Rate infiltration on mahogany stand and open area at Hasanuddin University

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Abstract. This study aims to compare the rate of infiltration on mahogany stand and open area at Hasanuddin University campus area. The result as the study was expected to be a valuable information for all parlyes who need rate infiltration data especially on mahogany stand and open area at Hasanuddin University campus area. The study was conducted from December to March 2018. Data was collected on 6 plots, 3 plots on mahogany stands with different crown densities and 3 plots on open area were covered by grass with different densities. The data obtained consist of infiltration rate and soil physical properties on every plots. The results showed that the infiltration rate on mahogany stands was 202.1 mm/hour as average to be categories as a speed rate while infiltration rate on open was 88.6 mm/hour as average that varied from medium to speed rate categories while the physical nature of the most influence on the rate of infiltration on the stands of mahogany that is moisture and open land that is porosity.

1. Introduction
Rainwater that falls on wooded areas will be held first by the canopy layer and some of them will be lost in the form of interceptions. Others dripping with canopy as water escapes (through fall) and others flow on tree trunks as trunk streams. Both the escaped water and the flow of the trunk will reach the forest floor which then moves to the ground level and into the ground through the infiltration process.

According to Arsyad (2010) the event of the entry of water into the soil, through the surface of the soil in a vertical direction is called the infiltration process [1]. Infiltration is the determinant of the amount of rainwater that scep and enters the soil directly. The magnitude of the infiltration that occurs is expressed as the rate of infiltration. Land closures can affect the availability of groundwater due to changes in the value of infiltration rates. The rate of infiltration depends on the vegetation factor to skip the water in the form of a rod flow and the water escapes.

The closure of different lands can cause differences in the physical properties of the soil. Land under the stand and open land can certainly have differences in the physical properties of the soil, which will subsequently lead to a difference in the rate of infiltration. Therefore, it is considered necessary to conduct research to compare the rate of infiltration on land under stand and on open land, including in the campus area of Hasanuddin University, especially on mahogany-covered land located in the graduate yard of Hasanuddin University.
2. Methods

2.1. Research location
The research was conducted at the Graduate Mahogany Stand of Hasanuddin University, The Open Field of Hasanuddin University and Laboratory activities were conducted in the Silviculture and Tree Physiology Laboratory of the Faculty of Forestry, Hasanuddin University.

2.2. Research procedures
2.2.1. Determination of observation points. In mahogany stands, data collection was carried out at 3 observation points, each in a tight canopy (Plot I.1), medium canopy (Plot I.2) and a rare canopy (Plot I.3). To find out the percentage of the ground plant, a plot size (2 m x 2 m) is made using the percentage of soil cover according to Paine (1981) [2] presented in Figure 1.

![Figure 1. Percentage of soil cover plants.](image)

In open land data collection was carried out at 3 observation points, those are tight (Plot II.1), medium (Plot II.2), and rare grass vegetation (Plot II.3). In each plot, the infiltration rate was measured 5 times, so that the number of infiltration measurements carried out in this study was 30 times.

2.2.2. Determination of tree canopies and ground cover vegetation. Tree canopy determination is done by visually observing the extent of the canopy by following the Life Crown Diameter guidelines, and selecting a tight, medium and rare canopy. Then calculate the area of the canopy by measuring the diameter of the 4 directions, which are east, west, south, and north to project the canopy above ground level and then averaged to obtain the diameter of the canopy.

The area of canopy cover can be known by using the formula:

\[
L = \pi r^2
\]

- \( L \): Canopy cover area
- \( \pi \): 3.14
- \( R \): radius of Tree
Determination of soil cover vegetation is carried out by visually observing and then matching it with the percentage of land cover vegetation that is differentiated into a lot of soil cover, while there is no vegetation according to Paine's method (1981) [2] and so on measuring the height of the ground cover vegetation.

2.2.3. Infiltration rate measurement. Measurement of infiltration rate is done by installing Double Ring Infiltration at the observation point and then filling the water into the ring by first inserting the outer ring and then continued in the inner ring. When the ring is filled with water then turn on the stopwatch and record the infiltration rate that occurs. To measure soil moisture plugged soil tool PH & Moisture tester DM-15 model until the needle scale on the tool does not move.

