The characteristics of infiltration in natural forest in teaching forest of Hasanuddin University University at Maros Regency

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Abstract This study aims to know the amount of infiltration and its characteristics of natural forest in the teaching forest of Hasanuddin University (Unhas) at Bengo-Bengo in Maros Regency. The results of this study are expected to find some information about the characteristics of infiltration on natural forest. It can be used to review and to guide the recovery recommendation for optimizing the land and the water supply and to improve the public welfare by giving them some values about the maintenance of water supply resistance. The data were collected from 12 plots which categorized based on the cover crop and the slope. The infiltration data was taken by measured the infiltration rate for 9 times. The collected data consisted of the characteristic of infiltration in each plot and the physical properties of soil analysis. The result shows that the characteristic of infiltration was varied while the infiltration rate was categorized in very quick infiltration. The natural forest cover on the UNHAS teaching forest according to the results obtained, it can be classified as good and should be maintained.

1. Introduction
Teaching forest of Hasanuddin University is very strategic and appropriate for forestry development activity, educational centers, research, training, and forestry service because it’s located in Maros Regency, about 63 km from Makassar. The located beside the provincial road and about 40 km from the Sultan Hasanuddin International Airport. Geomorphological conditions of this region consist of the flat, hilly and mountainous area. Agricultural land dominates the flat area. A mountainous area has very steep slopes in the upstream. It is the water sources for people who live in and around Teaching forest of Hasanuddin University. Farming, gardening, breeding, and other activity were using the water that sourced from the river which its upstream is in the teaching forest of Hasanuddin University.

The growth of the ground cover vegetation, especially forests in the teaching forest always parallel with the growth of soil characteristic under it. That situation will cause the rainfall transformation changes from canopy to soil and flowing underground [1]. The ability of soil passing the water (infiltration) getting high over time, so the water table is rising too. Nevertheless, because of the water requirement also increased along with the increasing number of population, water resistance could be disturbed in the future.

Water resistance defined as a situation where there is no lack of water [1]. To keep that water resistance are not disturbed by the various interests then it needs efforts, one of them is to determine the soil's ability to pass water or often called Infiltration. The amount of Infiltration can vary due to the variation of the vegetation which grows in that place. The data shows that most of the teaching forest are secondary forest and pine forests, thicket and primary forest. Pine spread from south to the north which some pine is slightly in the north of the teaching forest. Therefore this research will investigate the amount of infiltration and its characteristics of natural forest in the Unhas teaching forest.
2. Materials and Methods

2.1. Study area
This study was conducted on natural forest located in the Mahaka subwatershed at Teaching Forest of Hasanuddin University, Bengo-Bengo, Maros Regency.

2.2. Tools and Materials
Tools and material in this study are:
- Double ring infiltrometer, to measure the rate of infiltration, equipped with a ruler to determine decreasing water in infiltrometer ring,
- Stopwatch, to determine decreasing time in the ring infiltrometer during observation,
- Water tank, to take water and fill it into double ring infiltrometer,
- Sample Ring, to take soil samples for determine a physical character of soil,
- Hexameter to measure slope,
- Cleaver, GPS (Global Positioning System), Rollmeter, Ruler, Knives, Hammer, Rope, rubber bands, permanent marker, label paper, duct tape/insulation, and tally sheet.

2.3. Research Procedure

a. Making The Land Use Map
Land Use maps of Teaching Forest was obtained from the Teaching Forest boundary map and Land Use Map in 2009. After determining the land use of Unhas Teaching Forest, the density of natural cover was determined too. Natural forest density selected is high-density natural forests, medium density natural forest, and low-density natural forests.

Every form of density can be seen from the imagery looks of Google Earth where high-density natural forests show a darker color while moderate and low-density natural forest show a lighter color. Then the boundaries digitizing used as a reference or basis to search the observations plot in location.

