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RESEARCH ARTICLE

Implication of Catchment Morphometric on Small River Discharge of Upper Citarik River, West Java

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Abstract Upper Citarik River is the Inter Mountainous Valley of Volcanic Denudational Landform in the eastern part of Bandung basin, West-Java. The research area compounds of several degraded small catchments with very low water flow in dry season. This research aims to understand the implications of morphometric characteristics (Slope, Cr, Dd, Hi) on average river flow discharge of small sub-catchments of Upper Citarik River. Discharge data collected based on measurements, while catchments morphometric identified and analyzed based on topographic map using GIS techniques. Correlation graphs were used to understand the relationship among the morphometric parameter and the average river flow discharges. The result were as follow the steeper the slope, the more elongated the shape of catchment, the more distant was the river density, meaning the more younger the erosion cycle of the landform. The younger the erosion cycle of the landform, the smaller was the average river discharge per areal unit of catchments.

1. Introduction

Morphometry is defined as the measurement of forms, that related to hydrology, first, been done by Strahler and Horton between 1940 and 1950 (Pidwirney, 2006). Morphometric analysis with particular regard to the quantitative measurement of various aspects of the size of the catchment, i.e. stream order, river length, drainage density, the frequency of drainage, bifurcation ratio, etc., has been done by Pawar et.al. (2009). Catchments morphometry analysis also conducted to determine the characteristics of Korattalaiyar, Tamil Nadu catchments in India, to understand the topography, erosion status and drainage patterns in preparing comprehensive basin development plans (Geena and Ballukraya, 2010). Remote sensing technique and Geographical Information System (GIS) to analyses soil characteristic, erosion phenomenon, and landscape process, in relation with micro catchments morphometric characteristic have done by several researcher (Bagyaraj and Gurugnanam, 2011., Malik et. al., 2011). Investigation of possible relationship between morphometric characteristics of small to medium drainage basins and hydrological indices have been done in the Peloponnese in southern Greece (Karalis et. al., 2014). Morphometric analysis to determine floods in the Upper Krishna basin using Cartosat DEM have also been done (Surabhi and Ahmed , 2014).

From the various catchments morphometric studies that have been stated, there are no studies that connect between morphometric parameters and average river flow discharge, especially on the volcanic Denudational landform. By understanding the relationship among the catchments morphometric parameters and average discharge of the river in volcanic denudatinal landform, it could provide indication for comparison among the catchments. It will be useful in the local catchments management and the local development of water resources.

Area of a basin (A) and perimeter (P) are the important parameters in quantitative geomorphology. Basin area directly affects the size of the storm hydrograph, the magnitudes of peak and mean runoff (Smart and Surkan, 1967). The circularity ratio (Rc) is used as a quantitative measure for visualizing the shape of the basin. It is affected by the lithological characteristics of the basin (Strahler, 1964; Christopher et. al., 2010).

Science related to water phenomena associated with landform is hydrogeomorphology. The quantitative research of drainage basins or watersheds provides a theoretical basis for the hydrogeomorphic approach, indicating that certain relatively uniform characters of catchments can be correlated with the hydrological response of the watershed. The measurable description of the drainage basin can be grouped into linear aspects of the channel network, aspect of the drainage basin area, the basin shape, and the relief aspect of the channel system (Agone, 2014).

Upper Citarik River is located in the most eastern part of Bandung Basin, West Java Province, Indonesia. Citarik is one of the main river tributaries of Upper Citarum River in which Bandung City is located in the north surrounding part. (Figure 1). Upper Citarik Catchment consists of Young and Old undifferentiated volcanic material, i.e. lava, breccias, tuff (Silitonga, 1973).

