Evaluation of soil characteristics and infiltration capacity under *Dimocarpus Longan* Fruit-tree based agroforestry in Selopamioro, Imogiri, Bantul, D.I.Yogyakarta

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**Abstract.** Selopamioro village in Imogiri sub district, Bantul-D.I. Yogyakarta is located along southern mountains of Java. Nowadays, this village is developing agro-ecotourism through fruit-tree based agroforestry for improving household economy while keeping environment of hilly areas. The main objective of this study was to explore and evaluate physical characteristic of soil and infiltration capacity under *Dimocarpus longan* fruit-tree based agroforestry in Selopamioro village. Total area of *Dimocarpus longan* fruit-tree based agroforestry is 0.48 hectare with total 52 trees. The soil characteristics were focused on bulk density ($\rho_b$), particle density ($\rho_s$), porosity, textures, structure, soil moisture, content of organic material (COM), and lime content. The empirical models of infiltration, Kostiakov, was adopted to define soil infiltration capacity. The measurement of infiltration rate in the field was carried out by using Double-ring Infiltrometer method. The soil sampling and infiltration measurement were conducted in three different characteristics of slope, i.e., upper, middle, and lower slopes. The soils were taken from three points and two depth (0-40 cm and > 40 cm) per slope category, whereas the infiltration test was conducted solely in each points of slopes. A regression and correlations method were applied to evaluate the soil characteristics and infiltration capacity. The slope of upper, middle, and lower in *Dimocarpus longan* land were 30°, 17°, and 39° respectively. The *Dimocarpus longan* fruit-tree based agroforestry in middle slope was mixed with rainfed rice, the lower was nuts, while the upper slope was dominated by weeds. The soil was characterized as clay, sub angular blocky structure, bulk density ($\rho_b$) 1.26-1.46 gr/cm$^3$, particle density ($\rho_s$) 2.04-2.10 gr/cm$^3$, porosity 28-40%, soil moisture 36.90-42.00% mass, COM 1.16-1.78%, and lime content 2.69-3.46%. The average of infiltration capacity was 265.10 mm/hours which classified as very fast categories. The strongest relation between physical characteristic of soil and the infiltration capacity was owned by the soil textures. It had correlation coefficient -0.621, while the water content 0.883.

1. Introduction

Soil is an important component for life [1] in [2]. It is classified in several types such Mediterranean soil which is distributed in Nusa Tenggara, Maluku, and Jawa Tengah. Different types of soil will affect their physical, chemical, and biological characteristics. Mediterranean is created by weathering of limestone, so the permeability of soil is poor [3], [4], underlined the texture of Mediterranean soil is dominated by clay. The Mediterranean infiltration capacity is low due to high clay content. Infiltration capacity has a vital role in soil and water conservation as affect the surface runoff, erosion [5], and
landslide [6]. Therefore, the internal characteristic of Mediterranean soil has a high risk to erosion and landslide. It will be raised if soil position on the slope [7] heavy rainfall, and intensive agriculture with no conservation practices [8]. This case can be seen in the fruit-tree based agroforestry in Selopanaiomo village. Thirty five hectares of fruit-tree based agroforestry developed by local government in 2013 for agro-eco tourism. Five tropical fruits (Soursop (Annona muricata L.), Durian (Durio zibethinus Murr.), Rambutan (Nephelium lappaceum L.), and Kelengkeng (Dimocarpus longan)) were planted between wood plant species (Jati (Tectona grandis L. f.), and Sonokeling (D. latifolia)) and horticulture (peanut (Arachis hypogaea), chili (Capsicum frutescens), eggplant (Solanum melongena), and padi gogo/rainfed rice (Oryza sativa L.)). The main objective of this study was to explore and evaluate physical characteristics of soil and infiltration capacity under Dimocarpus longan fruit-tree based agroforestry in Selopanaiomo village.

