Influence of Lithology and Slope Gradient to Infiltration of the Mount Malabar, West Java

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Abstract. Volcano is an area which serves as a catchment area for the lowlands. Ability of rock or weathered-soil to absorb the rain water depends on several things, such as lithology and large of slope. Different lithology has different characteristics, including in terms of porosity which is directly related to the ability of rock to store water. Characteristics of lithology in volcanic area can change rapidly, both vertically and laterally. Large of slope in volcanic area that change significantly also can affect the infiltration rate (the seepage of rain) in rock or weathered-soil. Therefore, the influence of lithology and large of slope to the infiltration rate should be proven to predict the infiltration zone in volcanic area. Observations has been conducted on the eastern slopes of Mount Malabar with an area 78 km^2, at coordinates $7^0$03'28.04" LS - $7^0$10'32.05" LS and $107^0$38'37.64" BT - $107^0$41'50.6" BT. The infiltration rate observed on the weathered-soil using simple single infiltrometer made of PVC pipe 50 cm long, on March-April 2015. The measurement is carried out at several points where the weathered-rock result has been known, as much two times for different slope in each point. 26 measurement points have been obtained from different slopes and weathered-soil of different five-lithology. The results showed that the infiltration rate proportional to the percentage of rock porosity and large of slope. Infiltration rate sequence from the smallest to the greatest are weathered-soil andesites, basaltic andesite, laharic breccias, alteration of dacite, and pyroclastic breccias. The greatest infiltration rate obtained is 10.11 cm/minute in pyroclastic breccia with 25^o slope, while the smallest is 0.0437 cm/minute in pyroclastic breccias with 4^o slope.

1. Introduction

Volcano territory is one of areas that have many benefits. In addition of being recognized with the abundance of mining and energy resources including geothermal, volcano territory also has the potential to become a recharge zone. Mount Malabar is one of a type B volcanoes located in South Bandung, West Java which has natural resources. Mount Malabar is one of catchment area [1]. However, land clearing for plantations and agriculture cause its function as catchment area to be disturbed. The existence of the plant at ground level can impede the flow of water on the surface thus the infiltration becomes greater. In addition, its roots can speed mechanical weathering into soil [2]. The thicker the soil, the larger infiltration capacity [2]. Infiltration is one of the parameters to determine the catchment area potential. Potential of Mount malabar as catchment area must be analyzed in order to keep its function. Along with the increasing of water that infiltrating the soil, the run off water volume that considered as one of causes of flood is decreasing. The infiltration rate affected by many factors including soil texture and slope gradient [3]. This research will focus on

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those two due to the differences in geology and geomorphology condition between volcano territory and plain territory. According to [4] the key characters of volcano territory is the rapid lithological change both vertically and horizontally, in addition the various morphology configuration.Therefore it will be best to know how lithology and geomorphology condition affected infiltration rate in the research area. Results from this research are expected to be a reference in determining the catchment areas potential in future research.

2.Theory

In a hydrogeology cycle the rain drops that reach earth surface will be undergoing 2 process which is flow on the surface as run off and infiltrating underground. The infiltration process of rain water to unsaturated known as infiltration [3]. Meanwhile, capacity to absorb the rain water known as infiltration capacity [5]. The iniltration ability is different in any weathering result soil. This condition affected by 5 factors including precipitation characteristic,earth surface condition, earth surface cover condition, ground texture and structure, and also the infiltrated water characterictics [3]. According [5] the infilttration capacity for any soil also different that can be approached by analyze the soil porosity or the origin rock that form the soil. In addition of being a container for fluid, porosity also relate with permeabiltiy which is the main factor of fluid movements inside of soil or rock. According to[6] porosity is lineary linked with permeability logarhtym, but not in several case due to rock/soil textures such as sorting and grain size. Soil texture can determine whether the porosity in rock/soil interconnected or not where the interconnected porosity will will increase the permeability. In addition the high porosity and permeability make the weathering more intensive therefore the weathering result soil will formed faster.