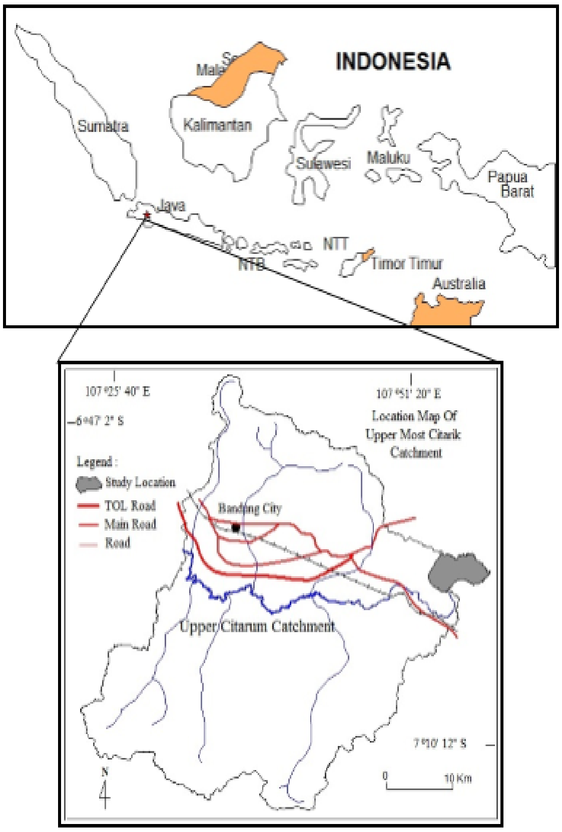

Figure 1. Location of research area

Table 1. Area of small catchments

Catchment area	Area (Sq.km)
SU-1	2.31
SU-2	1.96
SU-3	0.26
SU-4	1.22
SU-5	1.22
SS-1	1.06
SS-2	0.81
SS-3	1.48

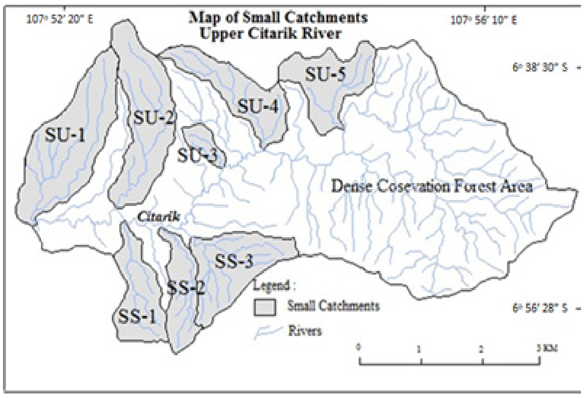

Figure 2. Distribution of measured small catchments

Geomorphologically the landform of research area is Intermountainous Valley of Volcanic Denudational Landform. Hydrogeomorphologically the research area compounds of several degraded small sub-catchments with very low even no river flow discharges in dry season due to the intensive agricultural activities in the very steep slope.

Eight small catchments analyzed were generally second order of stream based on Strahler Stream ordering system. Volcanic landform is different from other types of landform, it is the result of both a constructive and destructive force almost simultaneously (Thouret, 1999).

2.The Methods

The objective of this research was to understand the relationship among these parameters and between this parameter to the average river flow discharge as the water yield, especially in volcanic landform.

Topographic Map with scales 1: 25.000 was used to identify, measures, and analizes catchments area as sample measurements and to describe morphometric characteristic of catchments. Making a slope distribution map and using regional geological map of 1: 100.000 scale to describe physical characteristic of catchments. Areal distribution of small catchments is presented in Table 1 and Figure 2. Momentarily discharge measurements for several days in the relatively same weather conditions at the outlet of catchments using "currentmeter" and areal sections method.

Morphometric parameters used in this research area were.

(a) Areas of catchments were measured in topographic map. Basin area is the direct outcome of the drainage development in a particular basin. It is usually seen that the basin are pear shaped in early stages, but as the cycle advances, the shape tends to become more elongated (Padmaja, 1978 in Geena and Ballukraya, 2010).

(b) Slope was also analysis and mapped based on topographic map.

