The infiltration rate on candlenut stands in Lamoncong Village Bontocani District Bone Regency

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Abstract. This study was aimed to compare the infiltration rate in candlenut stand with cocoa and candlenut stand without cocoa in the Sanrego sub watershed, Walanae watershed. The data collected consists of the rate of infiltration and physical properties of the soil. Measurement was collected on 2 plots, Plot 1 consisted of candlenut trees with cocoa plant and Plot 2 consisted of candlenut trees without cocoa plant. The results showed that the infiltration rate in the candlenut stand with cocoa was 2,585.4 mm / hour and the infiltration rate of candlenut without cocoa was 2,299.2 mm / hour. The infiltration rate of the two plots included in the category is very fast, the physical properties of the soil which most influence the infiltration rate in the candlenut stand were soil texture, bulk density, organic material, soil porosity and soil permeability.

1. Introduction

Forest is a plant community that provides natural resources, including planks and living natural resources, so that their existence must be maintained. Besides, it also as a regulator of an area's water system. This is because forests are able to collect rainwater and distribute it into the soil layer. If the forest is disturbed or damaged, that role will also be disturbed so that the movement of rainwater into the ground is also disturbed.

The role of forests in distributing water into the soil starts when rainwater falls on the vegetated surface of the earth. Before reaching the ground level, rainwater first falls through the canopy. Part of the rainwater is held back by the canopy, experiences interception (evaporation), some moves towards the soil surface and penetrates into the soil, organic matter and soil flora and fauna [1]. The process of entering water into the soil is called infiltration.

Infiltration is the process of entering water vertically into the soil through pores on the soil surface. The higher the infiltration ability of a soil, the lower the surface flow that occurs. Based on the scientific definition, the notion of soil infiltration is the process of moving the entry of water into the soil layer which is controlled by the force of gravity, capillary movement, and soil porosity [2]. Infiltration changes that occur are expressed in the amount of infiltration rate. This infiltration rate will affect the size of the land holding capacity. The large soil holding capacity can be seen from the water that infiltrate is first absorbed to increase soil moisture, the rest will decrease to the surface of the soil. Infiltration varies according to rainfall intensity, but after reaching its limit.

A watershed is a unit that cannot be separated from forest, land, and water because they are the main constituents that act as objects. If one of the three elements is in trouble, especially in the upstream part, it will disturb a watershed, especially in the infiltration capacity of a soil. In the upstream part, there will
be runoff due to infiltration which is smaller than rainfall. Surface flow will cause soil erosion which sweeps away nutrients. Water and land that are washed away into the river, causing silting of the river [3]. As a result, there are floods in the rainy season and drought in the dry season. Remembering the importance of the meaning of infiltration, especially in preventing erosion, this study aims to determine the rate of infiltration that occurs in the forest at various levels of slope.

Candlenut stands are located in Lamoncong Village, Bonto Cani District, Bone Regency which is part of the Sanrego Sub-watershed, Walanae Watershed. The stand is classified as community forest with the understory vegetation is cocoa. When viewed from the composition of its vegetation, this candlenut community forest can also be categorized as kemiri-cacao agroforestry. Candlenut as a shade crop for cocoa is a forestry tree while its cocoa itself is classified as an agricultural/plantation crop [4,5]. The combination of these two plants will affect the physical and chemical properties of the soil which may cause the movement of groundwater to be different from other types of plants.

The results of the infiltration rate in Jabon stands is in the very fast category, around 5.2 times compared to teak stands which are classified as fast. Based on this, the research on the infiltration rate of candlenut stands is interesting to study because currently there is no previous data in Lamoncong Village, Bonto Cani District, Bone Regency regarding the infiltration rate of these stands. Therefore, this research can give scientific information on how big the role of candlenut is to enter water into the soil (infiltration).