The determination of natural forest density in location were obtained by calculating the number of trees and stands in the 20m X 20m plot that was created before. It called high density if the number of
trees and stands were over 600 / ha, the medium density if the number of trees and stands between 500-600/ha, and low density if the number of trees and stands is less than 500/ha.

b. Taking the field data
Field data collected by looking at the canopy condition enclosure, number of trees, sunlight entering the forest floor, and slope. Observations doing in natural forests on different slope, <40% and> 40%. In each slope, there is six plot in which each plot is 20m x 20m. There is 2 plot in high-density natural forest, 2 plot in medium density, and 2 plot in low density. A total number of plots are 12 plots and infiltration rate measurement doing in every each plot which has 9 repetitions.

c. Measurement of the infiltration rate
Infiltration rate data are doing with double ring infiltrometer. Infiltration methods using ponded infiltration falling head on several locations in study areas with three condition land cover [2]

![Figure 2. Double ring infiltrometer](image)

d. Soil physical character measurement
Determination of soil physical characteristic was conducted by taking 12 intact soil samples tests in location to analyze permeability, porosity, and bulk density, and 12 agitated soil samples to analyze the texture and organic matter was analyzing in the laboratory. Sampling the soil based on the number of infiltration rates measurement plots.

2.4. Analysis
Analysis of infiltration rate data can be obtained by using equation [3]

\[
\text{The Rate of Infiltration (mm / h)} = \frac{\Delta H}{t}
\]

Where:
\(\Delta H\) = High decrease (mm) within a certain time interval.
\(t\) = Time to infiltrate the water into the soil (minute); to convert it to an hour, it must be multiplying with 60

Infiltration characteristics based on infiltration value obtained as in Table 1.

| Description          | Infiltration (mm/hr) | Percolation (mm/hr) |
|----------------------|----------------------|---------------------|
| Very slow            | 1                    | 1                   |
| Slow                 | 1 – 5                | 1 – 5               |
| Moderately slow      | 5 – 20               | 5 – 16              |
| Moderate             | 20 – 65              | 16 – 50             |
| Moderately fast      | 65 – 125             | 50 – 160            |
| Fast                 | 125 – 250            | > 160               |
| Very fast            | > 250                |                     |
3. Results and Discussion

3.1. Determination of observation point

The results of the land use map analysis in 2009 showed that the area on the teaching forest is covered by natural forest (primary forest and secondary forest), pine forests, farm, meadow, habitation, rice fields, cleared land and shrubbery. The first year of this research was specifically done on natural forests which were categorized into three groups density classes: high-density natural forest, medium and low. The density classes were categorized based on the number of the trees, the saplings, and the poles in every location that will be used as the measurement plots. The number of trees, saplings, and poles can be seen in Table 2.

| Plots | slope  | trees/plots | stands/plots | trees/ha | stands/ha | Total (ha) | Stands density |
|-------|--------|-------------|--------------|----------|-----------|------------|----------------|
| 1     | <40%   | 9           | 13           | 225      | 325       | 550        | Medium         |
| 2     | <40%   | 4           | 10           | 250      | 350       | 400        | Low            |
| 3     | >40%   | 11          | 18           | 450      | 725       | 875        | High           |
| 4     | >40%   | 11          | 10           | 250      | 525       | 775        | Medium         |
| 5     | <40%   | 9           | 18           | 450      | 675       | 1125       | High           |
| 6     | >40%   | 6           | 10           | 250      | 400       | 650        | Low            |
| 7     | >40%   | 5           | 4            | 100      | 225       | 275        | Low            |
| 8     | <40%   | 8           | 14           | 125      | 250       | 350        | Medium         |
| 9     | <40%   | 14          | 12           | 300      | 650       | 950        | High           |
| 10    | <40%   | 3           | 10           | 75       | 325       | 400        | Low            |
| 11    | >40%   | 10          | 17           | 250      | 675       | 925        | High           |
| 12    | >40%   | 8           | 15           | 200      | 575       | 875        | Medium         |

