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Original research article

# Relationship Between Soil Physical Characteristics and Infiltration Rate of The Practice Area of SMK PPN Banjarbaru

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ABSTRACT

The practice area for the Banjarbaru State Agricultural Development Vocational School (SMK PP N Banjarbaru) is located in Kemuning Village, South Banjarbaru District, Banjarbaru City, South Kalimantan Province. Regarding the land use in the research location, the majority is used for plantation land, which is one of the lands suitable for water catchment areas in Banjarbaru City. The Practice Land of PP N Banjarbaru Vocational School is one of the models of good catchment area land from good land use and irrigation systems. Conducted this analyze the infiltration rate and its influence on the physical properties of the soil. From the results of the infiltration test using a double ring infiltrometer which was then analyzed using the Horton method, the most considerable infiltration rate was in open land, namely 33.83 cm/hour, rubber plantations of 22.57 cm/hour, on palawija land it is 15.57 cm/hour and on mahogany land, it is 14.47 cm/hour. From the results of the analysis using the linear regression approach, the physical properties of the soil that can affect the infiltration rate include 16.7% bulk density, 75% permeability, and 90% moisture content. Meanwhile, particle density and porosity only affect 0.7% and 3.5%.

## 1. Introduction

In the hydrological cycle, infiltration is the one element on it. It is play a major role in the availability of water on earth. It was mean as the process of entry water into the soil layer assisted by the force gravity. This process will help increase the water content and moisture content of the soil, replenish the aquifer layer and also have an impact on the existence of river flows during the dry season. The ability of infiltration in an area is influenced by several factors including the condition of the physical properties of the soil such as soil type, soil structure, porosity, water content, hydraulic conductivity, soil surface conditions to the type of land cover and vegetation [1].

## 2. Material and Methods

### 2.1. *Background*

Measurement of infiltration rate generally uses the Horton method. Compared to other methods, the Horton method is one of the most frequently used infiltration methods in hydrology. Horton stated that the infiltration capacity decreases over time until it approaches a constant value. This model use becaue is very simple and more suitable for experimental data in the field [2].

This infiltration parameter was measured in the Banjarbaru State Development Agriculture Vocational High School, South Banjarbaru District, Banjar Baru City, South Kalimantan Province. Therefore, the data from the infiltration rate analysis can be used as a reference for more effective land use. In addition to this, capacity and infiltration rate data can also be used by future researchers who need this data.

### 2.2. *Research Purposes*

- To test the physical properties of the soil on open and closed land in the SMK PP N Banjarbaru Practice area.
- To analyze the size of the infiltration rate that occurs in the PP N Banjarbaru Vocational School Practice area.
- To be able to determine the relationship between the physical properties of the soil and the infiltration rate on open and closed land in the SMK PP N Banjarbaru Practice area.

### 2.3. *Infiltration*

Infiltration is the flow of water into the soil through the soil surface. In the country, water flows in a lateral direction, as interflow to springs, lakes, rivers, or vertically, known as percolation to groundwater. The movement of water in the

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soil through the soil's pores is influenced by gravitational forces and capillary forces [3].

According to [4], infiltration rate is the amount of water entering the soil during rainfall, expressed in units of mm/hour or cm/hour. When the soil is dry, the infiltration rate is fast. If the soil is saturated with water, the infiltration rate will decrease and become constant. Data from measurements of the infiltration rate can be calculated by Eq (1) [5].

$$f = \frac{\Delta H}{t} \quad (1)$$

Where:

- F = infiltration rate (cm/hour)
- ΔH = Height of water drop in a certain time interval (cm)
- T = time needed by water at ΔH to enter the ground (minutes)

#### 2.3.1. *Horton's Method*

One of the soil infiltration tests can be done with the Horton Method. According to Horton, the infiltration capacity will decrease over time until it reaches a constant value. Horton stated that the decrease in infiltration capacity is controlled more by factors at the soil surface than by the flow process in the soil. Factors that reduce infiltration rates include land cover, the closing of soil cracks by soil colloids and forming soil crusts, the destruction of the land surface structure, and the transport of fine particles to the soil surface by raindrops. The infiltration capacity based on the Horton model is following Eq (2) [6].

