Infiltration rate in various landcover type in Bakka Sub-Watershed

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Abstract. Infiltration rate is strongly influenced by understorey density. There are three land covers, primary forests and garden which have a category of dense, medium, rare and very rare, meanwhile shrubs only have a category of dense cover crop. The difference in the density of understorey gives a different effect on the entering water to the soil (infiltration). This study aims to determine the magnitude of the infiltration rate at various land covers in Bakka Sub-watershed. Measurement of infiltration rate is carried out at one point in each observation plot per land cover made using purposive sampling. In each plot 4 subplots were made based on densities of dense, medium, rare and very rare plants based on Paine (1981) methods. Infiltration rate in the field is measured using a double ring infiltrometer, another variable measured is the physical properties of the soil include soil texture, permeability, porosity, bulk density, and organic matter. Based on the research results it is known that the infiltration rate at various land covers in Bakka Sub-watershed is 3,154 mm/hour for primary forest, 612 mm/hour for gardens and 224 mm/hour for shrubs. The infiltration rate in primary forests and gardens is categorized very fast while shrubs are categorized fast. This is influenced by the physical properties of the soil, especially the bulk density and the understorey.

1. Introduction

Forest is land cover with the dominance of trees covering the land surface, and is also a natural spatial plan that affects water management. Water management is a natural phenomenon that describes the process of obtaining, losing and storing groundwater. As land cover, the forest will affect the process of receiving water gushing from the atmosphere on the land below. Rainwater from the atmosphere before reaching the forested soil surface will be received first by the forest canopy layer. Rainwater will be intercepted by the tree canopy, which passes from the interception of the canopy is called through fall and reaches the forest floor, and rainwater that flows through the forest tree trunks is called stem flow and finally reaches forest floor [1].

Water that falls to the earth surface the used by living things. Water management by living things can be taken from water collected on the ground or water collected in the ground. Water on the ground in the form of sea water, lakes, rivers or ditches made by the community to irrigate rice fields or fields. Whereas water in the ground can be in the form of ground water which is then used also by the community as a source of mineral water or by plants as a staple material to carry out the photosynthesis process in order to survive. Retained groundwater in an area is very influential on the growth of the plants above it. The movement of rainwater that falls to the ground surface will be continued in two directions, runoff water (run-off horizontally) and water that moves vertically (infiltration) [2].
Infiltration is the occurrence of water entering the ground, which generally passes through the surface and vertically. The infiltrated water will move into the soil profile. The downward movement of water within the soil profile is called percolation. The Bakka sub-watershed is one part of the downstream Saddang watershed, which is located in the Cendana District, Enrekang Regency. Even though it is located in the downstream part of the Saddang watershed, the Bakka sub-watershed has varied slopes, ranging from steep to very steep with land cover in the form of primary forest, shrubs and gardens. Various coverings have different effects on the movement of water into the soil (infiltration). This study aims to see the contribution of each type of land cover to water that enters the soil (infiltration). This data can be used as a reference in the correct use and management of land by the community in the Bakka sub-watershed area.

2. Material and methods

2.1. Research location
This research was conducted from July to August 2019. The research was carried out in Cendana District, Enrekang Regency and Silviculture and Tree Physiology Laboratory, Faculty of Forestry, Hasanuddin University.

2.2. Tools and materials
The tools that will be used in this research include:

- a. Double Ring Infiltrometer
- b. Ring Sample
- c. GPS Receiver
- d. Stopwatch
- e. Knife
- f. Bottle (Water Storage)
- g. Stationery
- h. Digital Camera

Materials used in research, among others

- a. Water
- b. Soil
- c. Plastic Storage
- d. Labels
- e. Rubber Bands
- f. Neat Rope

2.3. Research procedure

2.3.1. Data collection. Data were collected on three observation plots. Plot is made with a size of (20 x 20) meter. Within the plot, a subplot is made based on the density of understorey based on the Paine method (1981) [3]. Determining the location of the plots was carried out by means of purposive sampling of 4 plots, divided into very rare, rare, medium and dense plots. Each subplot with a size of (2 x 2) meter. In subplot, infiltration measurements were carried out five times, so the number of infiltration measurements in the three plots (land cover type) was 60 times.