3.2. The infiltration rate

The result of the infiltration rate was measured on 12 observation plots which obtained with 9 times repetition. It was measured throughout 15 minutes in every repetition. The value of the measurement results at each point of observation divided by observations time and obtained infiltration rate value (cm/min) and then converted into (mm/hour) to determine the categories of infiltration rate. Results can be seen in Table 3.

| Observations Plots | Value Infiltration rate | Description (*) |
|--------------------|-------------------------|-----------------|
|                    | cm/min      | mm/min      | mm/hour    |
| 1                  | 0.62        | 6.20        | 372.00     | Very Fast |
| 2                  | 0.67        | 6.68        | 400.80     | Very Fast |
| 3                  | 0.85        | 8.52        | 511.20     | Very Fast |
| 4                  | 0.48        | 4.77        | 286.20     | Very Fast |
| 5                  | 0.63        | 6.34        | 380.40     | Very Fast |
| 6                  | 1.05        | 10.51       | 630.60     | Very Fast |
| 7                  | 0.88        | 8.81        | 528.60     | Very Fast |
| 8                  | 0.74        | 7.37        | 442.20     | Very Fast |
| 9                  | 1.23        | 12.31       | 738.60     | Very Fast |
| 10                 | 0.66        | 6.60        | 396.00     | Very Fast |
| 11                 | 1.00        | 9.96        | 597.60     | Very Fast |
| 12                 | 0.83        | 8.25        | 495.00     | Very Fast |
| Rata-rata           | 0.80        | 8.02        | 481.60     | Very Fast |

Note: (*) cited from Lee, (1988)
Based on observations result in Table 3 show that the value of the infiltration rate has the same category for low, medium, and high-density natural forest that is very fast. Another study in the natural forest which did by [5] also showed the same result as it. It showed that an average infiltration rate in natural forest is about 404.13 mm/hour and it was also categorized as very fast.

3.3. Soil physical characteristic properties

Soil physical characteristic properties based on the laboratory analysis results shown in Table 4.

Table 4. The soil physical characteristic properties on 12 observations plots

| Analysis                  | Plots 1 | Plots 2 | Plots 3 | Plots 4 | Plots 5 | Plots 6 | Plots 7 | Plots 8 | Plots 9 | Plots 10 | Plots 11 | Plots 12 |
|---------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|----------|----------|
| Permeability (cm/h)       | 3.6     | 2.5     | 3.4     | 3.1     | 2.9     | 1.8     | 2.4     | 2.6     | 3.6     | 3.4      | 2.8      | 2.6      |
| Organic matter (%)        | 2.16    | 2.22    | 2.14    | 2.32    | 2.51    | 2.41    | 2.19    | 2.33    | 2.24    | 2.14     | 1.98     | 2.41     |
| Porosity (%)              | 50      | 55      | 50      | 51      | 56      | 50      | 50      | 51      | 51      | 52       | 49       | 53       |
| Bulk density (BD)         | 1.25    | 1.19    | 1.22    | 1.14    | 1.16    | 1.25    | 1.21    | 1.19    | 1.24    | 1.16     | 1.24     | 1.19     |
| Particle density (PD)     | 2.52    | 2.63    | 2.43    | 2.35    | 2.66    | 2.52    | 2.42    | 2.45    | 2.53    | 2.41     | 2.42     | 2.53     |
| Soil texture:             |         |         |         |         |         |         |         |         |         |          |          |          |
| Sand (%)                  | 32      | 35      | 36      | 32      | 29      | 34      | 40      | 32      | 38      | 36       | 34       | 38       |
| Silt (%)                  | 30      | 30      | 40      | 36      | 26      | 24      | 29      | 22      | 33      | 42       | 39       | 27       |
| Clay (%)                  | 38      | 35      | 24      | 32      | 45      | 42      | 31      | 46      | 29      | 22       | 27       | 35       |

3.4. Infiltration rate characteristics

a. Infiltration rate curve on low density natural forest

Figure 3. The curve of infiltration rate - low density in natural forest

Characteristics of infiltration in low-density natural forest with two different classes slope showed that the infiltration rate curve had a differentiation. Curves of infiltration rate on slope class <40% in the early minute's observation had the same relative value as well as with it rate infiltration decrease.
But in the 5th minute and 6th in either plot showed an increase infiltration rate and varies of infiltration rate.