$$f = f_c + (f_0 - f_c) \cdot e^{-k.t} \quad (2)$$

Where:

- F = Infiltration capacity or maximum infiltration rate (cm/hour)
- $F_0$ = Infiltration capacity at the beginning of the infiltration process (cm/hour)
- $F_c$ = Set infiltration capacity (when t approaches infinity) (cm/hour)
- e = Logarithmic base number Neperians
- t = Time calculated from the start of the rain (hours)
- k = Constant for soil type

#### 2.3.2. *Relationship of Solid Physical Properties with Infiltration*

The rate of infiltration on some land varies depending on land use and several factors that affect the physical properties of the soil, among others, organic matter, bulk density, porosity, stability/aggregate stability, and water content [7].

## 3. Method

### 3.1. *Research Sites*

This research was conducted at the Banjarbaru State Agricultural Development Vocational School of Practice in Kemuning Village, South Banjarbaru District, Banjarbaru City, South Kalimantan Province. Data on the area of each research area, namely rubber land 0.79 ha, mahogany land 0.29 ha, palawija land 0.12 ha, open land 0.14 ha. The research was conducted on December 10, 2022. Location of the research is shown in Figure 1.

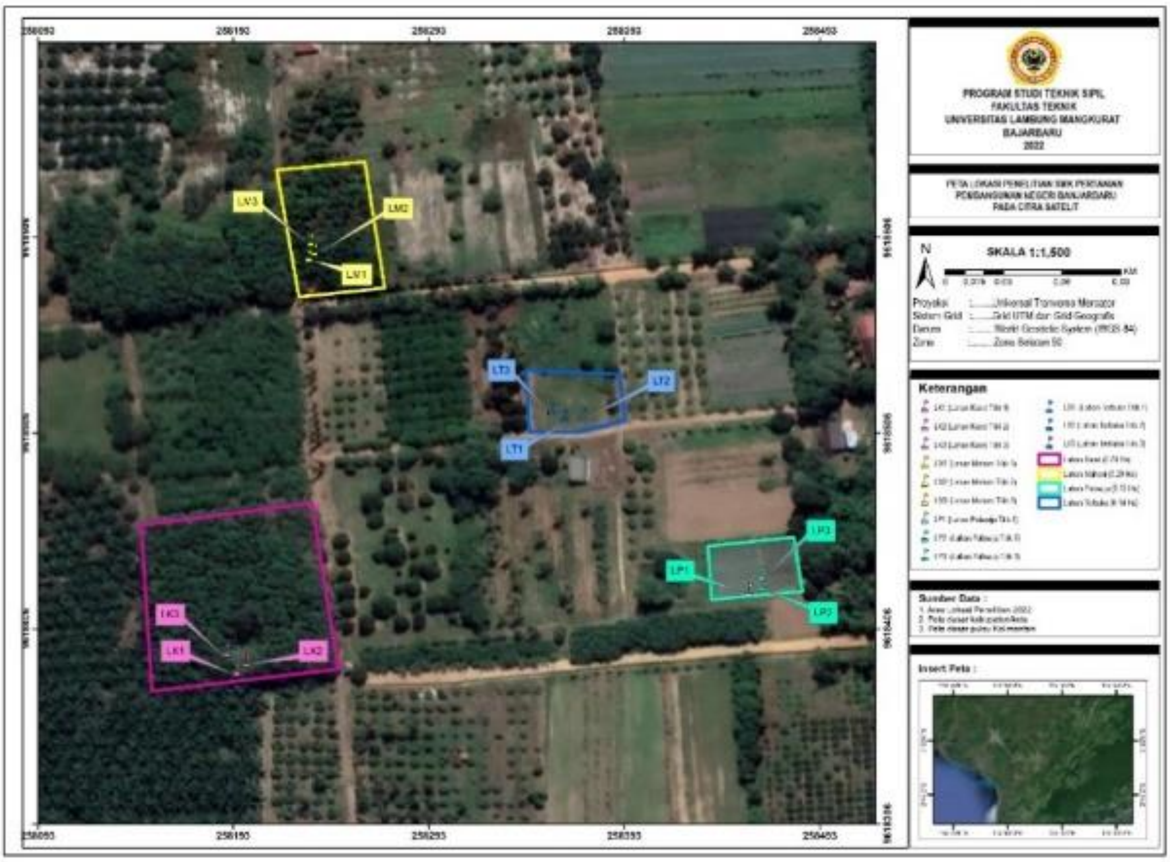


Figure 1. Research Locations that display each point of land

### 3.2. Research Procedure

- Preparation for this study was to carry out survey activities at the research location and prepare the research tools to be used.
- Determination of points for each research area
- Data retrieval

