq. km, it means that the research area in general will often experience dryness so that it will be easily eroded, the structure is characterizing that the lithology in the study area has a variety of lithologies, the results are the results volcanic.

3.4 Circularity ratio (Rc) and Engolation ratio (Re)

The Circularity ratio is the ratio between the area of the watershed and the perimeter of the watershed and the value of the circularity ratio is influenced by the lithology of the rock. The circularity ratio and elongation ratio indicate surface runoff and water concentration in a watershed. The higher the elongation ratio value of a watershed, the slower the surface runoff so that the flow concentration is also slower. The higher circularity ratio value of a watershed, the higher the surface runoff and the higher the water concentration. Map and calculation results of circular and elongation ratios

The higher the elongation ratio of a basin indicates active denudational process with high infiltration capacity and low runoff in the basin and lower indicates higher elevation and high headward erosion along tectonic lineaments (Reddy et al., 2004; Yadav et al., 2014). Values close to 1.0 are typical of regions of very low relief, whereas values in the range 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964) Circularity ratio (Rc) <of the elongation ratio (Re) for 59 DTA indicates less surface runoff while the sub-watershed which has circularity ratio (Rc)> of the elongation ratio (Re) for 25 DTA indicates greater surface runoff indicates the shorter time of concentration before the peak flow. The sub-watershed with high runoff is mostly located in the middle west part of the study area.

3.5 Shape factor (BS) and Length of Overland Flow (Lof)

Shape factor means ratio of square of basin length to the area of the basin. Shape factor of a basin helps to analyse shape irregularity of the drainage basin (Yadav et al., 2014). The average shape factor for the upper Cimanuk watershed is 2,05.

Length of overland flow (Lof) is the length of water on the ground before being concentrated in the river basin. The smaller the Length of overland flow (Lof), the higher the flow will go to the river basin and the potential for flash floods will be high. Based on the calculation, Lof values less than 2 (Lof <2) are 66 sub-watershed, shows that the research area has a high potential for flooding. The average length of overland flow for the upper Cimanuk watershed is 1.66 km, and for the sub-watersheds ranges from 0.79 km (DTA66) and 2.61 km (DTA11).

3.6 Texture ratio (T) and Form Factor (Rf)

The texture ratio (T) shows the number of flow sections of the orders each boundary from area. Texture ratio is distinct of the most important concept of geomorphology. Drainage texture depends on the underlying lithologhy, climate, rainfall, vegetation, relief, soil and rock types, infiltration rate, and the stage of development (Horton, 1945) has classified drainage texture into five categories i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8). In the present study, the average of drainage texture for the basin is 1.83 and it indicates a very coarse drainage texture.

Rf indicates the ratio of the area of the watershed to the square of the basin length. higher values of form factor indicate a more circular shape of the watershed, and, the smaller the value of Rf (<0.785), the more the watershed will be elongated. The highest Rf is 0,62 for DTA46 and lowes is 0,35 for DTA71. The average of Rf for upper Cimanuk watershed is 0,49.

3.7 Drainage frequency (Fs)

The number of streams (Nμ) in per unit area (A) is known as drainage density of the basin. Fs value may range from less than 1 to 6 or even more depending on the lithology of the basin (Kale and Guptha, 2001). High Fs indicates greater surface runoff and steep ground surface (Horton, 1932). In the present study, the average of stream frequency for the basin is 5.27 and it indicates a high runoff and relief.

IV. LINEAMENT DENSITY

This lineament density analysis calculates the lineament frequency of the broad unit according to Hung characteristic of fracture in research area based on numbers of lineaments (Fig.1). Lineament density is processed using ArcGIS software, with range 0-15,45 km/sq.km. The high lineament density areas area affected by Quaternary volcanism shown in red, located in the East, Southeast, South, Southwest, and Northeast parts of the study area.