2. Methods
The soil characteristics were focused on bulk density \(\rho_b\), particle density \(\rho_p\), porosity, textures, structure, soil moisture, content of organic material (COM), and lime content. The empirical models of infiltration, Kostiakov, was adopted to define soil infiltration capacity. The measurement of infiltration rate in the field was carried out by using Double-ring Infiltrometer method. The soil sampling and infiltration measurement were conducted in three different characteristics of slope, i.e., upper, middle, and lower slopes. The soils were taken from three points and two depth (0-40 cm and > 40 cm) per slope category, while the infiltration test was conducted solely in each points of slopes. A regression and correlations method were applied to describe the correlation of soil characteristics and infiltration capacity.

3. Results and Discussion
3.1 Dimocarpus longan fruit-tree agroforestry in Selopanaiomo
In 2013, Selopanaiomo village provided an area of 35 hectares used for fruit plantations. The land is located in Nawungan hamlet, which was later named Nawungan orchard (Kebun Buah Nawungan). However, the fruit trees were planted in agroforestry and mixing with horticulture as seen in Fig. 1. So, it more precisely termed fruit-tree based agroforestry. There are several types of fruit plants planted in the Nawungan orchard including Kelengkeng (Dimocarpus longan), Soursop (Annona muricata L.), Durian (Durio zibethinus Murr.), and Rambutan (Nephelium lappaceum L.). Dimocarpus longan’s block is located at an altitude of ± 262 msl with a slope of 15 - 40° and has an area of 4,789 m². The Dimocarpus longan’s population are 52 trees, but there are only left 33 trees while the another plants died by drought, disease, and pests.

[9] reported the average of temperature in the study area is 28.52°C, humidity of 93.13%, and rainfall of 1,450 mm/year. [10] argued that the optimum temperature for Dimocarpus longan growth is 20 - 33°C with a relative humidity of 65 - 90% and rainfall of 2,500 – 4,000 mm / year. Climatologically, Dimocarpus longan cultivation in fruit-tree based agroforestry is not appropriate.
3.2 Soil properties of *Dimocarpus longan* fruit-tree based agroforestry

The soil texture was determined by particles between gravel, sand, dust, and clay. The soil textures identified in this study are summarized in Table 1.

| Area       | Silt (%) | Clay (%) | Sand (%) | Classification |
|------------|----------|----------|----------|----------------|
| Upper Slope| 32.79    | 55.80    | 11.40    | clay           |
| Middle Slope| 24.77   | 57.87    | 17.36    | clay           |
| Lower Slope| 36.40    | 47.53    | 16.07    | clay           |

Based on Table 1, the highest percentage is clay fraction and the lowest is sand fraction, so that the classification of the soil texture is clay. [3] explains, Mediteran/Alfisol soil has clay or clay loam texture, with several physical features, namely moderate to shallow solum depth (90-200 cm), angular blocky structure, and neutral pH up to rather alkaline. From the analysis, the soil structure found in *Dimocarpus longan*’s block was sub-angular blocky with a diameter of 4.5 cm with a magnification of 0 - 1000x.

Bulk density (ρ_b) is a ratio between solid weight and soil volume (including pore space), while the ratio of dry soil weight per unit volume without pore space is called particle density (ρ_s). The values of ρ_b, ρ_s, and porosity are shown in Table 2.

| Area       | ρ_b (gr/cm³) | ρ_s (gr/cm³) | Porosity (%) |
|------------|--------------|--------------|--------------|
| Upper Slope| 1.36         | 2.10         | 34.45        |
| Middle Slope| 1.46       | 2.09         | 28.60        |
| Lower Slope| 1.26         | 2.04         | 38.20        |

Table 2 shows that the middle slope has the highest ρ_b and the lowest on the lower slope. The differences in ρ_b for each slope caused by method of soil tillage as well as cultivation (fertilizer or types of plant). Based on observations, no processing has been carried out on the upper slope at all, the middle slope starts to be often processed and compaction is carried out because it will be turned into rice fields, and lower slopes are often treated because they will be planted with peanuts. This is consistent with [11], that the denser the soil layer, the greater the volume weight, and vice versa.