The data taken are as follows:

- Primary data is data obtained by researchers directly from the object. Primary data is obtained from direct field research in the form of soil samples and infiltration rates.
- Researchers from intermediaries in the form of literature, books, journals, ArcGIS, and Google Earth obtain secondary data.

#### 3.2.1. Measurement

Measurement of the infiltration rate in the field is carried out to determine the value of the infiltration rate. Then from the value of the infiltration rate, infiltration parameters are obtained. Measurement of infiltration parameters using an infiltrometer, namely a double-ring infiltrometer. The location for data collection or measurement of infiltration rate was carried out by purposive sampling, meaning infiltration data collection and placement of the infiltrometer in an area considered representative of the studied area. The procedure for measuring infiltration parameters is as follows [8].

- We make sure the weather is fine without rain a day before.
- We are installing a double-ring infiltrometer at the observation point
- Insert the double-ring infiltrometer into the ground slowly.
- Fill water into the ring, first enter the outer ring and then continue in the inner circle. Filling water is done slowly so as not to damage the surface structure of the soil.
- Turn on the stopwatch when the inner ring is filled with water
- Record the initial water level by looking at the scale and record the decrease in water at certain time intervals. The time interval depends on the speed of the water decline. In this study, the water reduction interval was used every 5 minutes.
- Add water after 5 minutes and record the initial water level. Repeat until three times there is a constant decrease in water.
- The data take in three different point and three different time.

#### 3.2.2. Soil Sample

A sampling of disturbed soil, disturbed soil is used for analysis purposes. Parameters observed from the soil sample are grain distribution, bulk density, water content particle density, soil porosity, and permeability.

Soil samples will be taken at several test points. The soil samples taken are representative soil samples at the sampling location, while the procedure for taking disturbed soil is as follows:

- Level and clean the ground surface.
- Dig the dirt to a depth of about 5cm around the test point.
- Take a soil sample with a hoe of as much as 1-2 kg.
- Place the soil sample in a plastic bag.
- Then label the plastic bag.

## 4. Result and Discussion

### 4.1. Soil Physical Properties at Research Sites

Differences in soil physical properties at each location will affect the amount of infiltration rate to be measured. This happens because the physical properties of the soil, such as grain distribution, bulk density, water content, particle density, porosity, and soil permeability, will affect how quickly water enters the ground and reaches the saturation point. The physical properties of the soil that have been analyzed will be presented in the Table 1-Table 3.

Table 1. Grain Analysis, which displays the distribution of grains at each location

| No | Land | Land Classification % | | | | | |
|---|---|---|---|---|---|---|---|
| | | Gravel | Rough sands | Medium Sand | Fine Sand | Silt & Clay | Clay |
| 1 | Rubber | 26,63 | 5,62 | 9,00 | 12,25 | 25,72 | 20,78 |
| 2 | Palawija | 0,60 | 7,27 | 32,38 | 27,23 | 17,22 | 15,30 |
| 3 | Mahogany | 19,13 | 6,97 | 12,93 | 16,52 | 20,95 | 23,50 |
| 4 | Open field | 5,97 | 3,23 | 10,75 | 26,48 | 29,34 | 24,23 |

Table 2. Permeability Analysis and Water content per land

| No | Land | Permeability cm/hour | Soil Water Content % |
|---|---|---|---|
| 1 | Rubber | 1,13 | 17,79 |
| 2 | Mahogany | 1,03 | 27,10 |
| 3 | Palawija | 2,50 | 30,73 |
| 4 | Open field | 3,84 | 11,03 |