(c) Circularity Ratio (Rc) Ratio is defined as the ratio of basin area (Au) to the area of circle (Ac) having the same perimeter (Pr) as the basin (Miller, 1953 in Geena and Ballukraya, 2010). The bigger the value of Rc the more circular the shape of the catchments.

$$R_c = \frac{4\pi A_u}{P_r^2}$$

(d) The Drainage Density (Dd) is defined as the length of streams per unit area. It is obtained by dividing the cumulative stream length (∑Lu) by the basin area (Au) (Horton, 1932 in Geena and Ballukraya, 2010).

$$Dd = \frac{(\sum L)u}{Au}$$

(e) Hypsometric Curve and Hypsometric Index (HI),

Hypsometric Curve, introduced by Langbein and Strahler is usually represented as the distribution of the relative heights (h/H) with an area of relative (a/ A) (Enrique, et al., 2008) (Figure 3).

Hypsometric Index (HI), sometimes called the Elevation/Relief Ratio, can be quickly calculated for any basin. HI values are reported to two decimals. Figure 4 show how to calculate Hi.

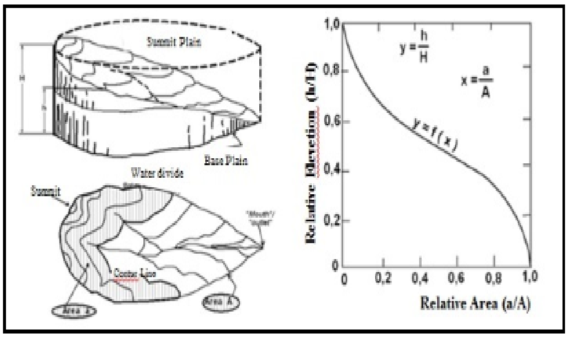

Figure 3. Hipsometric curve calculation (Strahler, 1957 in Chorley, 1976, and Keller and Pinter, 1996)

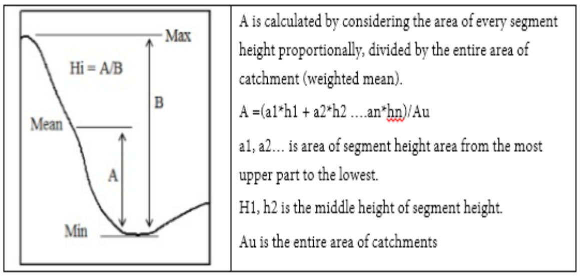

Figure 4. Elevation profile of basin hypsometric index (Hi)

3.Result and Discussion

Geology and Slope of Research Area

The eight small second order catchments are located in the most upper Citarik Sub-Catchment. Upper Citarik Sub-Catchment has an area of about 28.80 sq.Km. Citarik River is one of other six main tributaries of Upper Citarum River. In physiographic region setting of West Java, the Upper Citarum Basin included in Bandung Zone (Van Bemmelen, 1949 in Wimpy, 2004). Upper Citarik Sub-Catchment Area is geomorphologicaly a Volcanic Denudasional Landform, which consists of Geological formations of young and old volcanic undifferentiated product: Qyl, Qvl, Qvu (Figure 5). The Citarik Catchment Area is dominated by steep slope land with 86% area and the rest are very steep (12%) and slightly steep (19%) (Figure 6). The Variations in steepness of slopes

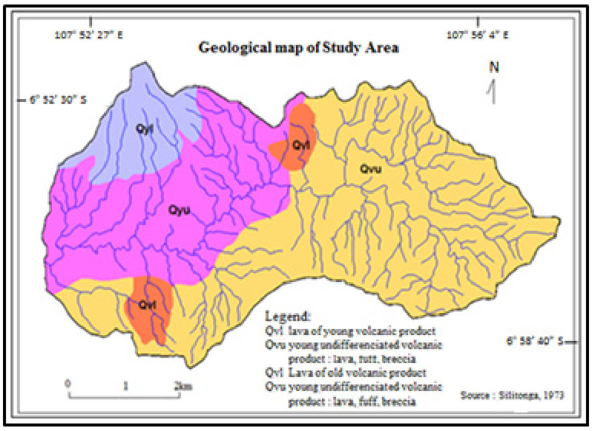

Figure 5. Geologic map of upper Citarik catchment area (modified from Silitonga, 1973)