3. Research Method

The infiltration rate observed on the weathered-soil using simple single infiltrometer made of PVC pipe 50 cm long and 8 cm diameter, on March-April 2015. That pipe plugged into the soil with 10 cm in depth and then fill it with water until 40 cm of height. Then we measure the water height in 0 minutes, 1 minutes, 2 minutes, 3 minutes and so forth until the water height relatively constant and not decreasing further (Figure 1). After the measurement done then we measure the slope gradient of this location using geological compass and board as pedestal. The measurement is carried out at several points where the weathered-rock result has been known, as much two times for different slope in each point. Ten measurement points have been taken for each weathered soil from 4 lithology also for each lithology the measurement conducted for several different slope gradient. Finally we got the

Figure 1. Simple Single Infiltrometer Device

infiltration rate per minute and then we process it with Microsoft Excel based on the equation (1) [7]:

$$f = a\,t^{n} \tag{1}$$

f = infiltration rate; a, n = constanta; t = time (minutes)

"a" and "n" constanta were evaluated from cumulative infiltration rate for determined times. The integral form of cumulative infiltration rate shown in the equation (2) :

$$F = \int_0^t a\,t^{n} = \frac{a}{n+1} t^{n+1} \tag{2}$$

F = Cumulative Infiltration Rate

4. Regional Geology

This Research located in Malabar Volcanoes area which which in administrative belong to Banjaran and Arjasari District, Bandung Regency, West Java Province. Geographycally the research area located at 7° 03' 42" - 7° 10' 44" LS dan 107° 38' 53" - 107° 41' 36" BT. Research area shown in red rectangle and cover 78 km^2 (13 x 6 km) area which covered the east slope area of Malabar Volcanoes. According to [8] Southern Bandung Area can be divided into eleven unit, they are: Soreang VolcanicRock Unit (SV), Baleendah Volcanic Rock Unit (BV), Pengalengan Volcanic Rock Unit (PV), Tanjaknangsi Volcanic Rock Unit (TV), Kuda Volcanic Rock Unit (KV), Kendeng Volcanic Rock Unit (KdV), Dogdog Volcanic Rock Unit (DV), Wayang-Windu Volcanic Rock (WV), Malabar Volcanic Rock Unit (MV), Pengalengan Pyroclastic Unit, and Alluvium Unit (Figure 2A).

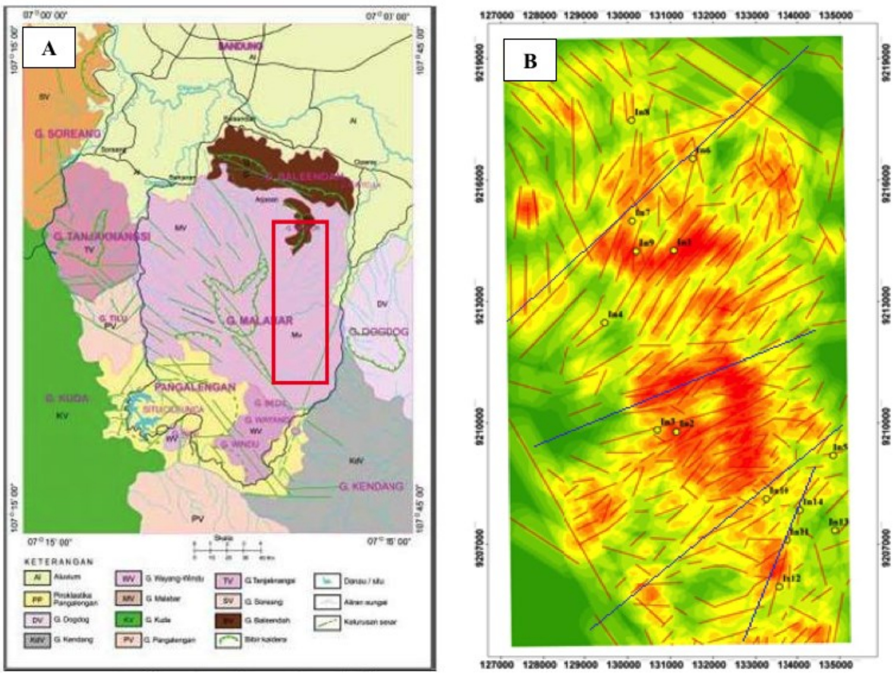


Figure 2. A) Geological Map of South Bandung [1], B) Fault and Fracture Density (FFD) map of research area, yellow circle show measured point of infiltration rate, red line show lineaments, blue line show fault interpretation