2. Material and methods

2.1. Location and time of study

This research was conducted for 5 months starts from September 2018 to January 2019. Field research was conducted in Lamoncong Village, Bonto Cani District, Bone Regency and Laboratory activities were conducted at the Silviculture and Tree Physiology Laboratory, Faculty of Forestry, Hasanuddin University.

2.2. Tools and materials

The tools used in this research are:

1. The infiltration gauge turf-tec infiltrometer is used to measure the infiltration rate which is equipped with a ruler to determine the water drop in the infiltrometer ring.
2. The stopwatch is used to determine the time of dropping water in the infiltrometer ring during observation.
3. Water storage is used to collect water to fill the turf-tec infiltrometer.
4. The sample ring is used to take soil samples at the research location which will then be analyzed in
the laboratory with tools in the form of a thin knife to flatten the edges of the soil sample on the ring, plastic to store soil samples in the ring, and rubber bands to tie the soil sample to the plastic to prevent it. damage to soil samples.

5. Writing instruments were used to record the results of measuring the infiltration rate at the study site.

6. Roll Meter is used to measure plots.

7. A thin knife is used to clean the soil adhering to the outside of the sample ring.

8. Clear plastic is used to store soil samples

9. Camera to take pictures as research documents

10. Abney level is used to measure tree height

The materials used in this research are soil and water.

2.3. Research procedure

2.3.1. Field data collection. For candlenut stands, data collection was conducted at two observation points with various characteristics. The determination of the characteristics of candlenut stands is divided into Plot 1 (candlenut trees with cocoa plants) and Plot 2 (candlenut trees without cocoa plants). Determination of the plot position was done by purposive sampling with a size of 20 m x 20 m. The measuring plot 20 m x 20 m is then made into five subplots with a size of 2 m x 2 m each. The subplot measuring 2 m x 2 m was measured five times the infiltration points of observation, so that the number of infiltration measurements in the candlenut stand was 25 infiltration measurement points.

2.3.2. Infiltration rate measurement. Measurement of infiltration rate in the field was conducted using a double ring infiltrometer. This tool has a double cylinder with an inner cylinder measuring 3/8 in (6.03 cm) and an outer cylinder measuring ¼ in (10.79 cm) with a depth of 6 in. The measurement of the infiltration rate is carried out in the following ways:

a. Prepare tools and materials
b. Installing the Double Ring Infiltrometer at the observation point. Then insert the tool by pressing it slowly into the ground.

c. Put the water into the ring by first inserting the outer ring then continuing in the inner ring. Water replenishment is done slowly so as not to damage the soil surface structure.

d. The stopwatch is turned on when the inner ring is filled with water

e. Observe the water drop in the inner ring until it reaches a constant point.

f. Record the results of the water drop that occurs in the infiltration process

2.3.3. Soil sampling. Determination of the physical properties of the soil was carried out by taking 10 soil samples in the field based on the infiltration rate measurement points. Soil test sampling were taken to analyze the texture, permeability, porosity, organic matter and weight of the contents which were conducted at the Laboratory of Silviculture and Tree Physiology, Faculty of Forestry, Hasanuddin University. Soil sampling using the disturbed and undisturbed soil method. How to take soil samples with ring samples:

a. Clean the surface of soil body parts taken from plants, litter, and rocks then flatten them.

b. Put the sample ring on the surface of the soil body to be taken with a sharp part that intersects with the soil.

c. Press the sample ring gently with even pressure until it sinks three-quarters of a piece.

d. Put the second sample ring on top of the first cylindrical tube to the desired depth.

e. Dig the soil around the sample ring so that the tubes can be taken together while remaining intact and connected.

f. Tighten the excess soil on the front side of the first sample ring and between the sample ring with a thin knife then cover the first sample ring with the available cap.
g. Take samples of disturbed soil and not disturbed. After the soil sample is taken, the next process that will be done is observation in the laboratory to analyze the texture, porosity, permeability, organic matter, and bulk density of the soil.