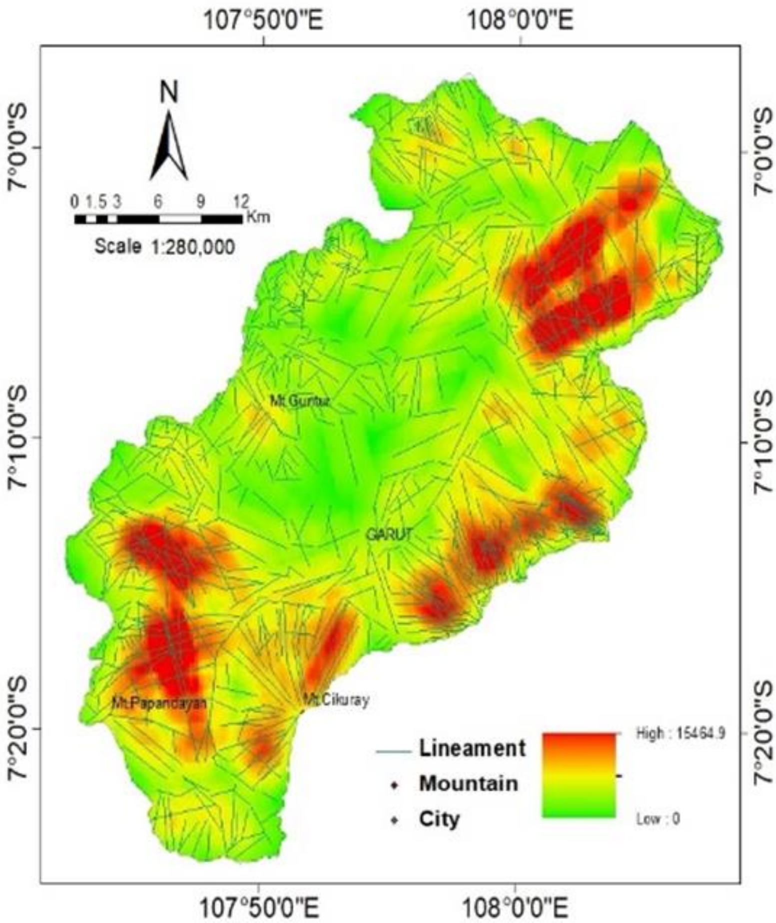

Fig 1. Lineament Density Map

4.1 Discussion

Morphometric is one of the responses from geomorphology that can be calculated quantitatively and can be applied. Morphometric characteristics are generated based on variables in the developing drainage pattern, which is Watershed. Geomorphology that develops in the upstream Cimanuk watershed is controlled by the presence of active tectonics, and complex. The morphometric parameters values namely; bifurcation ratio, drainage density, stream frequency, form factor, shape factor, texture ratio, elongation ratio, circularity ratio and length of overland flow were calculated. Each parameter has been assigned their ranks according to their value. Prioritization rating of all the eighty-four sub watersheds of upper Cimanuk watershed was carried out by calculating the compound parameter values. The sub watershed with the lowest compound parameter value was given the highest priority.