2.2.4. Soil sampling. Soil sampling is carried out on disturbed soil and intact soil in the ring. The disturbed soil is used to test for porosity and bulk density. The intact soil is used to test soil texture, porosity and organic matter.

2.3. Data analysis
To calculate the infiltration rate, the equation is used:

\[ \text{Infiltration Rate} = \left( \frac{\Delta H}{t} \times 60 \right) \]

\( \Delta H \) : Height decrease (mm) within a certain interval
\( t \) : Time lapse required by water to enter the ground (minutes) [3]

The data of observation of infiltration rate is presented in the form of curves. Kohnke (1968) in Lee (1988) class of infiltration rate and per collation rate, as can be seen from Table 1 [4].

### Table 1. Soil Infiltration And Collation Rate

| Description       | Infiltration (mm/h) | Percolation (mm/h) |
|-------------------|---------------------|--------------------|
| Very slow         | 1                   | 1                  |
| Slow              | 1 – 5               | 1 – 5              |
| Moderate Slow     | 5 – 20              | 5 – 16             |
| Moderate          | 20 – 65             | 16 – 50            |
| Moderate fast     | 65 – 125            | 50 – 160           |
| Fast              | 125 – 250           | > 160              |
| Very fast         | > 250               |                    |

3. Result and discussion
3.1. Vegetation conditions
Mahogany stands which are an aspect of the research are located in front of the Hasanuddin University Public Health Faculty. Mahogany stands are located at coordinates 5°7’39,8"south latitude and 119°29’11,2" East Longitude which is in the Unhas Campus area. The area of research on mahogany stands is 0.35 ha with a flat soil surface state. This mahogany stand consists of 90 trees with several types such as Swietenia macanophylla King, Mangifera indica, Alstonia Scholaris and Mimusops elengi trees. Mahogany stands are approximately six years old with an average diameter of 24.03 cm and the height of the tree is 15.27 m with a planting distance of 5 x 5 m. Mahogany stand images can be seen in Figures 2 and 3.
Figure 2. Vegetation conditions of mahogany stands.

The open land that became the object of research is located between the Faculty of Marine Fisheries and the Hasanuddin University Postgraduate School at the coordinates of south Latitude 5°7'43" and East Longitude 119°29'4", with an area of 0.20 Ha. In open land, some areas are dominated by heterogeneous grasses including cyperus rotundus L and Cenchrus purpureus. It is also surrounded by several trees that serve as a penetrating tree. If we look at the physical condition of the land in open land, it is thought that soil compaction will easily occur due to human trampling because it is often used as a playing field for soccer. Open land images can be seen in Figures 4 and 5.
3.2. **Physical properties of the soil**

The type of soil found in mahogany stands and open land is the Mediterranean soil type. The physical properties of soil in mahogany stands and open land analyzed were soil texture, porosity, permeability, bulk density, and soil organic matter. Soil sample analysis was carried out at the Laboratory of Silviculture and Tree Breeding, Hasanuddin University Faculty of Forestry. The results of the analysis are presented in tabular form for each plot in mahogany stands and open land. The following is a table 2 and 3 of the results of the analysis of soil physical properties in mahogany stands and open land at Hasanuddin University.

| Plot | BD (g/cm³) | Porosity (%) | Permeability (cm/h) | Soil texture | C organic content (%) | Organic Ingredients (%) |
|------|------------|--------------|---------------------|--------------|-----------------------|-------------------------|
| I.1  | 1.27       | 30           | 0.43                | 33 12 55     | 0.63                  | 1.08                    |
| I.2  | 1.23       | 37           | 0.54                | 54 14 32     | 0.52                  | 0.89                    |
| I.3  | 1.3        | 31           | 0.52                | 55 10 35     | 0.44                  | 0.75                    |
| Average | 1.26   | 32.66        | 0.49                | 47.33 12 40.66 | 0.53                  | 0.90                    |
Table 3. Results of analysis of the physical properties of land in open land.

