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The Impact of Land Cover Density on the Water Infiltration Process in the Nyadeng Lake Area, Merabu Village Berau District, East Kalimantan

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Abstract. The sustainability of water resources depends on the state of the nearby forest. Land cover is essential for sustaining life systems in a region; the higher the quality of the land cover or forest vegetation, the greater the biodiversity value of the region. This research attempts to determine whether or not the vegetation in the Merabu Village area of Nyadeng Lake has the capacity to process the infiltration rate. The vegetation was sampled using simple random sampling, and a 20 m x 20 m plot was used to represent the area under investigation. Data collection was accomplished by establishing research plots that can represent the entire area or research area, with the size of the plot varying according to plant class. This research utilized a total of six plots. Three plots on the west and three on the east were laid out at a distance of five meters from the lake's shore. The infiltration rate was measured by creating 0.5 m x 0.5 m infiltration subplots with five replicates per sample plot. These locations have been established approximately five metres away from the shore of the lake. High vegetation cover has a tremendously positive effect on infiltration. The coefficient of determination, with a value of 72%, indicates that the infiltration ability is influenced by the existence of vegetation to a significant degree.

1. Introduction

The sustainability of water resources is contingent on the condition of the local forest. Initially, when a forest is cut down, the water yield will increase due to decreased evapotranspiration. However, the water yield will decrease over time as the water stored in the soil decreases [1].

Land cover is an essential factor in sustaining life systems in a region; the better the type of land cover or forest vegetation, the higher the biodiversity value of the region. Changes in land cover, both as a result of human activities and as a result of natural processes, are considered to be one of the factors that influence environmental integrity, biodiversity, and the ability of an area to support life.

Infiltration is the process of water entering the soil from precipitation, whereas the infiltration rate is the quantity of water entering the soil per unit of time [2]. This process is an essential part of the hydrological cycle that can affect the amount of water on the soil's surface, where the water on the soil's surface will enter the soil and then flow into the river.

The soil texture, mass density (bulk density), permeability, soil moisture content, and vegetation affect the infiltration rate. The greater the infiltration rate, the lower the mass density of the soil, the larger the soil fractures, and the crumblier the soil [2]. Regarding vegetation, the greater the root penetration, the greater the absorption capacity of the roots, and the greater the accumulation of soil organic matter, the greater infiltration rate [3]. Vegetation influences erosion because it prevents rainfall from damaging the soil. Some of the water on the soil surface remains in the top soil layers and is evaporated back into the atmosphere through the soil surface or soil evaporation. Several factors, including soil texture and structure, initial soil moisture, biological activity and organic matter, litter type and thickness, vegetation type, and understory, influence the quantity of water entering the soil through infiltration [3].

Nyadeng Lake is the primary water supply for the residents of Merabu Village. Various types of vegetation believed to be capable of retaining and storing water exist near the primary source of springs, resulting in abundant available water for the community.

The primary water source used by Merabu Village residents to fulfill their daily life requirements is the Nyadeng Lake water. The current adequacy of water resources for the community can be deemed satisfactory. The diverse vegetation surrounding the primary spring source is believed to contribute to its water protection and storage capabilities. Nevertheless, the current understanding of how land cover vegetation contributes to the infiltration process and its associated capability remains underdeveloped.

This study sought to evaluate the varieties of land cover vegetation in the Nyadeng Lake district of Merabu Village and the vegetation's capacity to process infiltration rates. The research is intended to furnish the Merabu Village community with valuable insights into the critical role of vegetation in infiltration. By doing so, it will be expected that the community will become empowered to protect and maintain the biodiversity of the vegetation surrounding Nyadeng Lake.