Particle density (ρ_s) has a value below the range of minerals soil in general (2.60 - 2.75 gr / cm³). The small amount of ρ_s caused by the influence of soil chemical properties, namely the high lime content in the soil. The middle slope has the highest limestone content and the upper slope has the lowest limestone value, so the middle slope soil weight is lower than the upper slope. This is in accordance [12], that the high lime content can decrease the ρ_s because of the mixing of two ingredients that have ρ_s is different.

The porosity value in the *Dimocarpus longan* block is in the poor category to very poor. The highest porosity found in the lower slope, while middle slope characterized by the lowest porosity. The high and poor porosity are influenced by ρ_b, because the higher ρ_b may decrease the porosity value [13]. If it is associated with the conditions for growing *Dimocarpus longan*, the porosity of the soil in the study area does not meet the requirements. Because *Dimocarpus longan* needs the land whose has porosity of 50 - 60% (good category) [10].

Soil chemical characteristics (organic matter and pH) had a correlation with the physical characteristics such as bulk density, texture, porosity, and COM. Table 3 shows the overall soil physical and chemical characteristics in the *Dimocarpus longan*’s block and Figure 2 shows the correlation between COM and bulk density.
Table 3. Physical Characteristics of Soil on longan’s Block

| Area            | $\rho_b$ (gr/cm³) | $\rho_s$ (gr/cm³) | Porosity (%) | COM (%) | pH  | Texture | Structure     |
|-----------------|-------------------|-------------------|--------------|---------|-----|---------|---------------|
| Upper Slope     | 1.36              | 2.10              | 34.45        | Bad     | 1.28| 5.27    | Clay          |
|                 |                   |                   |              | Very    |     |         | Sub-angular blocky |
| Middle Slope    | 1.46              | 2.09              | 28.60        | Bad     | 1.78| 5.64    | Clay          |
|                 |                   |                   |              | Very    |     |         | Sub-angular blocky |
| Lower Slope     | 1.26              | 2.04              | 38.20        | Bad     | 1.16| 6.19    | Clay          |

Figure 2. The Correlation Between COM and Bulk Density

Based on Figure 2, only the middle and lower slope had a negative linear between COM and Bulk density ($\rho_b$), while the upper slope shows a positive correlation. The correlation between $\rho_b$ and COM on the middle slope and lower slope is in accordance with the definition of [14]. [15] argued that the differences of the $\rho_b$ in every slope may come due to the variety of fauna and tillage practices. The correlation or relation between soil physical and chemical characteristics is presented in Table 4.

Table 4. Correlation Coefficient Between Physical and Chemical Properties

|          | $\rho_b$ | Clay | COM   | Porosity | $\rho_s$ |
|----------|----------|------|-------|----------|----------|
| $\rho_b$ | 1        | 0.535| 0.436 | -0.793   | 0.483    |
| Clay     | 1        | 0.232| -0.728| -0.174   |          |
| COM      |          |      |       |          | 1        |
| Porosity |          |      |       |          | 0.120    |
| $\rho_s$ |          |      |       |          | 1        |

The correlation coefficient between $\rho_b$ and porosity is -0.793, which means that $\rho_b$ has a strong correlation with porosity and the direction of the correlation is negative linear. If the bulk density ($\rho_b$) getting higher, then the porosity gets lower [6,13]. Table 4, the highest $\rho_b$ value has the lowest porosity and the lowest $\rho_b$ has the highest porosity. Furthermore, the correlation between clay and porosity has a second strong correlation after $\rho_b$ and porosity. The clay and porosity also has an inverse correlation, if the clay content getting higher, then the porosity gets lower [16].