| Plot | BD (g/cm³) | Porosity (%) | Permeability (cm/h) | Soil texture | C organic content (%) | Organic Ingredients (%) |
|------|------------|--------------|---------------------|--------------|-----------------------|-------------------------|
| II.1 | 1.35       | 28           | 0.34                | Sand 26      | 17                    | 57                      |
|      |            |              |                     | Dust 21      | 33                    |                         |
| II.2 | 1.34       | 24           | 0.20                | Sand 14      | 19                    | 67                      |
|      |            |              |                     | Dust 28      | 38                    |                         |
| II.3 | 1.53       | 23           | 0.16                | Sand 23      | 28                    | 49                      |
|      |            |              |                     | Dust 21      | 33                    |                         |
| Average | 1.40   | 25           | 0.23                | Sand 21      | 33                    | 57.66                   |
|      |            |              |                     | Dust 21      | 33                    | 0.15                   |
|      |            |              |                     | Clay 57.66   |                       | 0.25                    |

3.2.1. Soil texture. Determination of the soil texture classification is done using a texture triangle diagram based on the USDA (United States Department of Agriculture) classification. Based on this classification, it was found that the soil texture in the Mahogany stands was classified as sandy loam and on open land it was classified as clay class. Soil texture is basically related to the pore state of the soil. The number and size of pores that determine the number of large pores. The more large pores, the greater the infiltration capacity. Clay has fine pores and less large pores. It is inversely proportional to the sand fraction which has many large pores and few fine pores, therefore the infiltration in sandy soil is much greater than that of clay [5].

3.2.2. Bulk density. Based on laboratory analysis, the bulk density value for mahogany stands was 1.26 g/cm³ and on open land was 1.40 g/cm³. This is presumably because in open land there is a lot of trampling or overcrowding by humans who carry out sports activities and cause the soil to be solid. This value indicates that the relationship between bulk density and infiltration rate is inversely proportional to the fact that the smaller the bulk density value, the greater the infiltration rate. High bulk density is an indicator of soil density that is difficult to pass water or plant roots penetrate [6].

3.2.3. Porosity. Mahogany stands have a soil porosity value of 32.66% and on open land has a soil porosity of 25%. Mahogany stands have stable soil aggregates and will form many pores and will accommodate water that enters the soil, unlike open land which has unstable soil aggregates. The amount of total soil pore space indicates that the soil is loose and has a lot of soil pore space and the process of water absorption or infiltration rate is fast [3].

3.2.4. Permeability. Permeability in mahogany stands is 0.49 cm / hour and in open land is 0.23 cm / hour. Open land has dense soil and it is difficult to pass water into the soil because it has a high density compared to mahogany stands, which causes the permeability value in open land to be higher than in mahogany stands.

3.2.5. Organic materials. The results showed that the organic matter content in mahogany stands was 0.90% and 0.25% in open land. Organic matter in the two land coverings did not show much different results, this was due to the fact that in mahogany stands there were very few or almost no ground cover plants, therefore the production of organic matter was minimal while on open land it showed low organic matter. This is supported by research Rahayu, et al., (2009) in Budianto, et al., (2012) that the higher the organic matter of a land where there is a lot of litter covering the soil surface will increase the activity of microorganisms in decomposing organic matter and will maintain the soil structure while the areas that are without litter is likely to harden and form a crust due to high surface flow [7].