Table 3. The results of the analysis of bulk density, particle density, and porosity values

| No | Land | BD (gr/cm3) | PD (gr/cm3) | Porosity (%) |
|---|---|---|---|---|
| 1 | Rubber | 1,483 | 1,912 | 22,437 |
| 2 | Palawija | 14,13 | 2,475 | 42,909 |
| 3 | Mahogany | 1,744 | 2,400 | 27,333 |
| 4 | Open field | 1,469 | 2,425 | 39,423 |

### 4.2. *Results Analysis of the Average Infiltration Rate*

Based on Figure 2 and Figure 3, it is known that from the three observation locations, the highest average infiltration rate is in the open field with 39.383 cm/hour, then in rubber land with 22.57 cm/hour, the third is palawija with 15.57 cm/hour and the last 33.83 cm/hour (Table 4).

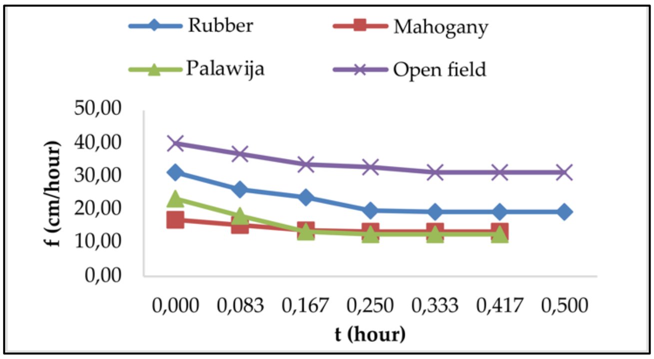


Figure 2. Infiltration rate recapitulation graph

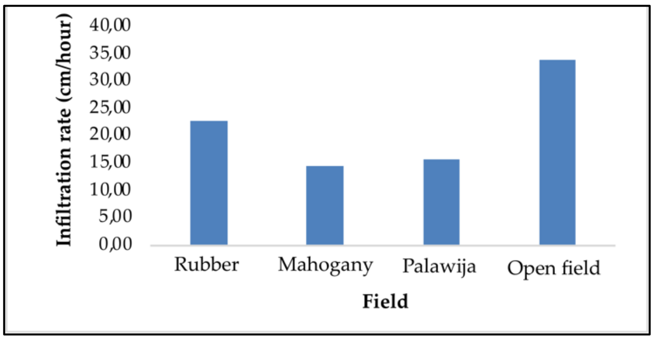


Figure 3. The average infiltration rate value

### 4.3. *Relationship Between Soil Physical Properties and Infiltration Rate*

Figure 4 show the result of the regression graph of infiltration rate and bulk density is R2 = 0.167. Soil bulk density harms the infiltration rate in the soil, so it can be said that if the bulk density in the soil is high, the infiltration rate will decrease. Figure 5 show the Regression graph of infiltration rate and particle density results in R2 = 0.007. So, particle density does not significantly affect the infiltration rate in the soil. Particle density has a positive effect on the infiltration rate. They were expressed by where any increase in the number of grains of sand in the ground will be able to increase the infiltration rate. Figure 6 show the results of the regression graph of infiltration rate and porosity are R2 = 0.356. Figure 7 show the regression graph of infiltration rate and Permeability results obtained R2 = 0.752. In the regression chart above, we can see 4 (four) blue dots and a straight line drawn by comparing the infiltration rate with the soil permeability value. The straight line is the perfect score limit, or it can be said to be 100%. So that if the location of the blue dot is closer to the straight line, the value limit will be the higher the correlation value between the two variables used, and vice versa. If the point is further away from the straight line, the value will get lower. According to [9], permeability is a unit that cannot be separated from the infiltration rate in the soil. Soil permeability has an upper layer and a lower layer. Figure 8 show the result of the regression graph of infiltration rate and bulk density is R2 = 0.9057. This explains that water content or soil moisture influences 90% of the infiltration rate. Soil water content negatively affects the infiltration rate in the soil, so it can be said that if the water content in the soil is high, the infiltration rate will decrease.