2.3.2. Infiltration rate measurement. Measurement of infiltration rate in research location was carried out using a double ring infiltrometer. Double ring infiltrometer has a double cylinder with an inner cylinder measuring 3/8 inches (6.03 cm), an outer cylinder measuring ¼ inches (10.79 cm) and depth 6 inches.

2.3.3. Soil sampling. Identification of soil physical properties was carried out by taking 15 soil samples. Location was adjusted to the infiltration rate measurement location. Soil samples were taken to analyse texture, permeability, porosity, organic matter and bulk density. Soil sampling was carried out on undisturbed land areas. Soil sample tests were carried out at Silviculture and Tree Physiology Laboratory, Faculty of Forestry, Hasanuddin University.
2.3.4. Data analysis. Infiltration rate value can be obtained from infiltration value at 15 minutes of each measurement which is then divided by measurement time (15 minutes). Value of these results is added and then divided by the number of measurement each plot, unit of this value is (mm/minute) or using the equation:

\[
\text{Infiltration Rate} = \frac{\Delta H}{t} \times 60
\]

\(\Delta H\) : Drop in height (cm) over time
\(t\) : Time required for water at \(\Delta H\) to enter the soil (minutes).

3. Result and discussion

3.1. Description of land cover type in bakka sub-watershed

3.1.1. Vegetation

3.1.1.1. Primary forest. Primary forest at research location, enters to the forbidden area (35 ha), with a slope of ± 45%. In a plot measuring 20 m x 20 m, the vegetation is classified as diverse vegetation density. The condition of the primary forest at the research location can be seen in Figure 1.

![Figure 1. (a) Primary Forest Condition, (b) Understorey Condition](image)

Research plot in the selected primary forest consisted of 4 subplots, dense understorey (Figure 2.a) with a percentage of 85%, medium understorey (Figure 2.b) with a percentage of 55%, rare understorey (Figure 2.c) with percentage 15% and very rare understorey (Figure 2.d) with a percentage of 5%.

![Figure 2. Understorey density of primary forest, (a) dense; (b) medium; (c) rare; (d) very rare](image)

3.1.1.2. Garden. The garden which became the object of the study was a clove (Syzygium aromaticum) garden on an 8% slope. Clove plants (Syzygium aromaticum) have a height of up to 5-10 meters, a spacing of 6m x 8m and are approximately 5 years old. 20 meter x 20 meter plot consists of
8 clove trees and the lower vegetation is dominated by grasses and litter. The condition of clove (Syzygium aromaticum) gardens can be seen in Figure 3.

![Figure 3. Garden at Research Location](image)

The research plot in the garden consisted of 4 subplots, namely dense undergrowth (Figure 4.a) with a percentage of 95%, medium understorey (Figure 4.b) with a percentage of 55%, rare understorey (Figure 4.c) with a percentage of 25%, understorey is very rare (Figure 4.d) with a percentage of 5%.

![Figure 4. Understorey density of garden, (a) dense; (b) medium; (c) rare; (d) very rare](image)

3.1.1.3. Shrubs. Shrubs types do not have canopy cover compared to primary forest and gardens because the type of vegetation found in shrubs at the plots are plants that grow wild. The condition of the scrub can be seen in Figure 5.

![Figure 5. Shrubs type condition, (a) shrubs; (b) bush](image)

3.1.2. Sample observation. Observations were made on various land covers, primary forest, garden and shrubs which consisted of 4 subplots, dense, medium, rare, and very rare. Infiltration rate measurements were carried out at 9 observation points with a measurement time of 15 minutes every subplot. Primary forest consists of 4 observation points, garden consists of 4 observation points, while shrubs consist of 1 observation point, because in shrubs the category of understorey is similar.
3.2. Soil physical character

Type of soil contained in various land cover type in the Bakka sub-watershed is dystropepts type. Physical character of the soil analysed were soil texture (percentage of sand, dust and clay), porosity (%), permeability (cm/hour), bulk density (gm/cm³) and soil organic matter (percentage of C and elemental content). Physically soil character of the soil are obtained through field sampling using a sample spoon at one location (disturbed soil and intact/uninterrupted soil). This soil sample analysis was carried out at the Silviculture and Tree Physiology Laboratory, Faculty of Forestry 2, for each plot at each land cover in the Bakka Sub-watershed can be seen in Table 1.