Based on this classification the research area belong to Malabar Volcanic Rock Unit and Baleendah Volcanic Rock Unit which is consist of basaltic – andesit-basaltic lava, pyroclastic breccia, laharic breccia, tuff, Baleendah layered lava flow with pyclastics breccia infix.

According to [8] by analyzing landsat image can be determined 2 main lineation pattern in South Bandung Region which is Northwest-Southeast and Northeast-Southwest. This statement match with landsat image observation result in research area. Lineament analysis executed with SRTM image and then converted to Fault and Fracture Density (FFD) in ArcGIS software (Figure 2B). FFD is one of methods used to determine fault and fracture density in area [9]. Fracture formed by the process of deformation due to the tectonic activity. That picture show 2 main lineation pattern in resaearch area which is match with regional lineation pattern in South Bandung Region. In addition, from the continuation of lineation pattern can be interpreted 4 major fault in reseach area with Northeast-Southwest relative orientation.

5. Discussions and Results

Infiltration rate measurement executed in 14 different location with 26 total measurement. Field observation show 5 different lithology which is the origin rock for wearhering result soil in the measurement location (Figure 3). Those lithology are pyroclastics breccia, laharic breccia, altered dacite, andecite, and basaltic-andecite with characteristics given below:

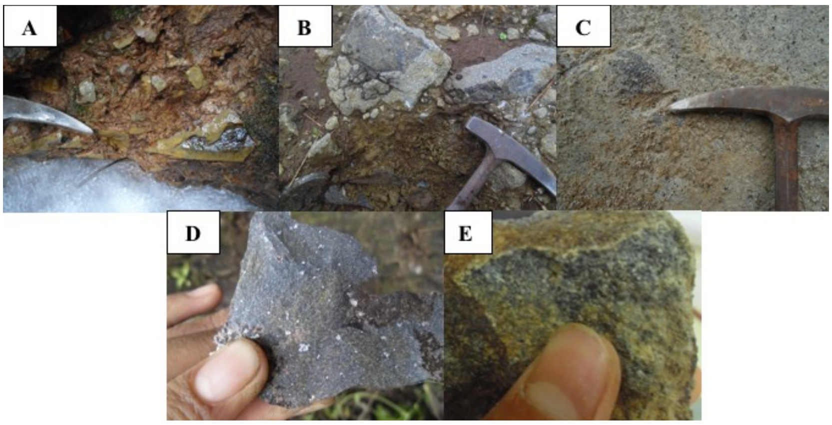


Figure 3. Outcrop image and hand specimen of : A) Pyroclastic Breccia, B) Laharic Breccia, C) Altered Dacite, D) Andecite basatic, E) Andecite

1. Pyroclastic breccia; Yellowish brown-dark brown; grain size pebble-boulder (Wentworth,1922); grain shape angular; poor sorted; matrix supported; fragment including lithic andecite, lithic andecite basaltic, and lithic dacite; matrix ash-lapili including lithic and volcanic glass.
2. Laharic breccia; yellowish brown-dark brown; grain size pebble-boulder (Wentworth,1922); grain shape subangular-angular; very poor sorted; matrix supported; fragment including lithic andecite, lithic andecite basaltic, and lithic dacite; matrix ash-lapili including lithic and volcanic glass.
3. Dacite; bluish gray; aphanitic, porphyritic, inequigranular, holocrystaline, hypidiomorphic, mineral consist of plagioclase (30%) and clay mineral (70%)
4. Andecite; light gray, aphanitic, porphyritic, inequigranular, holocrystaline, hypidiomorphic; mineral consist of plagioclase (40%), quartz (5%), hornblende (10%), aphanitic minerals (45%).
5. Andecite basaltic; dark gray; aphanitic; porphyritic; inequigranular; holocrystaline; hypidiomorphic; mineral consist of plagioclase (15%), and aphanitic mineral (85%).