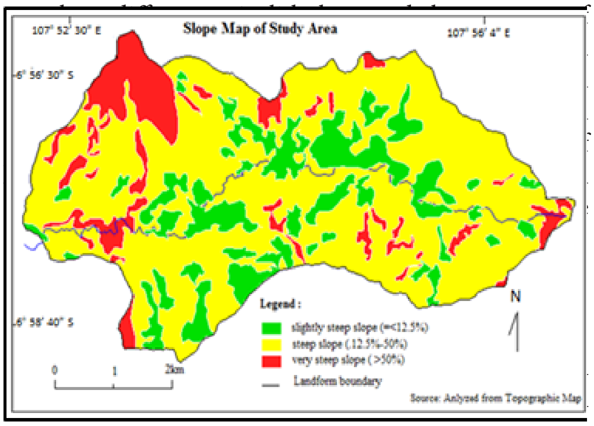

Figure 6. Slope map of upper Citarik catchment area

the weighted mean of catchments slope have been calculated. Likewise for drainage density (Dd), Circularity Ratio (Rc), and Hypsometric Index (Hi). The result of identifying and calculating morphometric parameters and the median of measures flow discharge per hectare (liter/sec per ha) of small catchments is presented in Table 2.

Dispersal graphs for correlation analysis among the parameters and between parameters and average river flow discharge as were constructed to identify the relationship among the parameters and the implication of parameters on the water yield.

The hypsometric integral is abtained from the hypsometric curve and is equivalent to the ratio of the area under the curve to the area of the entire square formed by covering it. It is expressed in percentage units and is obtained from the percentage hypsometric curve by measuring the area under the curve (Singh et al., 2008). The relationship between Slope and Catchment circularity (Rc) were depicted in Figure 7a. It shows that the steeper the slope the smaller the value of the Rc means the more elongated the shape of catchment. The tendency of negative correlation between Slope and Rc are more clear depicted on the graph when these catchments was classified into groups of catchments

Table 2. Morphometric parameter of small catchments and river flow discharge

Catchment	Area (sq.km)	Slope (%)	Dd	Rc	HI	Q/Ha (liter/sec per ha)
SU-1	321	43	3.58	0.53	0.45	0.59
SU-2	196	57	3.12	0.45	0.46	0.59
SU-3	26	29	5.39	0.65	0.34	1.15
SU-4	124	31	4.08	0.37	0.43	0.57
SU-5	122	31	2.68	0.46	0.55	1.09
SS-1	149	28	3.41	0.47	0.50	0.60
SS-2	105	23	4.61	0.40	0.55	0.50
SS-3	81	20	3.97	0.60	0.42	0.81

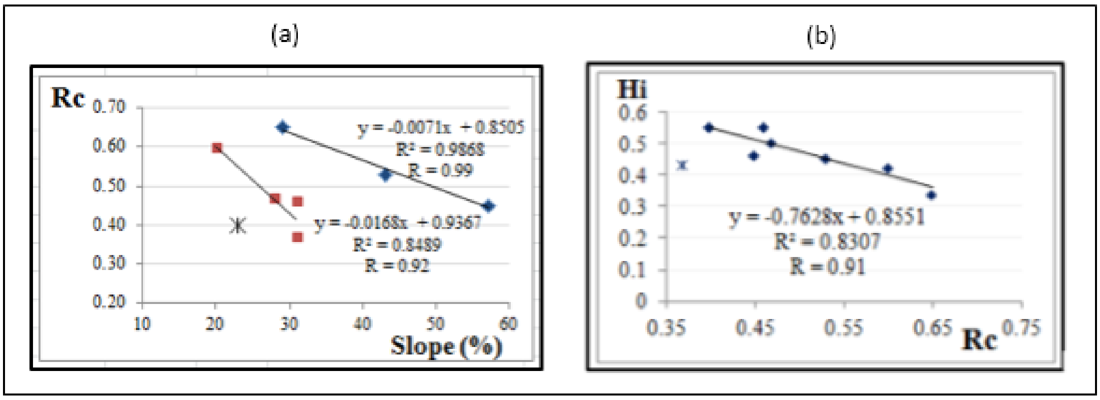

Figure 7. (a) The correlation graph of slope and Rc; (b) The correlation graph of Rc and Hi