3.3. Soil moisture
Soil moisture measurements were carried out in each plot on mahogany stands and open land. The results of soil moisture obtained can be seen in Table 4.
Table 4. Percentage of soil moisture.

| No | Observation plot | Mahogany Stand Moisture (%) | Observation plot | Open Land Humidity (%) |
|----|------------------|----------------------------|------------------|-----------------------|
| 1  | I.1              | 60                         | II.1             | 60                    |
| 2  | I.2              | 50                         | II.2             | 65                    |
| 3  | I.3              | 50                         | II.3             | 70                    |
|    | Average          | 53.3                       |                  | 65                    |

The results showed that open land has a high humidity of 65% obtained from each plot. Plot I.1 is 60%, Plot I.2 and I.3 are 50% (Table 4). While the open land has a high humidity of 65% with the humidity of each plot is 60% in plot II.1, 65% in plot II.2 and 70% in plot II.3. The high humidity in open land is caused by the texture of clay that is able to hold more water than other texture classes while on the mahogany stand has the texture of sandy loam clay texture soil. Hillel (1998) states that soil absorption is low when soil moisture is high and soil absorption will increase with decreasing soil moisture, as a result of which the initial infiltration rate is higher in dry soil than wet soil [8].

3.4. Infiltration rate in mahogany stands and open land

Measurement of the infiltration rate five times on each plot with a measurement time of 15 minutes for each plot, the measurement of the infiltration rate was carried out randomly. The infiltration rate in mahogany stands and open land can be seen in Table 5.

Table 5. Infiltration rate.

| Plot Observation | Mahogany Stand Infiltration Rate cm/min mm/h | Description | Plot Observation | Open Land Infiltration Rate cm/min mm/h | Description |
|------------------|---------------------------------------------|-------------|------------------|------------------------------------------|-------------|
| I.1              | 0.268                                       | 160.8       | Fast             | 0.256                                    | 153.6       | Fast         |
| I.2              | 0.378                                       | 227.2       | Fast             | 0.142                                    | 85.2        | Moderate Fast|
| I.3              | 0.364                                       | 218.4       | Fast             | 0.045                                    | 27          | moderate     |
| Average          | 0.336                                       | 202.1       | Fast             | 0.148                                    | 88.8        | Moderate Fast|

Based on the results of the study, the infiltration rate on mahogany stands and open land in Table 7, it was obtained 202.1 mm/h for mahogany stand and 88.8 mm/h for open land. The rate of infiltration in mahogany stands is categorized as fast and the rate of infiltration on open land is categorized as a moderate fast based on the classification table of soil infiltration rate and percolation according to Kohnke (1968) in Lee (1988) [4]. The magnitude of the infiltration rate in mahogany stands was influenced by the varying density of the canopy and understory vegetation compared to open land without tree crowns. Mahogany special is most useful [9,10]. The condition of the soil cover and litter vegetation in this study also plays a role in which in mahogany stands the ground cover vegetation is minimal and on open land the vegetation cover is dominated by grass. The infiltration will be smaller in land uses that have vegetation with short roots compared to land that has a lot of vegetation.

According to Morgan (2004) in Irawan and Yuwono (2016), the effectiveness of vegetation in suppressing surface runoff and erosion is influenced by canopy height, canopy area and vegetation density [5]. Vegetation plays an important role in protecting the soil from direct rainwater blows by breaking its kinetic energy through canopies, twigs and trunks. In addition, the magnitude of the infiltration rate in mahogany stands is influenced by the condition of soil texture, bulk density, porosity, permeability, organic matter and soil moisture. The results of the analysis of the physical properties of the soil show that the physical properties of the soil in mahogany stands strongly support the infiltration process that occurs compared to open land. Soil texture determines the number of pores found in the soil, where the number of large pores, the greater the infiltration capacity because infiltrated water enters the soil filling the empty pores. Soil texture with a high sand fraction makes the soil have a high...
infiltration rate.

Based on laboratory analysis, it was found that the average bulk density value for mahogany stands was 1.26 g/cm³ and open land was 1.40 g/cm³. This value indicates that the relationship between bulk density and infiltration rate is inversely proportional, i.e. the smaller the bulk density value, the greater the infiltration rate, this is in accordance with what is stated in Hardjowigeno (2007) which states that high bulk density is an indication of soil density that is difficult to pass water or penetrate [6]. Plant roots. Porosity is related to the value of soil bulk density and soil texture. The higher the weight value of the soil, the pore space in the soil will decrease, while the porosity in mahogany stands is 32.66% and in open land it is 25% because in open land the value of soil fill weight is higher than in mahogany stands. This means that the water conductivity is decreasing. In line with that, the permeability will decrease so that the infiltration will also decrease. The resulting permeability in mahogany stands is 0.49 cm/hour and open land is 0.23 cm/hour, this value is categorized as low class [6]. Porosity and permeability are also influenced by the amount of organic matter in the soil so that the soil becomes crumbs and the pore space will also increase.