2.3.4. Observation of soil physical properties
a. Determination of Soil Texture
Soil texture determination is determined based on the results of soil sample analysis that has been done in the laboratory. From the results of this analysis, it can be seen the percentage of sand, dust and clay so that the texture class can be determined using the texture triangle from the United State Department of Agriculture (USDA).

b. Determination of soil volume weight (BD) and soil particle weight (PD)
Determination of BD / PD is carried out using the core method, which is based on soil sampling using a ring sample. The soil sample in the sample ring was then dried in an oven for 24 hours at 105°C, then weighed to determine the volume weight of the soil.

c. Determination of soil porosity
The determination of soil porosity was obtained from the results of the analysis of the percentage of soil volume weight (BD) and soil particle weight (PD) which were then multiplied by 100%.

d. Determination of soil permeability
This determination is determined using the ratio of time and volume. Soil samples were taken using a sample ring, then immersed in a soaking tub. After that, the saturated soil is then transferred to a measuring instrument to measure its permeability rate.

e. Organic material
Determination of organic matter is done by titration method until the soil turns green, the results of the titration are processed by data to obtain Organic C content and organic matter content.

2.4. Data analysis
2.4.1. Infiltration rate analysis
The infiltration rate value can be obtained from the infiltration value at 15 minutes of each measurement which is then divided by the length of measurement time (15 minutes). The value of the result is added up which is then divided by the number of measurement points on each plot, the unit of this value is (mm / minute) or using the equation:

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

Information
\[ \Delta H : \text{Height decrease (mm) within a certain interval} \]
\[ t : \text{Time required for water to enter the ground (minutes)} \]
\[ \Delta H : \text{Height decrease (mm) within a certain interval} \]
\[ t : \text{Time required for water to enter the ground (minutes)} \]

(to convert minutes to hours multiplied by 60)

2.4.2. Infiltration curve
The observed data from the infiltration rate in each observation plot that are entered to produce an infiltration curve are the observation time (minutes) and the infiltration rate (mm / minute).

2.4.3. Infiltration rate classification
Kohnke (1968) in Lee (1988) classify the class of infiltration rate and percolation rate as can be seen in Table 1.
Table 1. The classification of soil infiltration and the rate of percolation

| Description     | Infiltration (mm / hour) |
|-----------------|-------------------------|
| Very slow       | 1                       |
| Slow            | 1 - 5                   |
| Moderate slow   | 5 - 20                  |
| Moderate        | 20 - 65                 |
| Moderate fast   | 65 - 125                |
| Fast            | 125 - 250               |
| Very fast       | > 250                   |

3. Result and discussion

3.1. General conditions of the observation plot

3.1.1. Vegetation conditions for plots 1. The candlenut stands which is the object of the research is located in Lamoncong Village, Bontocani District, Bone Regency with an area of ± 1 ha and is a community forest area. The type of soil in this location is inceptisol with a slope of 0-8%. In the measuring plot 20 m x 20 m, there are 8 candlenut trees and several types of ground plat, which are dominated by cocoa. This stand is approximately 50 years old with an average trunk diameter of 127.5 cm, an average tree height of 15.27 m and a branch-free height of 12.67 m with a planting distance of 6-10 m. The conditions of the Candlenut stand in plot 1 can be seen in Figure 2.

3.1.2. Vegetation condition of plot 2. Candlenut stands with a plot of 20 m x 20 m and the same slope of 0-8%, there are 12 candlenut trees, 4 breadfruit trees, 1 forest mango, and several types of ground plants dominated by Leea indica. This candlenut stand is approximately 50 years old with an average diameter of 146.18 cm, an average tree height of 14.6 m, an average branch-free height of 12.7 m and an average distance between trees of 5.8. m. The conditions of the candlenut stand in plot 2 can be seen in Figure 3.
3.2. Soil physical properties

3.2.1. Soil texture. Soil textured analysis from the Laboratory of Silviculture and Tree Physiology, Hasanuddin University Faculty of Forestry can be seen in Table 2.