Infiltration rate characteristics on slope > 40% indicate the infiltration rate was relatively same where the 2nd plot has a value between 1.5 to 2 cm/min, but plot 7 in slopes > 40%, it’s infiltration rate is more varied than 6th plot. Infiltration rate values in either slope categories and the same density shows the influence of the slope.

About laboratory analysis results of soil physical characteristic indicate that the permeability, organic matter, porosity, bulk density, particle density and soil texture in low density natural forests on <40% and >40% slopes are shown in Table 5.

### Table 5. The characteristics of soil physical properties – low density in natural forests

| Analysis        | Slope <40% | Slope >40% |
|-----------------|------------|------------|
| Permeability (cm/h) | 2.5        | 3.4        |
| BO (%)          | 2.22       | 2.14       |
| Porosity (%)    | 55         | 52         |
| BD (g/cm3)      | 1.19       | 1.16       |
| PD (g/cm3)      | 2.63       | 2.41       |
| Texture (%)     | Clay Loam  | Clay Loam  |
|                 | Clay       | Clay Loam  |

Characteristics of infiltration rate about the soil physical characteristic in low density natural forests showed a similar condition of the two slopes. Movement of the infiltration rate at the beginning of the observation was always high, and sooner it will decrease. This movement pattern is accordance with the general pattern of infiltration. This pattern was related to the soil physical characteristic. Soil physical properties such as permeability, porosity, texture, BD, PD, and organic matter is very decisive for infiltration rate that happen on land or soil. [7] stated that the permeability was the soil’s ability to pass water. Permeability also associated with the structure, texture and organic matter content in the soil. Soil with a high permeability would increase the infiltration rate and reduce the running water or runoff that could damage the surface of the soil.

Characteristic of permeability can be maintained by keeping the land cover conditions which is vegetation especially forests. Vegetation role is breaking the precipitation that falls on it, so that reduces the rainwater collisions. That thing is in line with the states of [7] that the vegetation acted to stabilizing soil aggregates because its roots can bind soil particles and is also able to maintain the mashed power of rainwater grains directly to the soil surface, so the destruction of the soil can be prevented. Therefore, even though the physical properties of soil was varied, but the infiltration rate of low-density natural forests at all was still very fast.

### b. Infiltration rate curve on medium density natural forests

![Figure 4](image-url)  
**Figure 4.** The curve of infiltration rate - medium density in natural forests
Infiltration rate curve on the medium density plot category of natural forest with different slopes classes also showed variations in infiltration rate which slope class<40% its infiltration rate value in the early minutes of the measurement was less than 1.5 cm/min and above 1.5 cm/minute. On the slope class> 40% also showed differences values of infiltration rate in the early minutes of measurement equal to the slope grade <40%, which means that the infiltration rate of medium density natural forest was not influenced by the slope.

About results of soil physical properties laboratory analysis, it indicates that the permeability, organic material, porosity, bulk density, particle density and soil texture in medium density natural forests on a slope <40% and> 40% are shown in Table 6.