The pore space contained in the soil has an influence on the movement of water in the soil, and if the soil has plant roots, this pore space can increase in size along with the root growth. The high infiltration rate is due to the good physical quality of the soil, especially the high soil porosity due to the high C-organic content. The high soil organic matter in mahogany stands is 0.53% and 0.15% open land. According to Franzluebbers (2002) in Irawan and Yuwono (2016), one of the important roles of organic matter is to reduce soil weight and increase soil infiltration rate [5].

3.5. Infiltration rate curve on mahogany stands and open land

The infiltration rate in mahogany stands and open land in each observation is presented through the infiltration curve for each plot obtained from the difference in the infiltration rate per minute. After measuring the infiltration rate for 15 minutes, the infiltration rate for each plot in the mahogany stands can be seen in Figure 6 and the infiltration rate for each plot in open land can be seen in Figure 7.

![Figure 6. Infiltration rate curve on mahogany stand.](image)

The highest infiltration rate in mahogany stands occurred in medium-crowned trees with the highest decrease in water in the first minute of 9 mm/minute then in the 2nd to 7th minute it experienced a small decrease. When entering the 8th minute the infiltration rate has decreased which varies until the 13th to 15th minute the rate is constant. Whereas the lowest rate in mahogany stands was on trees with tight crowns with a decrease in water in the first 7 mm/minute, then in the next minute the infiltration rate was small until 11-15 minutes the infiltration reached a constant state. Infiltration rate in rare canopy shows that the rate is not much different from trees with medium crown, the first minute decrease is 8.2 mm/minute and the next minute decreases varying until the 14th minute the decline reaches a constant point.
The infiltration rate of the 1st to 3rd minutes on vegetation-covered land experienced a large decrease, and at the next minute there was an insignificant decrease. In the 6th minute there is a constant infiltration rate until the 8th minute this condition continues until the last minutes. This is presumably because at the time of data collection, conditions in the field were dry because there was no rain for several days and it was known that the height of the grass in this plot was 7 cm high. Based on this curve it can be said that at the initial stage the infiltration rate in open land with medium grass vegetation soil cover was 4.6 mm / minute, in the next minutes it experienced an insignificant decrease until the 13th to 14th minutes no longer showed drop. This occurs because the initial moisture in the soil is higher than the dense vegetation plot. The height of the grass in this plot is 3 cm. The smallest infiltration rate occurred on bare land where the initial decline was 0.18 cm / minute. Then in the following minutes there is a small and insignificant decrease and at the 15th minute it reaches a saturation point. This is thought to be due to the very dense soil conditions in this plot. In addition, at night, before measuring the infiltration rate, rain occurs which causes the soil to become saturated with water.

3.6. Infiltration rate difference curve
The infiltration rate in mahogany stands and open land in the Unhas campus area was obtained from the average infiltration rate on each observation plot. The curve in Figure 8 shows the infiltration rate in two types of land cover, the infiltration rate in mahogany stands is greater than in open land based on Kohnke's Table (1968) in Lee (1988) [4].

Figure 7. Infiltration rate curve on open land.

Figure 8. The curve of differences in the rate of infiltration of mahogany and open land.
4. Conclusions
The level of canopy cover on mahogany stands and the level of lower plant cover on open land affect the infiltration process quite significantly. The rate of infiltration in mahogany stands that have a variety of canopies in the Hasanuddin University campus area belongs to the fast category with an average value of 202.1 mm/h and this value is about 2.3 times when compared to the rate of infiltration in open land that does not have a canopy but only vegetated grass which is only 88.6 mm/h including the category of medium to fast. While the physical properties that most affect the rate of infiltration and open land is porosity.

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