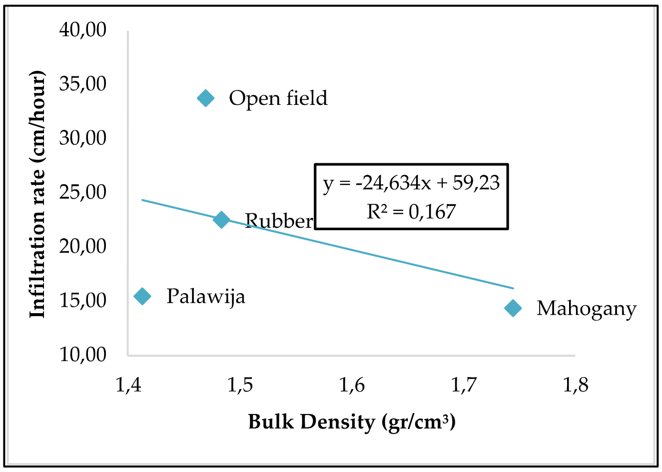


Figure 4. The result of the regression graph of infiltration rate and bulk density

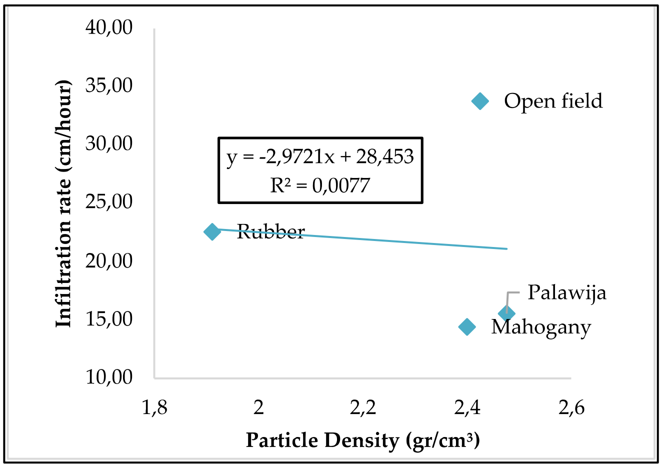


Figure 5. The Regression graph of infiltration rate and particle density results

Table 4. Analysis of the average infiltration rate of all fields

| No | t minutes | t hour | Infiltration rate (cm/hour) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LK1[a] | LK2[b] | LK3[c] | Average | LM1[d] | LM2[e] | LM3[f] | Average | LP1[g] | LP2[h] | LP3[i] | Average | LT1[j] | LT2[k] | LT3[l] | Average |
| 1 | 0 | 0,000 | 2,72 | 2,72 | 2,72 | 2,72 | 5,10 | 25,50 | 19,92 | 16,84 | 30,96 | 22,50 | 16,80 | 23,42 | 35,88 | 39,36 | 44,70 | 39,98 |
| 2 | 5 | 0,083 | 2,72 | 2,72 | 2,72 | 2,72 | 3,60 | 24,00 | 18,00 | 15,20 | 25,20 | 18,00 | 10,80 | 18,00 | 30,00 | 37,20 | 43,20 | 36,80 |
| 3 | 10 | 0,167 | 2,72 | 2,72 | 2,72 | 2,72 | 2,40 | 22,80 | 16,80 | 14,00 | 20,40 | 14,40 | 6,00 | 13,60 | 24,00 | 34,80 | 42,00 | 33,60 |
| 4 | 15 | 0,250 | 2,72 | 2,72 | 2,72 | 2,72 | 2,40 | 22,80 | 15,60 | 13,60 | 18,00 | 14,40 | 6,00 | 12,80 | 21,60 | 34,80 | 42,00 | 32,80 |
| 5 | 20 | 0,333 | 2,72 | 2,72 | 2,72 | 2,72 | 2,40 | 22,80 | 15,60 | 13,60 | 18,00 | 14,40 | 6,00 | 12,80 | 19,20 | 32,40 | 42,00 | 31,20 |
| 6 | 25 | 0,417 | 0,00 | 0,00 | 2,72 | 0,91 | 2,40 | 22,80 | 15,60 | 13,60 | 18,00 | 14,40 | 6,00 | 12,80 | 19,20 | 32,40 | 42,00 | 31,20 |
| 7 | 30 | 0,500 | 13,20 | 40,80 | 0,00 | 18,00 | | | | | | | | | 19,20 | 32,40 | 42,00 | 31,20 |
| | | | | | | 4,64 | | | | 14,47 | | | | 15,57 | | | | 33,83 |

