The effect of the land cover plant on infiltration rate in Alas Bromo, Karanganyar

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Abstract. Forest management is a way to keep the forest well-preserved. Forest management can mitigate the impacts of climate change. It will affect the balance of the environment such as the balance in the hydrological or water systems aspect. Infiltration is one of the water system factors in hydrology. This research aims to determine the value and classification of the infiltration rate. This research was conducted using a descriptive exploratory method to determine the infiltration rate of each land cover plant. This research is in Alas Bromo, Karanganyar, Central Java which has Alfisol soil types with six land uses: seasonal mixed, annual mixed, mahogany, pine, pine-mahogany, and renewal. Different types of land cover and plant characteristics affect the soil condition and the ability to absorb water into the soil. The calculation of the infiltration rate uses the Philip method. According to the classification of the infiltration rate in Alas Bromo, four classes were obtained including: moderately rapid 9.15 cm.h⁻¹ (Mahogany), moderate 3.72, and 2.77 cm.h⁻¹ (Pine and Pine-mahogany), moderately slow 0.87 cm.h⁻¹ (annual mixed), slow 0.28 and 0.265 cm.h⁻¹ (seasonal mixed and renewal). Therefore, the presence of land-cover plants increases the infiltration rate.

1 Introduction

Forest management is an effort to restore forest conditions, and it is a very necessary action. Forest management can mitigate the impacts of climate change, and it will affect environmental balance from the aspect of hydrological balance or water management. Infiltration is an inseparable part of the hydrological cycle. Infiltration is the process of water entering the soil which is measured by how quickly the water can be absorbed into the soil and is usually expressed in cm per hour [1]. Water that enters the soil will fill the pore space and continue to seep until it reaches the underground layer (aquifer) as a groundwater source. The infiltration rate is determined by the size of the infiltration capacity and the rate of water supply.

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When the soil is dry, the infiltration rate is high. As time passes, the infiltration rate will decrease until it is constant, this indicates that the soil has experienced a water saturated condition. [2] stated that in the infiltration process, when water falls onto the relatively dry or unsaturated soil surface, water movement will occur to the lower soil layer which is influenced by the suction/pull of the soil matrix and gravitational forces. The longer the infiltration process takes, the soil water content increases, and when the soil begins to become saturated, the movement of water underground is only influenced by gravity.

The condition of vegetation diversity and topography on land can influence the infiltration rate. This is supported by research by [3], where the infiltration rate in each land use will be different because it is influenced by the physical properties of the soil and vegetation on the land. Different land cover plants will affect the physical properties of the soil, so this can affect the ability of water to enter the soil. This research aims to determine the value and classification of infiltration rates in different land cover plants. Because at this location no research has ever been conducted before, it is hoped that this research will provide information and a database on the condition of water infiltration into the soil in each land cover so that it becomes a consideration for the management of the Gunung Bromo Forest Education or called Alas Bromo.

2 Research methodology

2.1 Time and location

The research location was in Alas Bromo, Sebelas Maret University, which is in Karanganyar District, Karanganyar Regency, Central Java, Indonesia. Laboratory analysis of soil physical properties was carried out at the Soil Physics and Conservation Laboratory, Faculty of Agriculture, Sebelas Maret University, Surakarta. This research was conducted from July to December 2019. Alas Bromo has an area of 126.291 ha with an altitude of 200-337.5 meters above sea level. The soil on Alas Bromo has the Alfisol soil order. This is supported by [5] that the soil of Alas Bromo is Alfisol and according to Data from the Indonesian Central Bureau of Statistics [6], the soil in that area is Mediterranean Reddish Brown which has the equivalent of Alfisol. The topography and slope of the Alas Bromo area vary observations are made in areas that have a slope of 0 – 8% (flat-sloping). This can also be used as a factor in determining the sample point.

![Map of Alas Bromo Land Cover](Source: Aerial Photo Data, 2020).

Alas Bromo has 6 (six) land covers: Mahogany, Pine-Mahogany, Pine, Mixed annuals (dominated by Kedawung or tree bean (Parkia timoriana), flamboyant (Delonix regia), Saga or Acacia Coral (Adenanthera pavonina), Sonokeling or rosewood (Dalbergia latifolia), and...
Kusum (*Schleichera oleosa*) or gum-leac tree), Mixed annuals (dominated by corn, peanuts, and cassava), and Renewal (Figure 1).