2. Material and Method

2.1. Study locations

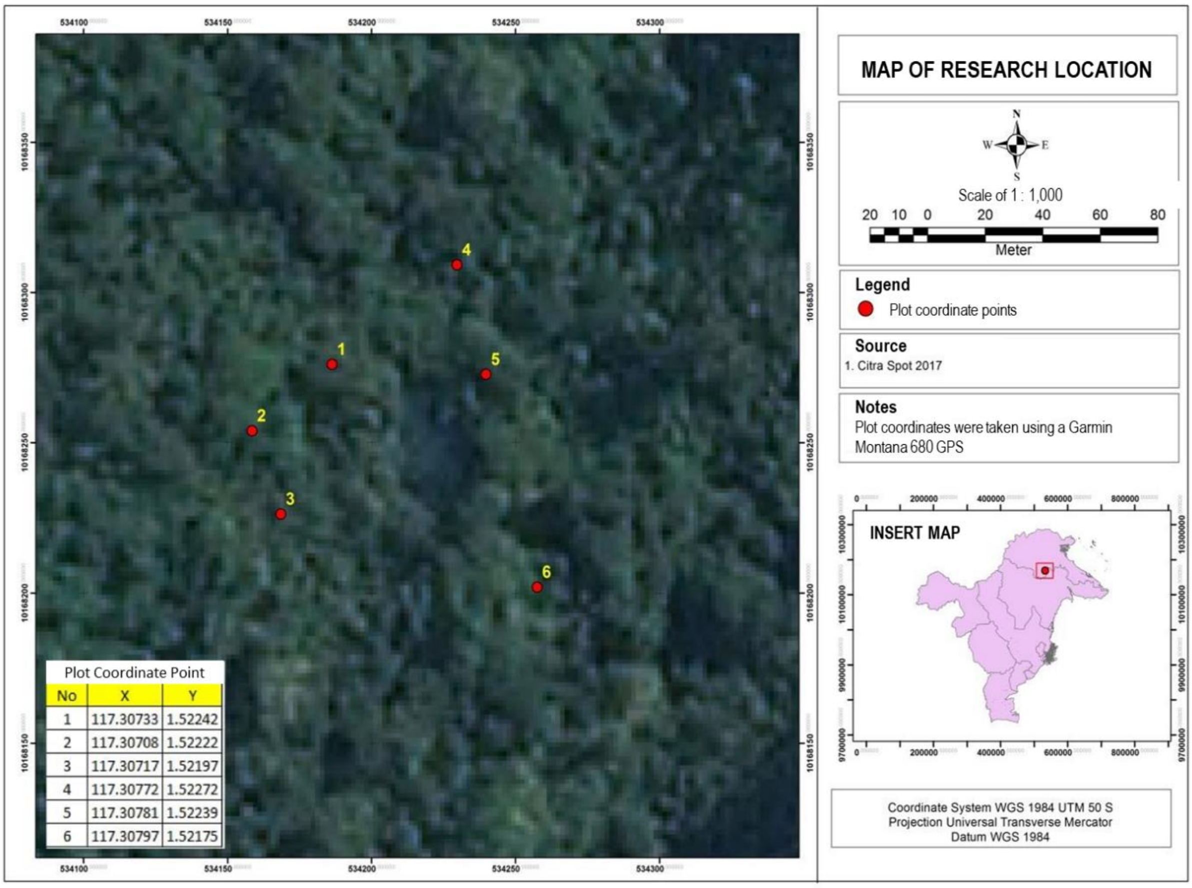
This study was conducted in the Nyadeng Lake Region, Merabu Village, in the Berau Regency of East Kalimantan, Indonesia. Geographically, the location of Merabu Village is between 117°12' and 117°2' East Longitude (EL), 1°19'12" and 1°38'24" South Latitude (SL). Merabu village is located about 400 meters above sea level (asl), part of the Berau Regency territory. It can be found in the region's southern 22,000 hectares. Figure 1 illustrates the specific geographical area where the research was conducted, its visual representation, and the designated plot where observations were made.

2.2. Research procedure

These research sites were 20 meters by 20 meters in size. Data collection was accomplished by establishing research plots that can represent the entire area or research area, with the size of the plot varying according to plant class [4] as depicts by Figure 2 following these rules:

1. Plot size 20 m x 20 m (400 m^{-2}) sites for vegetation data collection at tree level.
2. Plot size of 10 m x 10 m (100 m^{-2}) for vegetation data collection at pole level.
3. Plot size of 5 m x 5 m (25 m^{-2}) for vegetation data collection at the sapling level.
4. Plot size of 1 m x 1 m (1 m^{-2}) for vegetation data collection at understorey (sherbs, herbs)/ seedling level.

This research utilized a total of six plots. This is a reasonably precise representation of the conditions along the shores of Lake Nyadeng. Three plots on the west and three on the east sides of Nyadeng Lake were laid out five meters from the lake's shore. The ability of various vegetation varieties to store water was determined by measuring the infiltration rate. The infiltration rate was measured by creating 0.5 m x 0.5 m infiltration subplots with five replicates per sample plot. Measuring the infiltration rate [5] was conducted by employing an artificial rainfall simulation technique (Figure 3). Calculating the difference in liters per minute between rainfall and surface discharge yields the infiltration rate.



Plot Coordinate Point

No	X	Y
1	117.30733	1.52242
2	117.30708	1.52222
3	117.30717	1.52197
4	117.30772	1.52272
5	117.30781	1.52239
6	117.30797	1.52175

Figure 1. The research involved the investigation of location maps and the establishment of a total of six observation plots.

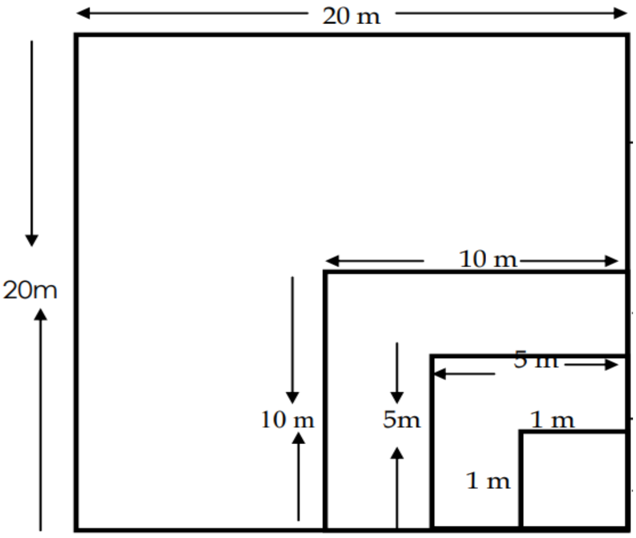


Figure 2. Plot for Vegetation Sampling Investigation

Figure 3. Double Ring Infiltrometer Installation to measure the rate of soil water infiltration (a), and to collect data on infiltration rate (b)