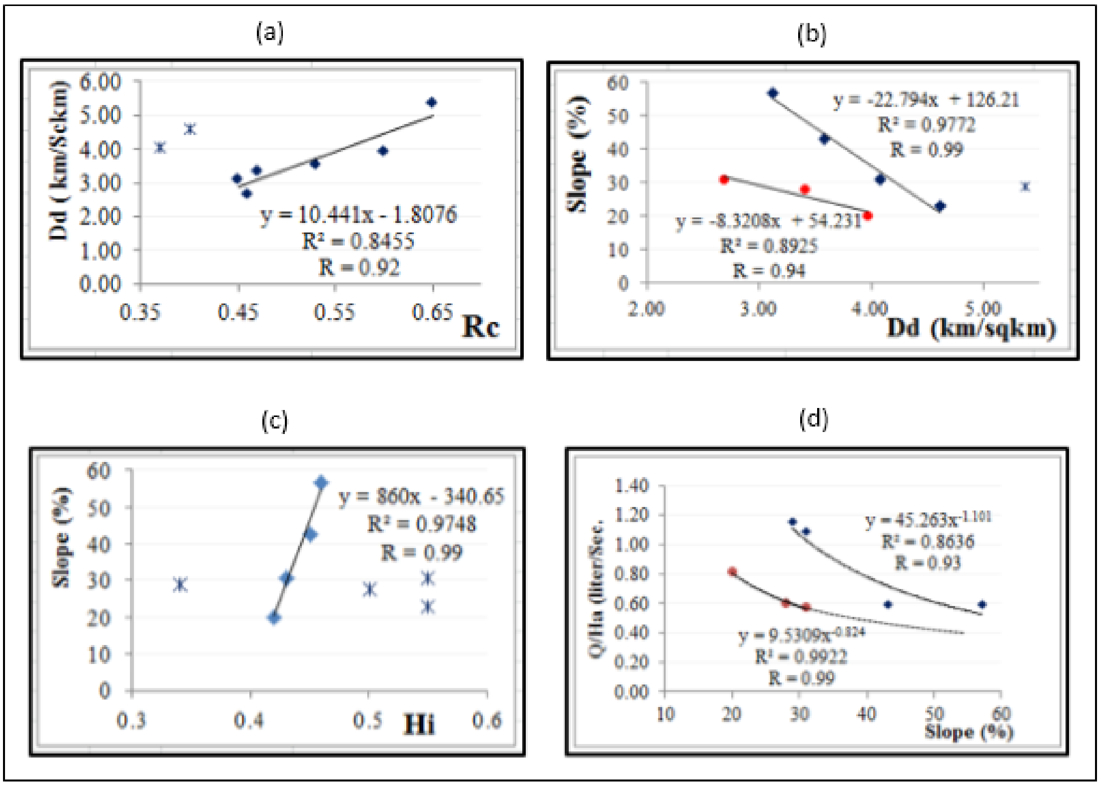

Figure 8. (a) The correlation graph of Rc and Dd; (b) The correlation graph of Dd and Slope; (c) The correlation graph of Hi and slope; (d) The correlation graph of slope and Q/Ha