### 2.2 Research Methods

This study used a descriptive exploratory method through field surveys conducted by observing, measuring, and identifying as well as direct testing on Alas Bromo on each land cover. The sample points in this study amounted to 18 based on 6 land cover plants which were replicated three times in each study area. Soil samples for laboratory analysis were taken using purposive sampling at each research observation point. Samples are taken at a depth of 0-20 cm and ensure that they are not on a sloping surface and at a minimum distance of 2 meters from the tree.

Calculation of infiltration rate and capacity using Philip's equation. The Phillips infiltration method considers the sorptivity (s) and conductivity/constant (A) values from field observations which are then shown by an equation (Philip, 1957 in [7]) as follows:

\[ I = S^{\frac{1}{2}} t + A \]  

\[ v = \frac{1}{2} S^{\frac{1}{2}} t + A \]  

Note: I = infiltration capacity (cm³); v = Infiltration rate (cm.hour⁻¹); t = Time; A = Constant that depends on the nature and content of water content; S = Sorptivity of soil

Data analysis was carried out to determine the effect of infiltration rate on each land cover using the F test (ANOVA) and DMRT 95%.

### 3 Results and discussion

Figure 2 shows that the highest infiltration rate was obtained under Mahogany, followed by Mahogany Pine, Pine, Annual Mixed, Seasonal Mixed, and Renewal. The graph shows the infiltration rate for 60 minutes. This value was obtained based on a formula calculation from the regression results for each land cover. In the Mahogany land cover (49.03 cm.hour⁻¹), Pine (12.06 cm.hour⁻¹) and Mahogany Pine (19.19 cm.hour⁻¹) the initial condition of the infiltration rate is in the fast classification, whereas in Annual Mixed (5.92 cm.hour⁻¹), Seasonal Mixed (1.50 cm.hour⁻¹) and Renewal (1.19 cm.hour⁻¹) have initial conditions that are in the medium class classification. This difference is due to the actual water content of each land cover being different, the Mahogany land cover plant has the highest value and the Renewal land cover plant has the lowest value.

![Results of Infiltration Rate for each Land Cover Plant](Image)
The infiltration rate of Mahogany land cover was the highest, because the vegetation on this land is more than 70 years old, the physical size of the vegetation is very large, the spacing or crowns are also dense so that it affects the physical properties of the soil. According to Elfiati and Delvian [8], forest soil has a high infiltration rate and relatively large macro porosity, accompanied by high soil and root biological activity. The entry of roots into the soil with a certain depth can make the soil aggregates loose, so that it will create gaps for water to enter the soil. One of them is that the water content capacity of this land cover has the highest value. In this land, there are also ground cover plants in the form of shrubs, this makes the land rich in litter which then affects the formation of pore structures in the soil. In addition, the physical properties of the soil in this land use such as low volume weight compared to the others and high porosity values also indicate that these values can support high infiltration rates. This can also be seen in every other land cover crop which shows that the value of the infiltration rate is inversely proportional to volume weight [9] and directly proportional to porosity [10].

Mahogany Pine land use has a character that is not much different from Mahogany or Pine land cover. This land cover has a planting distance between Pine and Pine of 8 m and Mahogany and Mahogany of 4 m, so that at every distance from Pine to Pinus there is a Mahogany tree in the middle. This land has ground cover in the form of bushes and some shrubs. The graph on this land is in the second part after the highest. Pine land use has the same graph in the middle. It has the character of land cover with a regular spacing of 4 meters, with a plant age of approximately 20 years and has a dense canopy, this can be seen from the lowest intensity of sunlight when compared to the others. Then the mixed land cover has quite a lot of and varied vegetation with a dense canopy density. The Mixed land cover graph itself is low.

Plants covering the seasonal mixed have a low infiltration value. The vegetation on the location only has a few plants and only a few trees. With minimal vegetation on the ground on a land, there is a minimal supply of plant remains that can be contributed to the soil. The ability of soil to absorb water can be seen from the presence of the type of vegetation on the surface of a land. Land with denser vegetation will tend to produce more litter than land with little vegetation, this can improve soil pore conditions so that infiltration becomes better. According to Supangat and Putra [11], the presence of many plants can increase soil infiltration capacity due to the role of roots in improving soil physical properties such as structure formation, increasing porosity, and stabilizing soil aggregates.