### Table 1. Results of Soil Physical Character at Various Land Covers Type in Bakka Sub-watershed

| Plot       | Bulk Density (g/cm³) | Porosity (%) | Permeability (cm/hour) | Percent Carbon (%) | Texture | Organic Matter (%) |
|------------|----------------------|--------------|------------------------|--------------------|---------|--------------------|
| Primary Forest | 1.26                | 52.24        | 0.83                   | 0.18               | 36.92   | 30.41              |
| Garden     | 1.27                | 51.63        | 0.54                   | 0.15               | 42.00   | 29.51              |
| Shrubs     | 1.64                | 37.74        | 0.41                   | 0.09               | 30.44   | 34.89              |

Determination of soil texture classification using a texture triangle diagram based on the USDA (United States Department of Agriculture) classification. The identification results show that plot 1 (primary forest) and plot 2 (garden) are classified as clay class, while in plot 3 (shrubs) are classified as clayey clay class. Soil texture affects the infiltration rate of a land. Soil texture is basically related to the pore state of the soil. Number and size of pores that determine the number of large pores. More large pores, the greater the infiltration capacity. Clay has fine pores and less large pores. Clay soil is soil with a proportion of sand, dust and clay in such a way that it is between sandy and clayey soils. Aeration and air and air systems are quite good, the ability to absorb water for plants [4]. Number and density of plant roots around the stands are also very influential in the infiltration process and accelerate physical destruction so that finer fractions will be formed quickly [5].

3.2.1 Bulk density. Results of laboratory analysis show that the bulk density value in primary forest is 1.26 g/cm³, in gardens 1.27 g/cm³ and in shrubs is 1.64 g/cm³. This value shows that the relationship between bulk density and infiltration rate is inversely proportional to the value. If bulk density value is small, infiltration rate will be large. The infiltration rate at various land cover type in Bakka Sub-watershed is in accordance with the soil density. so that infiltration rate in primary forest is greater. Primary forest has plant roots that can contribute to enlarging pores in the soil. High bulk density is an indication of soil density, that is difficult to pass water or plant roots penetrate [6].

3.2.2 Porosity

Results of laboratory analysis showed that the value of soil porosity in primary forest was 52.11%. gardens 51.63% and shrubs had a soil porosity 37.74%. Primary forests tend to have the highest infiltration rates compared to gardens and shrubs. Dense soil has a porosity that is difficult to absorb water, so the soil porosity is getting smaller. Same happens in shrubs that have dense soil. Porous soil means that the soil has enough pore space for the movement of water and air in and out of the soil freely [7].

3.2.3 Permeability. Permeability in primary forest is 0.83 cm/hour. garden is 0.54 cm/hour. while in shrubs it is 0.41 cm/hour. Based on soil permeability values, shrubs and gardens have high density level compared primary forest. Garden and shrubs have denser soil conditions so that it is difficult to pass water into the soil. This condition causes the permeability value in primary forest higher than in gardens and shrubs. Soil permeability value is directly proportional to the infiltration rate [8]. Level of
soil permeability can be caused by a percentage of soil particle fraction, total pores and root penetration (root penetration can form more macro pores).

3.2.4. Organic matter. Result of analysis showed that the organic matter in primary forest was 0.32%, gardens were 0.26% and shrubs was 0.16%. The difference in organic matter caused by plant litter on the surface of each type of land cover. Primary forest has a lot of feel that covers the soil surface. It caused primary forest type have the highest organic matter compared to other land cover type. More plant litter that covers the soil surface will increase an activity of microorganisms in decomposition of organic matter and also maintain soil structure [9–11]. Soil without litter causes hardening and forms a layer of crust due to high surface flow.