3.3 Infiltration Capacity

Infiltration capacity is the maximum infiltration rate (mm/hour) for a particular type of soil. The results of the analysis of infiltration capacity on Dimocarpus longan’s are presented in Table 5.
Table 5. Capacity Infiltration Analysis

| Area          | Infiltration (mm/h) | Infiltration Capacity (mm/h) | Classification |
|---------------|---------------------|-----------------------------|----------------|
| Upper Slope   | 253.76              | 243.52                      | Fast           |
| Middle Slope  | 274.56              | 269.35                      | Very Fast      |
| Lower Slope   | 285.01              | 282.43                      | Very Fast      |
| **Average**   | **271.11**          | **265.10**                  | **Very Fast**  |

The infiltration capacity in the *Dimocarpus longan*’s block is very fast, with an average of 265.10 mm h⁻¹. In this study, one of many factors that may increases infiltration capacity is vegetation/cover crop. Lower slopes planted with peanuts, have the highest infiltration capacity (282.43 mm/hour) and upper slopes that are not planted in any have the lowest infiltration capacity. [17] proved in her research and argued if vegetation may influence the infiltration capacity, that the soil in the scrub area with clay texture has a rather rapid infiltration rate. Another factor that can affect infiltration capacity is topography. Large slopes (> 45 °) can provide opportunities for water to flow on the ground than for infiltration [18]. The *Dimocarpus longan*’s block has a low slope (17 ° - 39 °). Low slope can minimize surface runoff, thereby increasing infiltration capacity.

3.4 Discussion
According to [18], several factors influence the rate of infiltration, such as soil physical characteristics, rain intensity, cover crops, and topography [19]. Soil physical characteristics that have an effect, including weight volume (ρ), porosity, texture, structure, and moisture content. Table 6 shows the correlation value between the soil physical characteristics (ρ, porosity, texture, and soil moisture) and slope degree with infiltration capacity.

Table 6. Correlation Between Physical Soil Characteristics and Slope Degree with Infiltration Capacity

| ρb  | COM  | Clay  | Porosity | Slope Degree | Soil Moisture | Infiltration Capacity |
|-----|------|-------|----------|--------------|---------------|-----------------------|
| ρb  | 1    | 0.943 | -0.992   | -0.995       | 0.152         | -0.330                |
| COM | 1    | 0.782 | -0.977   | -0.972       | 0.473         | 0.003                 |
| Clay| 1    | 1     | 0.897    | -0.906       | -0.18         | -0.621                |
| Porosity | 1 | 1.000 | -0.254   | 0.230        | 0.883         |                       |
| Slope Degree | 1 | 1     |          |              |               |                       |
| Soil Moisture |    | 1     |          |              |               |                       |

Based on Table 6, the strongest correlation between soil physical characteristics and infiltration capacity is soil moisture (0.883). The next strongest correlation is clay content (-0.621). [20] explained, that an increase soil moisture would reduce infiltration capacity, because the water in the soil meets the capillary pores. The conditions in the *Dimocarpus longan*’s block did not match the statement. Events that occur can be influenced by the strength of the capillary force. The difference in capillary force between the surface and underground, causes capillary forces to work together with gravity, so the infiltration rate increases [18]. The high value of clay content is caused by carbonate weathering from its parent rock which is carbonate. [21], the weathered soil from parent rock which is
carbonate/side-grained, has a relatively small infiltration capacity (slow). However, from the results of correlation analysis, high clay content actually produces very fast infiltration capacity. This can occur due to cover crop factors or the influence of vegetation.

4. Conclusion

1. Land in the Dimocarpus longan’s block, Nawungan orchard, clay with a rounded sub-angular block. The highest volume ($\rho_b$) is found in the middle slope (1.46 gr.cm$^{-3}$) and the lowest on the lower slope (1.26 gr.cm$^{-3}$). The high bulk density is followed by a low porosity value. The porosity of the Dimocarpus longan’s block is included in the bad class - very bad. Low particle density ($\rho_s$) (2.04 - 2.10 gr.cm$^{-3}$) is influenced by the high lime content (2-4%).

2. The infiltration capacity on Dimocarpus longan’s block is classified as very fast (240 - 285 mm.h$^{-1}$). In this study, factors that influence infiltration capacity are the presence of vegetation or cover crops and topography.

3. Of the eight soil properties, two of them have a strong relationship to infiltration. The nature of the soil is clay content and soil moisture. The clay has a correlation value of 0.621 and a soil moisture of 0.883.

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