**Table 6.** The characteristics of soil physical properties - medium density in natural forests

| Analysis       | Slope <40% | Slope >40% |
|----------------|------------|------------|
|                | Plots 1    | Plots 8    | Plots 4    | Plots 12   |
| Permeability (cm/h) | 3.6        | 2.6        | 3.1        | 2.6        |
| BO(%)          | 2.16       | 2.33       | 2.32       | 2.41       |
| Porosity (%)   | 50         | 51         | 51         | 53         |
| BD (g/cm³)     | 1.25       | 1.19       | 1.14       | 1.19       |
| PD (g/cm³)     | 2.52       | 2.45       | 2.35       | 2.53       |
| Texture (%)    | Clay Loam  | Clay       | Clay Loam  | Clay Loam  |

The results of the analysis of soil physical properties in Table 6 shows the varying values to determine the characteristics of infiltration that happen. Characteristics of soil physical properties that described determine the pattern of infiltration that occurs at each observation point. Variety of soil characteristics physical properties causes the infiltration rate at each point were varies too, but observations result showed that infiltration rate was very fast. Although organic matter content was moderate it can improve the soil physical properties, so the infiltration rate has been increased.

Explained that soil containing high organic matter and litter that covering soil surface. Litter on the soil surface could boost the activity of microorganisms to decompose into organic matter and protect soil structure, land with less litter causing the soil to harden and form a crust then result in runoff highly [6]

c. Infiltration rate curve on high density natural forests

The infiltration rate curve on high density natural forest with different slopes classes show the variation of infiltration rate where at slope class <40% plot 1 infiltration in the early minutes its measurement values are less than 1.5 cm/min and the infiltration decrease rate was stable enough during 15 minutes observation, and plot 9 with the same slope showed high infiltration rate value that is up to 2 cm/min and the decrease of infiltration rate is more varied.

Infiltration rate curve on the slope grade> 40% show different characteristics of infiltration rate in the 2nd plot. Infiltration rate value in early minutes on plot 3 shows smaller value than plot 6, but the
increase in plot 3 infiltration was more even while a decrease in infiltration rate on plot 6 is more varied.

In relation with results of soil physical properties laboratory analysis indicate that the permeability, organic matter, porosity, bulk density, particle density and soil texture in high-density natural forests slopes <40% and >40% are shown in Table 7.

Table 7. The characteristics of soil physical properties - high density in natural forest

| Analysis       | Slope <40% | Slope >40% |
|----------------|------------|------------|
|                | Plots 5    | Plots 9    | Plots 3    | Plots 11   |
| Permeability   | 2.9        | 3.6        | 3.4        | 2.8        |
| BO (%)         | 2.51       | 2.24       | 2.14       | 1.98       |
| Porosity (%)   | 56         | 51         | 50         | 49         |
| BD (g/cm3)     | 1.16       | 1.24       | 1.22       | 1.24       |
| PD (g/cm3)     | 2.66       | 2.53       | 2.43       | 2.42       |
| Texture (%)    | Clay       | Clay Loam  | Clay Loam  | Clay Loam  |

Infiltration rate characteristics of high-density natural forest showed varying rate pattern for two slope class observations. It was influenced by the content of soil physical properties. The content of soil physical properties based on Table 7 giving effect to infiltration rate that occurs in every observation plot. Value of soil physical properties content had a close relationship with the infiltration rate patterns, such as soil texture was the percentage of three factions soil compiler: sand, silt, and clay. If the content of sand fraction more higher, it will determine the soil’s macropore space in that soil. Macropore space helps the process in accelerating water flow into the soil which means is associated with the value of permeability and organic matter content. Permeability values obtain based on soil permeability, and infiltration value relationships table on procedures for preparation watersheds plans forest and land rehabilitation technique [8], so the value was a medium category, that value could affect the pattern of infiltration. While soil texture that accordance with the analyzed previously based on infiltration capacity prices table associated with soil texture and canopy (ground cover). According to [5], clay texture soil and clay loam have an infiltration value between 5-20 mm/hour.

4. Conclusions
In conclusion, according to results and discussion were conclude are:

a. The highest infiltration rate value was in high density natural forests and the lowest infiltration rate value was in moderate natural forests category.

b. The Characteristics of infiltration rate in Unhas Teaching Forest shown variation of the infiltration rate characteristics based on three density categories.

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