3.2.4.1. Infiltration rate at various land cover type in bakka sub-watershed. Based on infiltration rates at various land cover type in Bakka Sub-watershed. it was obtained 3.154 mm/hour at primary forest. 612 mm/hour for gardens and 224 mm/hour for shrubs. Infiltration rate in primary forest categorized as very fast. gardens are categorized as very fast and shrubs are categorized as fast based on the classification table of soil infiltration rates and percolation according to Lee (1988) [12] method. Land cover with the fastest infiltration in primary forest types. Infiltration value will be small on land cover in vegetation with short roots. Dense understorey can increase the infiltration rate of the soil surface. The biological productivity in producing nutrients and plant litter in primary forests is more so that it affects the size of the kinetic energy of rainwater which can damage the soil structure [9,13]. The results of measurements and direct observations at the research location are presented in Table 2.

| Land Cover | Soil Type  | Infiltration Rate (cm/minute) | Infiltration Rate (mm/hours) | Category |
|------------|------------|-------------------------------|-----------------------------|----------|
| Primary Forest | Dystropepts | 5.253                         | 3.154                      | Very Fast |
| Garden     | Dystropepts | 1.01                          | 612                        | Very Fast |
| Shrubs     | Dystropepts | 0.373                         | 224                        | Fast     |

Infiltration rate is also influenced by soil texture conditions, mass density, porosity, permeability and organic matter. Results of the analysis of the physical properties of the soil show that the physical properties of the soil in primary forests and gardens support the infiltration process that occurs compared to shrubs. Based on results of laboratory analysis, average mass density value in primary forest is 1.26 g/cm³, gardens 1.27 g/cm³ and shrubs 1.64 g/cm³. This value indicates that the relationship between bulk density and infiltration rate is inversely proportional. the value of bulk density is small. the infiltration rate is large.

3.2.4.2. Infiltration rate based on lower plant density at various land covers in the Bakka Sub-Watershed. The amount of infiltration rate in primary forest influenced by the density of understorey. Understorey plant will make soil's physical character better for infiltration process. Dense cover of understorey increases the biological activity on soil surface. The varying condition of understorey in primary forest causes the large infiltration rate. This is supported by the statement that with the abundance of understorey vegetation. the root system will increase the ability of the soil to absorb water. thereby increasing the infiltration rate and increasing soil permeability [14].
Table 3. Results of infiltration rate measurement based on density of understorey plant at various land covers type in Bakka Sub-watershed

| Understorey Plant Density | Infiltration Rate |
|---------------------------|-------------------|
|                           | Primary Forest    | Garden | Shrubs | Average  |
| Dense                     | 5.320             | 896    | 224    | 2,146.67 |
| Moderate                  | 2.640             | 824    | 224    | 1,229.33 |
| Rare                      | 2.376             | 456    | 224    | 1,018.67 |
| Very Rare                 | 2.272             | 272    | 224    | 923.33   |

Figure 6. Difference in Infiltration Rate in primary forest, garden and shrubs at Bakka Sub-watershed

The decrease in infiltration rate in primary forest is higher than garden and shrub due to the density of understorey plant. Infiltration rate in gardens is higher than in shrubs. This occurs because porosity in the garden is higher than shrubs.

4. Conclusion

Results of the infiltration rate observations that have been carried out in the Bakka Sub-watershed show that the infiltration rate values have different values at each land cover. The value of the infiltration rate which is categorized as very fast is primary forest which is indicated by a value of 3.152 mm/hour and garden 612 mm/hour, while in shrubs the infiltration rate is categorized as fast at 224 mm/hour. The difference in the value of the infiltration rate in the land cover type is influenced by the physical properties of the soil, especially the bulk density and understorey vegetation present in each land cover. The infiltration rate at land cover in the Bakka sub-watershed is classified as good because it is included in the very fast and fast category so that water reserves in the ground are more and it can be predicted that water availability in the dry season is fulfilled.

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