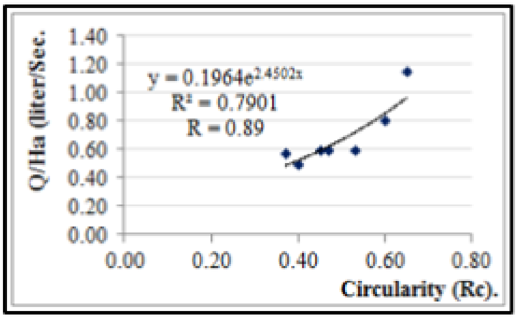

Figure 9. The correlation graph of Rc and Q/Ha

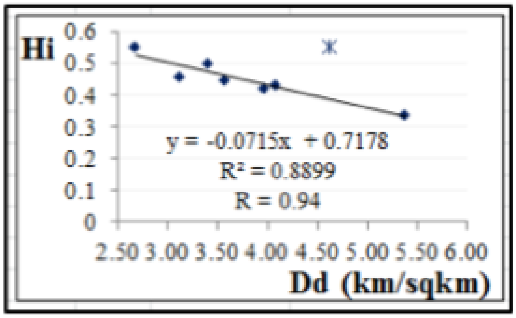

Figure 10. The correlation graph of Dd and Hi

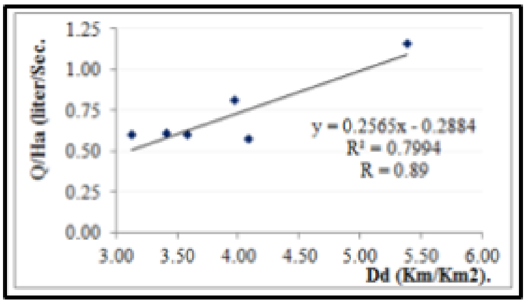

Figure 11. The correlation graph of Dd and Q/Ha

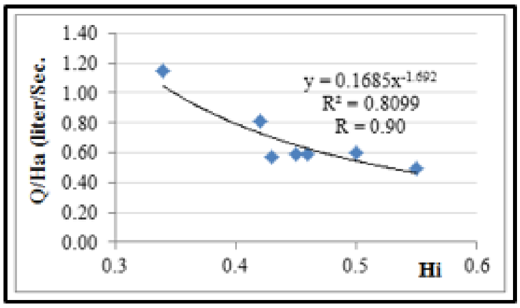

Figure 12. The correlation graph of Hi and Q/Ha

which developed in the predominantly young volcanic (SU-1; Su-2; SU-3) and old volcanic product (SU-4; SU-5; SS-1; SS3). If we considered the relationship between Rc and Hi, it shows that a negative linear relationship also occur (Figure 7b), the bigger the value of Rc the smaller the value of Hi meaning the older the landform stage of erosion. The estimation of HI itself is carried out from the graphical plot of the measured contour elevation and encompassed area and by using empirical formulae (Singh et al., 2008). This condition is caused by the initial formation of the catchment that influenced by volcanic processes i.e. material deposits which tend to form intermittent streams that are elongated, further process of catchments developments is dominantly influenced by exogenic processes i.e., surface erosion. This can be used as an indication that in the volcanic denudational landform, the older the erosion cycle the more circular is the catchment forms.

In addition the relationship between Rc and Dd (Figure 8a) shows that the more circular the shape of catchment or the bigger the value of Rc the denser the rivers or the higher the value of Dd meaning that the more intensive the river development. Abboud and nouval (2016) also describe that low value Dd means low resistant and highly fractured, permeable, and porous surface and subsurface rocks with scarce vegetation cover and high to moderate relief terrain. Dd values shows that the region with highest rainfall has high Dd values (Joji, et al, 2013). Based on the relationship between the slope and Rc, and the Rc and Dd, it could be state that the more gentle the slope the more rounded the shape of catchment, the denser the river density meaning that the older the stage of erosion cicle of the landform. That was proven by the relationship between Rc and Hi and between Hi and Dd (Figure 8b), the bigger the value of Rc the smaller the value of Hi means that the more rounded of catchment the more older the stage of landform, and also the denser the river density. This could be explained by the further development of catchments where the erosion is dominant, the river also develops and does not have to be a positive linear relation with the area development of the catchments.

Flood prone analyisis for maximum flood in Kunto River, Central Java has an area + 600 km2. As a result, the morphometric aspect of RC DD morphometric influences the potential for flooding in a large area (Suyono, 2013), but in this study the average watershed area was 6 km2 and with the same morphometric aspects were affected the average flood. It can be concluded that the larger the area of the watershed the greater the potential for flooding.