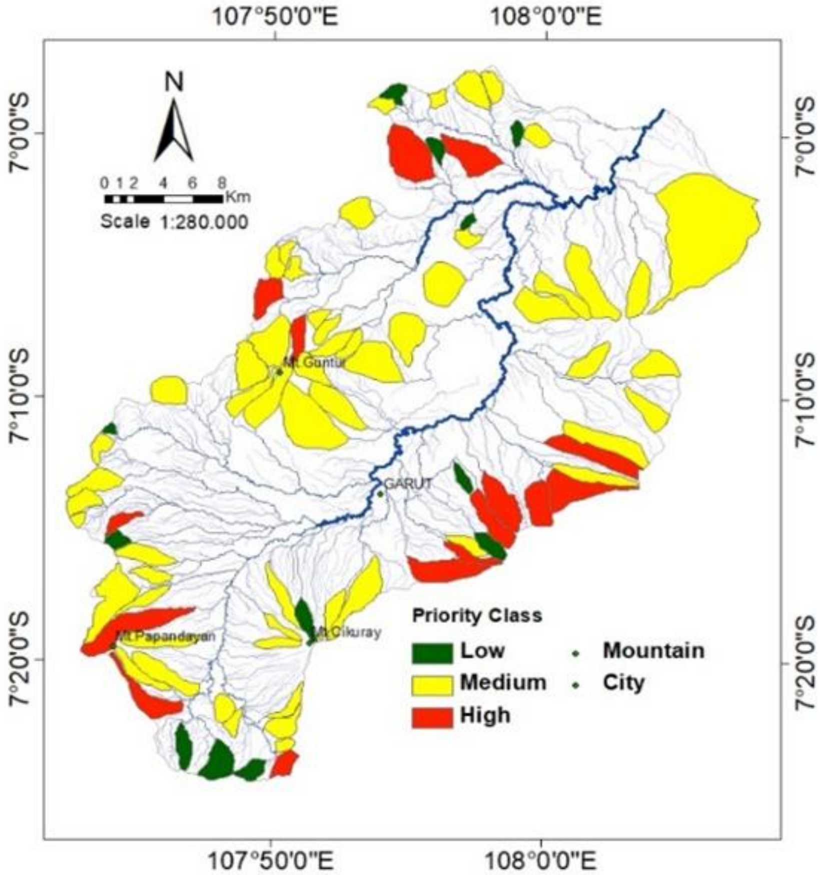

Fig 2. Priority Classes for 84 sub-watersheds

Amounts of 84 sub-watershed weight value (maximum:475, minimum:254, average:382,50, and standard deviation: 48,15) were calculated for prioritization of wub-watershed. Based on compound parameter, sub-watersheds were divided into 3 classifications including high priority (254-334,35), medium priority (334,35-430,65), low priority (430,65-475). High priority has 15 sub-watersheds that are evenly distributed in the North, East, West, Southwest, Northwest and South of the study area. Medium priority has 57 sub-watersheds spreading over the research area and low priority there are 12 sub-watersheds scattered in the North, central and western parts of the study area. The whole study sub-watersheds was included in medium priority as shown in Figure 2.

The high priorities sub-watershed with the results of the morphometric values including; Rb 1,04-2,22; Dd 2,70-4,04; Lof 1,35-2,02; T 0,31-1,70; Rf 0,42-0,52 Re 0,73-0,82; Rc 0,28-0,82; Bs 1,89-2,36; and Fs 1,59-5,15. Lithology dominated by tuff 42,31%; tuf, lava 18,50%; Tuff, lava 12,22%, the basic rocks are alluvium, andesite, basalt, fine-grained tephra, coarse-grained tephra from gravel to gravel.

The medium with the results of the morphometric values including; Rb (1,61-4,62); Dd (1,59-5,21); Lof (0,79-2,60); T (0,22-1,83); tuff, breccia 28,97%; andedite and basalt 21,97%; tuff,breccia, lava 13,49%, Low priority, with the results of morphometric values including; Rb (2,00-3,75); Dd (2,99-4,27); Lof (1,49-2,13); T (0,39-0,94); Rf (0,47-0,61); Re (0,77-0,88); Rc (0,54-0,80); Bs (1,62-2,13); and Fs (5,49-15,03) with lithology tuff 35,39%; brecia 16,34%; tuff, lava brecia 18,65%; The base rock is in the form of andesite, tuff, breccia and basalt.