Renewal land use has the lowest infiltration value compared to other land covers. It has a slow class because in the Renewal land cover there are only pine trees which are still more or less 3 years old with a spacing of 7 meters and there are seasonal crops that have been harvested in the form of cassava, peanuts, and corn. According to the texture analysis obtained, the fraction of sand in this land is the highest compared to the others, this results in when water enters the soil the particles will also be absorbed so that they can prevent water from seeping into the soil. In addition, human intervention for the land to become annual crop land resulted in the characteristics of the soil experiencing compaction. This is also supported by Endarwati et al. [12], who found that the level of infiltration in annual crop fields is higher compared to annual crops.

The condition of Seasonal Mixed and Renewal are open-space with no ground cover plants or large growing vegetation with higher sunlight intensity. The infiltration rate on open land has a low value [13] because water (rain) that falls to the ground surface damaged soil aggregates hence the soil become compact. The topsoil on the surface is washed away by surface runoff, resulting in low infiltration rate values.

After obtaining the infiltration value for each land cover, infiltration rate classification was carried out and the relationship between the influence of land cover plants on the infiltration rate was carried out using statistical analysis using ANOVA. In the ANOVA test,
the relationship between land cover crops and infiltration rate showed a very significant value of 0.000, which was then further tested as shown in Table 1.

Table 1. Infiltration Rates in specific Land Cover.

<table>
<thead>
<tr>
<th>Land Cover</th>
<th>Infiltration rate (cm.hour⁻¹)</th>
<th>Classification [14]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahogany</td>
<td>9.15 a</td>
<td>Moderately Rapid</td>
</tr>
<tr>
<td>Pine-Mahogany</td>
<td>3.72 b</td>
<td>Moderate</td>
</tr>
<tr>
<td>Pine</td>
<td>2.77 bc</td>
<td>Moderate</td>
</tr>
<tr>
<td>Annual Mixed</td>
<td>0.87 bc</td>
<td>Moderately Slow</td>
</tr>
<tr>
<td>Season Mixed</td>
<td>0.28 c</td>
<td>Slow</td>
</tr>
<tr>
<td>Re</td>
<td>0.27 c</td>
<td>Slow</td>
</tr>
</tbody>
</table>

Description: Results of DMRT (95% confidence level) obtained between land cover and infiltration rate. Numbers followed by different letters indicate that they are significantly different.

Land cover crops have a significant effect on the infiltration rate. Table 1 confirmed the highest infiltration rate value is found in the Mahogany land cover with a value of 9.15 cm.hour⁻¹, which is included in the moderately rapid. Then Mahogany Pine and Pine have a moderately class because they are in the classification value between 1.52 - 5.08 cm.hour⁻¹. Annual Mixed is in the moderately slow with a value of 0.87 cm.hour⁻¹. The Renewal and Seasonal Mixed have a slow classification with an infiltration rate of 0.152 – 0.51 cm.hour⁻¹[14]. Then a correlation test was carried out between land cover plants and the infiltration rate. The correlation value obtained is 0.000, which means it is correlated with a very strong relationship, for the Pearson correlation (-0.86), meaning that the two have a weak relationship or influence. In addition, a negative value means that the high infiltration rate value is not entirely due to land cover plants. Then the infiltration results are correlated with the physical properties of the soil, this aims to determine the relationship of the infiltration rate with the physical supporting properties of the soil.

4 Conclusion

The presence of land cover plants can affect the rate of infiltration. Mahogany land cover has the highest rate with moderately rapid. The land cover plants of Pine-Mahony and Pine have a moderate. Annual Mixed land cover have a moderately slow and the Mixed Seasonal and Renewal land cover have a slow. The land has different infiltration rates due to one of the factors, namely the differences in the characteristics of the land cover plants above it, such as root and leaf factors. Land cover crops correlate with the soil physical properties, especially the actual soil moisture, permeability, and soil bulk density.

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References
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