This result is in contrast with that have been stated by Padmaja (Geena and Ballukraya, 2010) that the basin are pear in shape in the early stages, and become more elongated in the advance stages. This might due to that this research conducted especially in the volcanic landform which had been explained above that begins with a volcanic process and then dominated by the erosion process. The logical relationship between Rc and Slope; Rc and Hi; Rc and Dd; Rc and Hi were also supported by the relationship between Dd and Slope (Figure 8b) and Hi and Slope (Figure 8c). Nevertheless this result of analysis still leaves the remainder of the outliers that might be due to the dominant role of another factor.

Further analysis was to understand the implication of that morphometric parameter on the average river flow discharges. In this correlation graph, the average slope of catchments as one of morphometric parameters is independent variable having effect on average river discharge as dependent variable. For comparison among these other catchments which have their own difference area, so the river discharge divided by the area of catchment to get Q per Ha. The discharge which is divided by its catchment areas is median of fifteen measurements in the same day assumed having the same weather condition (see attachment). Figure 8d show negative power regression correlation which means the steeper the average slope of catchment the smaller its average discharge per hectare. It seen that there are two groups of catchments, first developed in the predominantly young volcanic undifferentiated product which have relatively little bit bigger discharge than that of the second other group developed in in the old volcanic landform.

In line with the relationship between Slope and Rc that the more gentle the slope the more circular the shape of catchment, the bigger the average its river discharge, so it seen in Figure 9, the more rounded the catchment (the higher the value of Rc) the bigger the average river discharge with has a positive power regression correlation.

Likewise drainage density (Dd) and Hypsometric Index (Hi) (Figure 10), which have a negative power correlation with average river discharge (Q/Ha) (Figure 11 and Figure 12), are also in line with the relationship among the catchments morphometric parameter. To make it easy in explanation, so the matric table (Table 3) is presented.

The explanation of Table 3 is as follows: H is high and L is Low value. The higher value of slope means the steeper, the lower means the more gentle. The higher value of Rc means the more circular shape of a catchment, the lower means the more elongated. The higher value of Dd means the denser, the lower means the sparser its river density. The higher the value of Hi means the younger, and vice versa the lower means the older erosion cycle of the landform. The relationship among these morphometric correlation showed that the steeper the slope, the more elongated the shape of catchment and the higher the density of river, the younger the stage of erosion cycle, make the implication on the average discharge of the rivers smaller. The relationship were also correspond between Rc and other morphometric parameters, i.e., the more circular the shape of the catchments means the higher the value of Rc, the lower the average slope of the catchment, the higher the density of the rivers, the older the stage of landform erosion, and the implication on the river was the bigger the average discharge. Likewise when Dd were correlated with other morphometric parameters: the higher the Dd, the lower the slope, the more circular the catchments, the older the stage of erosion, and the implication on river was the bigger the average discharge of rivers. It is no difference with Hi: the higher the value of Hi means the younger the erosion cycle of the landform, the higher the average slope, the more elongation the shape, the lower the Dd of the catchments, and the consequences was the smaller the average discharge of rivers.

Table 3. Matric table relationship of morphometric parameters and correlation with the average river discharge

*	Slope	Rc	Dd	Hi	Q/Ha(Lt/ Sec.)
Slope*	X	H*/L	L*/H	H*/H	H*/L
Rc*	H*/L	X	H*/H	H*/L	H*/H
Dd*	H*/L	H*/L	X	H*/L	H*/H
Hi*	H*/H	H*/L	H*/L	X	H*/L

(H= the higher; L= the lower; *= indication)

4.Conclusion

The study using correlation analysis for the relationship among the morphometric parameters (slope, Rc, Dd, Hi) and the implication on average small river discharge in the volcanic landform are the steeper the slope, the more elongated shape of catchment, the more distant the river density, means the younger the erosion cycle of the landform.The younger the erosion cycle of the landform, the smaller the average river discharge per areal unit of Catchments.

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