Where,
[a]Point one rubber land
[b]Rubber ground point two
[c]Triple point rubber
[d]Mahogany land point two
[e]Point one mahogany land
[f]Three point mahogany land
[g]Point one rubber land
[h]Rubber ground point two
[i]Triple point rubber
[j]Mahogany land point two
[k]Point one mahogany land
[l]Three point mahogany land

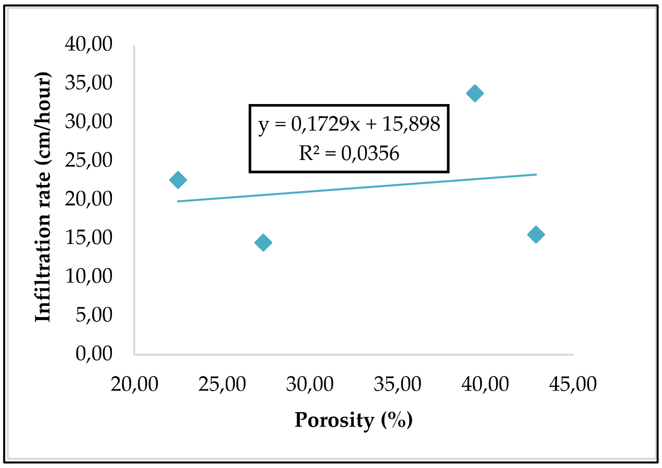


**Figure 6.** The results of the regression graph of infiltration rate and porosity

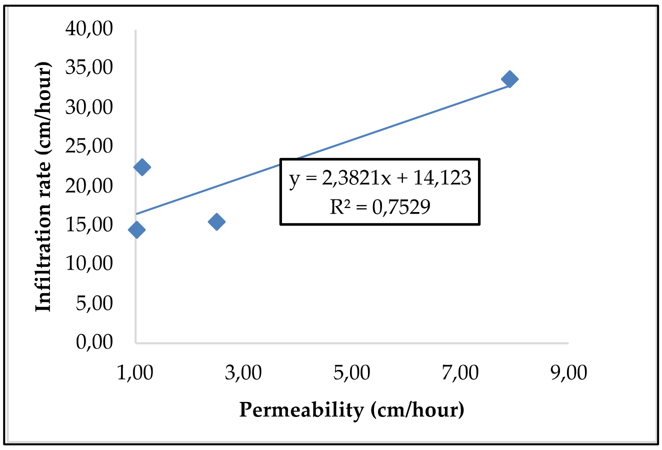


**Figure 7.** Regression graph of infiltration rate and Permeability

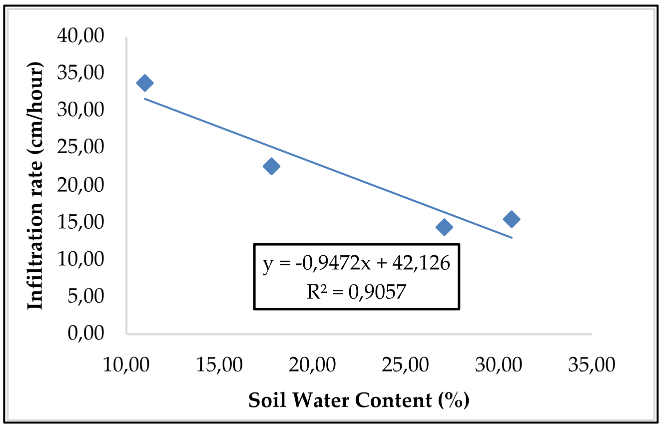


**Figure 8.** Regression graph of infiltration rate and soil water content

### 4.4. *Recapitulation of the Relationship Between Soil Physical Properties and Infiltration Rate*

Table 5 show the recapitulation of the Effect of Soil Physical Properties on Infiltration Rate. It is known that the results of the analysis using a simple linear regression approach obtained the value of R2. Each soil's physical property influences the infiltration rate, which is explained in the graph. The straight line on the chart is the perfect value line from the comparison between infiltration rate and soil physical properties. The closer the straight line point is between infiltration rate and bulk density, the higher the attachment value between the two variables or close to 100% and vice versa, the farther the point is from the straight line on the graph, the lower the attachment value between the two variables used. From the statement above, it can be assumed that several soil physical properties can affect the infiltration rate: bulk density at 16.7%, Permeability at 75%, and water content at 90%. Meanwhile, particle density and porosity only affect 0.7% and 3.5%.