| Location | Fraction | Soil Texture |
|----------|----------|--------------|
|          | Sand     | Dust         | Clay      |            |
| PLOT 1   | 39       | 48           | 13        | Sandy loam |
| PLOT 2   | 50       | 42           | 7         | Sandy loam |

From Table 2 it can be seen that the soil texture in Plot 1 (candlenut tree with ground cocoa plants) and plot 2 (candlenut tree without cocoa plants) belong to the sandy loam texture class determined by using the USDA triangle (United States Department of Agriculture). Based on the results of soil texture measurements in plot 1, the dust content is greater than sand and clay particles, which is 39% sand, 48% dust and 13% clay, while plot 2 has a greater content of sand, which is 50% sand, 42% dust and 7% clay. Soil texture affects the infiltration rate of a land. The texture of the soil is basically related to the state of the soil pores. The number and size of pores that determine the number of large pores. The larger 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.

3.2.2. Bulk density. Bulk density analysis on Plot 1 (candlenut trees with ground plants of cocoa) Plot 2 (candlenut trees without cocoa plants) can be seen in Table 3.

| Location | Bulk Density (g / cm$^3$) |
|----------|---------------------------|
| PLOT 1   | 1,056                     |
| PLOT 2   | 1,226                     |
3.2.3. Porosity. Analysis of soil porosity is obtained from the bulk density and soil particles density. Based on the formula used, it can be explained that the greater the particle density, the greater the porosity. The results of porosity measurements in plot 1 (candlenut trees with ground cocoa plants) and plot 2 (candlenut trees without cocoa plants) can be seen in Table 4.

Table 4. The result of soil porosity measurement

| Location   | Soil Porosity |
|------------|---------------|
| PLOT 1     | 30.8          |
| PLOT 2     | 24.8          |

The pore space or soil porosity in plot 1 is 30.8% and plot 2 is 24.8%. Both plot 1 and plot 2, biological activities such as plant and soil organisms affect the formation of soil aggregates. The number of roots increases the activity of microorganisms which in turn increases the porosity and stability of the soil structure. Porosity is the percentage ratio of the total pore space. The total soil pore space indicates that the soil is loose and has a lot of soil pore space and the water absorption process or infiltration rate is fast [4].

3.2.4. Permeability. Permeability analysis in Plot 1 (candlenut trees with ground cocoa plants) and Plot 2 (candlenut trees without cocoa plants) can be seen in Table 5.

Table 5. The result of soil permeability measurement

| Location   | Permeability |
|------------|--------------|
| PLOT 1     | 19.33 cm / hour |
| PLOT 2     | 14.33 cm / hour |

Based on the results of permeability measurements in the Silviculture and Tree Physiology Laboratory, obtained the average value of permeability in plot 1 is 19.33 cm / h and in plot 2 is 14.33 cm / hour. Soil permeability is the ease with which liquids can penetrate the soil in a saturated porous medium. Permeability is influenced by pore space in the soil. 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 growth of the plant's roots. This is due to the influence of vegetation which is directly proportional to the increase in this pore area in its function of releasing water into the soil. The permeability of plot 1 has a value of 19.33 cm / hour and plot 2 is 14.33 cm / hour. This is due to the soil texture because the soil which has a higher dust and sand content will easily pass water into the soil.

3.2.5. Organic material
Measurement of C-Organic content and soil organic matter content conducted in the laboratory can be seen in Table 6.

Table 6. The result of organic material analysis

| Location   | Content Organic C (%) | Organic Ingredients (%) |
|------------|-----------------------|-------------------------|
| PLOT 1     | 0.854                 | 1,468                   |
| PLOT 2     | 0.564                 | 0.968                   |

Table 6 shows the results of analysis of the organic material content in plot 1, which is 1,468% and in plot 2 is 0.968%. The organic material in both two plots did not show much different results. This is
because the both plots have almost the same ground plants density, therefore the production of organic matter is almost the same. Whereas plot 2 shows low organic material due to lower vegetation or litter than in plot 1. This is supported by research Restu et al., (2020) and Tongkaemkaew et al., (2018) that the higher the organic material 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 areas without litter are likely to harden and form a crust due to high surface runoff [5,6].