6. Lithology vs Infiltration Rate

The 26 numbers of infiltration rate measurement data classified into 5 groups according to the rock origin of the soil. In each group the average infiltration rate calculated. From that calculation we get that the infiltration rate from highest to lowest is in origin rock pyroclastic breccia, altered dacite, laharci breccia, andecite basaltic, and andecite (Figure 4). This result match with the porosity of each rocks. According to petrographic analysis the porosity percentage from highest to lowest is pyroclastic breccia matrix (33%), altered dacite (30%), laharic breccia matrix (23%), andecite basaltic (7%), and andecite (5%). The porosity in thin section pointed by blue dyed area (Figure 5). The high porosity made a high infiltration capacity that push the formation of secondary porosity due to dissolution because the infiltrating water can easily reacted with volcanic material that formed the rock which increase the permeability.

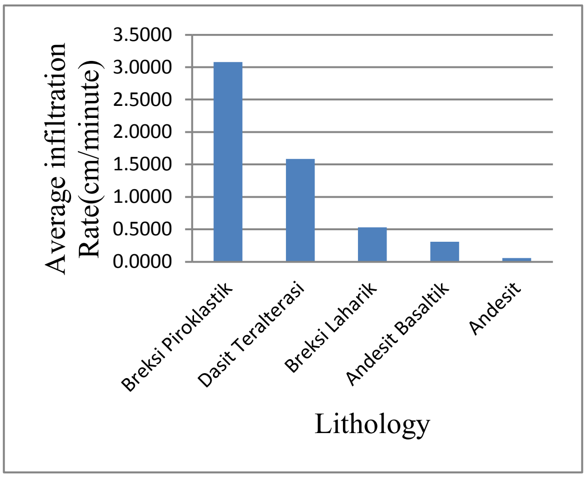
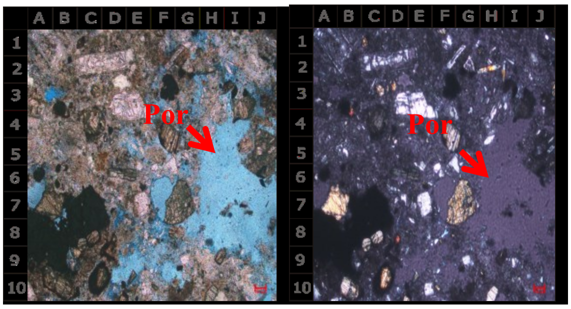


Figure 4. Lithology vs Infiltration Rate Graphic



Paralel Nicol
Lensa perbesaran 2.5 x
Code : 203
Rock name : Matrix of Laharic Breccia
Porosity : 25%

Cross Nicol
Lensa perbesaran 2.5 x
Code : 203
Rock name : Matrix of Laharic Breccia
Porosity : 25%

Figure 5. Thin section of Laharic Breccia

The high porosity and permeability cause the high infiltration rate that make weathering process more intensive. This statement support by the fact that thesoil from pyclastic breccia weathering can reach 10-25 m thick meanwhile the soil from the andecite weathering only reach 1-2 m thick. The high porosity and intensive weathering in dacite is related to the alterion process that happened. According to [12] rock that experienced hydrothermal alteration will form secondary mineral and make rock softer also has more porosity. In addition the thicker soil from andecite basaltic weathering can be affected by geological structure. Measurement in red zone which characterize the biggest lineation density and located near the interpreted fault zone.

Fracture which formed because of fault related structure can become a secondary porosity and become the infiltration way for surface water to the rock, therefore make the weathering process faster. This argument match with [10] statement which state that volcanic rocks is a good permeabel aquifer, one reason beacuse of the effect from faulting and cracking that formed after the rock formation.