Table 6 show the Regression statistics, obtained from multiple regression analysis for the R Square value of 5 variables from the physical properties of the soil, received a value of 1 or 100 attachments from several variables.

### 4.5. *Comparison with Other Studies*

In research [10] in the Banjarbaru ULM Area which also examined the infiltration rate and capacity on open and closed land in the South Banjarbaru District, a clear difference was at the time of infiltration rate data collection. Bangun and Helda [10] take infiltration rate data for an extended period at each point of approximately one month, and do not describe the weather before the day of infiltration rate data collection. Whereas in this study, data were collected from all points in one day and with clear weather conditions one day before the day of infiltration rate data collection. The average value of the infiltration rate found in several lands in the ULM Banjarbaru area is sequential. The highest, namely in forest land with a size of 24 cm/hour, open land of 16 cm/hour, and the lowest is in garden land, which is equal to 10 .4cm/hour.

In comparison with the results of the analysis in this study with [10], namely in the open land of the Banjarbaru ULM Area, the infiltration rate value obtained is 16 cm/hour, which indicates that the infiltration rate is fast. Whereas in the open land of SMK PP N Banjarbaru, an average infiltration rate of 33.83 cm/hour is obtained, it can be said that the infiltration rate in this area is speedy. The average of the other fields tested on open and closed land also produced a fast infiltration rate. It can be concluded that open and closed land areas in the South Banjarbaru sub-district are one of the right choices as water catchment areas.

Then on to research [11], the highest infiltration rate value is in Mahogany stands which is equal to 146.33 mm/hour. The second highest infiltration rate value is in mixed forests, with a value of 123 mm/hour. The lowest infiltration rate value is in the Alang-Alang plains, with a value of 19.66 mm/hour. O'clock.

Table 5. Recapitulation of the Effect of Soil Physical Properties on Infiltration Rate

| Soil Physical Properties | Bulk Density (gr/cm3) | Particle Density (gr/cm3) | Porosity (%) | Soil Water Content | Permeability cm/hour |
|---|---|---|---|---|---|
| R2 | 0.167 | 0.007 | 0.035 | 0.91 | 0.752 |
| Influence % | 16,7 | 0.7 | 3,5 | 90 | 75 |

Table 6. Regression statistics

| | |
|---|---|
| Multiple R | 1 |
| R Square | 1 |
| Adjustes R Square | 65535 |
| Standard Error | 0 |
| Observations | 4 |

This is in contrast to Mahogany land in the SMK PP N Banjarbaru area, which is the land with the lowest infiltration rate value of 16.84 cm/hour. This is due to the Mahogany land in KHDTK ULM showing that the physical properties of the soil on mahogany land support the infiltration process. Soil texture determines the soil density, where the number of large pores means that the infiltration capacity is more significant because the infiltrated water enters the soil to fill the empty pores. Soil texture with a high sand fraction gives the soil a high infiltration rate.

It can be concluded that from the results, the average infiltration rate in the ULM KHDTK area, Karang Intan District, Banjar Regency, is higher than in the PP N Banjarbaru Vocational School Practice Area, Kemuning District, Banjarbaru City.

## 5. Conclusion

From the analysis using the linear regression approach, the physical properties of the soil that can affect the rate and capacity of infiltration include 16.7% bulk density, 75% permeability, and 90% moisture content. Meanwhile, particle density and porosity only affect 0.7% and 3.5%. The distribution of soil grains at the study sites varied, one of which was the distribution of granules on rubber land, which was dominated by gravel, 26.63%. On palawija ground, there was a lot of medium sand, 32.38%, and on mahogany land, 23.50% was dominated by clay. Whereas in open land, the grain distribution is dominated by silt clay as much as 29.34%.

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## Author Declaration

### Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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### Availability of data and materials

All data are available from the authors.

### Competing interests

The authors declare no competing interest.

### Additional information

No additional information from the authors.

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