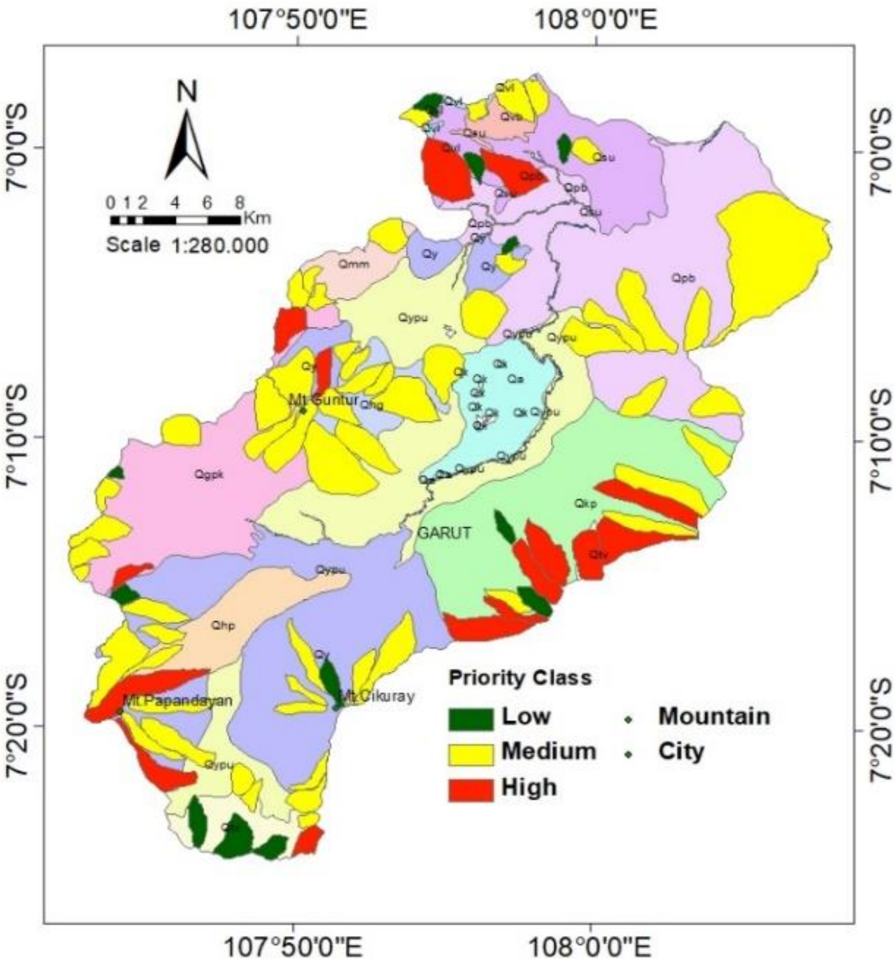

Fig 3. Morphometric Priority overlaid on geological map

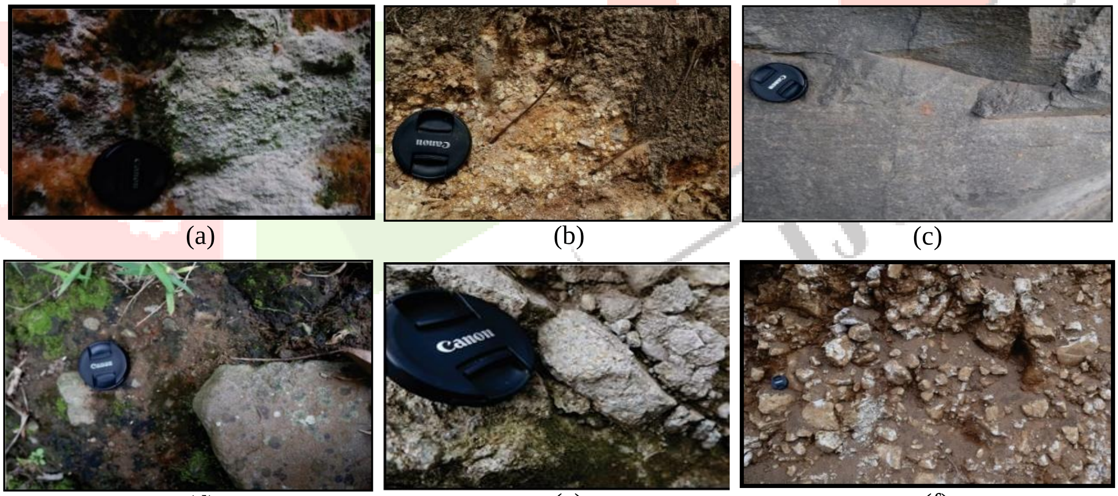

Fig 4. Lithology in study area.

Based on morphometric calculations, the research area indicates that there are active intermediate to weak faults, has undergone quite strong deformation, shows lineament density value is 7,21-15,46 km/sq.km with high to slow and large water lanes in the river are due to the Quaterly volcanic lithology response factor which is less resistant to weathering and erosion so that it forms wide slides in the Cimanuk watershed. Upstream. High morphometric priorities mostly found in the lithology of Tuff Kracak – Gede volcanics which is located in the Eastern of Garut city and this is indicative of high susceptibility to soil erosion within the study area. It can be seen from the results, the sub-watersheds for DTA 27, DTA 28, DTA 31, DTA 32, DTA 34, DTA 35, and DTA 37.

4.2 Conclusion

In general, based on the morphometric calculations on upstream Cimanuk sub-watershed in the form of bifurcation ratio, drainage density, drainage frequency, form factor, shape factor, texture ratio, elongation ratio, circularity ratio and length of overland flow, shows that there is a moderate to weak active fault indication value, where affects significantly the influence of the lithological to the study of the morphometric priorities. The lithology units of release and lava composed of basalt andesite, flow lava, tuff, pumice and pumice tuff which have lower weathering with high lineament density value ((7.21 to 15.46 sq.km) are characterized by high morphometric priority. This study can be useful for management techniques for soil erosion control and reducing the possibility of flooding downstream.

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