7. Slope Gradient vs Infiltration Rate

The Slope Gradient vs Infiltration Rate Graphic only made in 2 groups, they are origin rock pyroclastics breccia and laharic breccia because statistically number of measurements in both groups fulfilled the criteria, 14 data for pyroclastic breccia and 5 data for laharic breccia. Meanwhile the number of measurement data for altered dacite, andecite, and andecite basaltic just two for each group. Koefisien korelasi pada kedua grafik tersebut menunjukan nilai positif, yaitu 0.0279 dan 0.0171 (Figure 6). The coefficient correlation can be used to determine the relationship between two variables, in this case the slope and the infiltration rate. According to [11], two variables that are interconnected indicated with R^2 close to 1 or -1. If R^2 is positive, the two variables are linearly related. If the value of the variable increased by "x" then the other variables increased by "x". Whereas, when R^2 is negative, the two variables are inversely related. If the value of the variable increased by "x" then the other variables decreased by "x". The result is in pyroclastic breccia and laharic breccia slope gradient is weak linearly related with infiltration rate. According to [12] this condition caused by the relatively looser soil particle in higher slope gradient therefore water will be easier to infiltrate. Meanwhile in lower slope gradient the soil is more compact. In this case soil texture become the main factor that control the infiltration rate. From field observation we know that in steeper slope the soil particle is looser and not compact. The compaction that affected by human and animal activity also considered one factor that made soil in low slope gradient more compact.

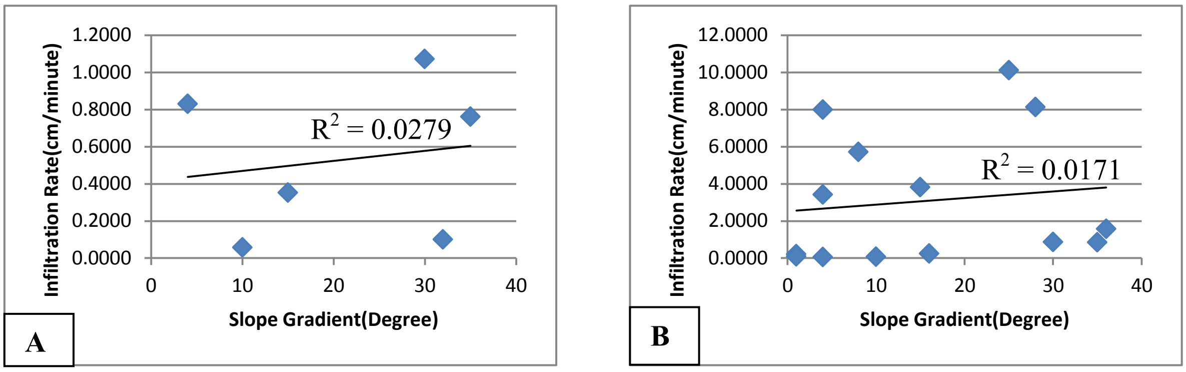


Figure 6. A) . Slope Gradient vs Infiltration Rate Graphic in laharic breccia origin rock, B) Slope Gradient vs Infiltration Rate Graphic in pyroclastic breccia origin rock

8. Conclusion

Infiltration rate proportional to the percentage of rock porosity and large of slope. Infiltration rate sequence from the smallest to the greatest are weathered-soil andesites, basaltic andesite, laharic breccias, alteration of dacite, and pyroclastic breccias.

The greatest infiltration rate obtained is 10.11 cm/minute in pyroclastic breccia with 25^{o} slope, while the smallest is 0.0437 cm/minute in pyroclastic breccias with 4^{o} slope. The high infiltration rate in pyroclastic rock relates to the secondary porosity forming due to dissolution which increase permeability. Hydrothermal alteration process cause rock to have a good porosity and permeability which make the high infiltration rate. Secondary porosity (fracture) in andecite basaltic become the infiltration way which cause more intensive weathering. The high slope gradient cause the soil became looser and uncompact therefore make the water easier to infiltrate. Hi-res and full size images are available on the following link https://onlinewaterbook.wordpress.com/2015/07/02/supplementary-page-influence-of-lithology-and-slope-gradient-to-infiltration-of-the-mount-malabar-west-java/.

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