3.3. Infiltration rate measurement
Measurement of the infiltration rate was conducted five times on each plot, where each plot had an unequal infiltration rate. The infiltration rate in plot 1 and plot 2 can be seen in Table 7.

| Minute  | Plot 1 | Plot 2 |
|---------|--------|--------|
| mm / minute | 43.09  | 38.32  |
| mm / hour  | 2585.4 | 2,299.2 |
| Category    | Very fast | Very fast |

Based on the results of measurements in the field, the infiltration rate is obtained with an average value in plot 1 of 2,585.4 mm / hour and plot 2 of 2,299.2 mm / hour which can be seen in Table 7. The infiltration rate in each of these plots is categorized as very fast based on the classification table of the soil infiltration rate according to (Kohnke, 1968 in Sofyan, 2006). The results of field measurements show that the average infiltration rate in plot 1 is faster than in plot 2 because plot 1 has ground cocoa plants while plot 2 does not have cocoa plants. This is because the cocoa plant has taproot (Radix Primaria) which absorbs more water than in plot 2 [7]. Apart from the cocoa crop factor, the permeability value in plot 1 is higher than in plot 2.

3.4. Infiltration rate curves for each measurement plot
After measuring the infiltration rate using a Turf tec-infiltrometer for 15 minutes, the infiltration rate was obtained from the 2 observation plots. To know more clearly about the infiltration rate that exists in each stand observation plot, it can be seen in Figures 4 and 5. Each infiltration curve is an accumulation of observational data for each stand observation.

![Figure 4](image-url)
Graph of the average infiltration rate in plot 1 or plot of candlenut stands with cocoa (Figure 5). The observations show that in the first minute the water subsidence happened so fast. This decrease occurs usually because in the first minutes of observation the pores of the soil are not filled with water and the soil pores still have plenty of space to hold water so that the water can seep well. Furthermore, at the 8th minute the water drop that occurs is not too large and at the next minute the water drop gradually starts to decline until the last minute.

![Figure 5. The rate of infiltration in plot 2](image)

The graph of the average infiltration rate in plot 2 or plot of candlenut stands without cocoa plants (Figure 6), shows the decrease in water is the same as the measurement in plot 1, i.e. rapid water drop in the early minutes, measurements as seen in the first minute to the 5th minute. In the next minute there was a drop in speed until the last minute.

![Figure 6. The differences rate of infiltration rate in plot 1 and plot 2](image)

In the results of the research that has been done can be seen in Figure 6 that the rate of infiltration in both plots is categorized very fast although the average number of infiltration rates obtained is different, where plot 1 is greater than the infiltration rate in plot 2. This can happen because porosity
and permeability in plot 1 are higher than plot 2. When the soil is still dry, the infiltration rate tends to be high. After the soil becomes saturated with water, the infiltration rate will decrease and become constant. Infiltration into the soil, which is initially unsaturated, occurs under the influence of matrix straws and gravitational forces. If the infiltration continues, more infiltration water enters the soil and deeper into the wet soil profile, so that the matrix straw will decrease [9]. The reduction in matrix straws is due to the further distance between the dry and wet parts of the soil. This is an explanation why the rate of water infiltration into the soil decreases with increasing time (length) of rain [10].

4. Conclusions
The infiltration rate in the candlenut stand area in Lamoncong Village was based on 2 plots, which are candlenut stands with cocoa plants and without cocoa plants, both categorized as very fast. Where the average infiltration rate in stands of candlenut with cocoa plants is 2585.4 mm / hour, while in stands of candlenut without cocoa plants is 2,299.2 mm / hour.

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