2.3. Data analysis

The Important Value Index (IVI) measures the significance of a plant's function in its ecosystem. If the IVI of a species is high, then that species impacts the ecosystem's stability. This IVI is derived from the sum of all Relative Density (RD), Relative Frequency (RF), and Relative Dominance (RDo) values, which describe as follow:

$$\text{IVI}\ (\%) = \text{RD}\ (\%) + \text{RF}\ (\%) + \text{RDo}\ (\%) \tag{1}$$

From [6], the value of Relative Density, Relative Frequency, and Relative Dominance are derived.

1. Density

When the number of individual plants is expressed per unit area, the value is referred to as density. Density value can indicate that species with high-density values have extensive patterns of adaptation.

$$\text{Density} = \frac{\text{The number of individuals in a species}}{\text{Observation plot area}} \tag{2}$$

$$\text{Relative Density (RD)} = \frac{\text{Density of Species}}{\text{Density all Species}} \times 100\ \% \tag{3}$$

2. Frequency

This parameter represents the distribution of plant species in an ecosystem or illustrates the distribution pattern of plants.

$$\text{Frequency (F)} = \frac{\text{Number of Plots Found of a Species}}{\text{total number of Plots}} \tag{4}$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of Species}}{\text{Frequency all Species}} \times 100\% \tag{5}$$

3. Dominance

The ratio between the area covered by a plant species and the total area of the habitat is identified as the dominant species or coverage area.

$$\text{Dominance (Do)} = \frac{\text{Basal Area of Species}}{\text{Observation Plot Area}} \tag{6}$$

$$\text{Relative Dominance (RDo)} = \frac{\text{Dominance of Species}}{\text{Dominance all Species}} \times 100\% \quad (7)$$

However, the importance of newly germinated, seedling and sapling, shrub, and herb species is determined only by their relative density and frequency. IVI for seedlings and saplings:

$$\text{IVI (\%)} = \text{RD (\%)} + \text{RF (\%)} \quad (8)$$

In the field, infiltration measurements are recorded as the quantity of water reduction in each plot, which will be processed later. The processing of these data yielded data on the infiltration rate at each time (ft). Infiltration can be expressed as follows:

$$\text{ft} = \frac{\text{Depth(cm)}}{\text{T(minute)}} \quad (9)$$

Where ft is infiltration rate at each time (cm.minutes^{-1}); depth (cm) is cumulative water input (water that enters the soil in the ring infiltrometer (cm); and T is observation time interval enters the water in the ring infiltrometer (minutes).

Simple Linear Regression Analysis [7] was utilized to determine the impact of a predictor variable (independent variable) on a dependent variable. The simple linear regression equation is expressed mathematically as follows:

$$\hat{Y} = a + bX \quad (10)$$

Where $\hat{Y}$ is regression line/response variable, a is constant (intercept), intercept with the vertical axis; b is regression constant (slope); and X is independent variable/predictor.

Using the equation, the constants a and b values can be determined.

$$a = \frac{(\sum Y_i)(\sum X_i^2) - (\sum X_i)(\sum X_i Y_i)}{n \sum X_i^2 - (\sum X_i)^2} \quad (11)$$

$$b = \frac{n (\sum X_i Y_i) - (\sum X_i)(\sum Y_i)}{n \sum X_i^2 - (\sum X_i)^2} \quad (12)$$

Where n is number of data.

3. Result and Discussion

Nyadeng Lake is situated in the Merabu Village Area of the Kelay District, Berau Regency in East Kalimantan, Indonesia. The water of Nyadeng Lake originates from a karst mountain boulder. A small stream from Nyadeng Lake flows into the Lesan River, a tributary of the Kelay River. The Kelay River is a river stream that flows from the Berau River to the sea. Nyadeng Lake is one of Merabu's ecotourism destinations (Figure 4), with a surface area of one hectare and an approximate depth of sixty meters, whose depth is uncertain. The water color of Nyadeng Lake is Tosca green because it originates from a mountain rock, which makes it fascinating. In addition to being a destination for ecotourism, Nyadeng Lake is also a source of clean drinking water for the residents of Merabu.

Figure 4. Nyadeng Lake, a tourist destination in Merabu village, Berau district

3.1. Vegetation in the Nyadeng Lake Area, Merabu Village

Vegetation is defined as a collection of all plants that coexist in a region and can be characterized by constituent species or structural and functional combinations that provide physiognomic characteristics or the outward appearance of vegetation [8]. Vegetation is a collection of plants, including herbs, trees, and shrubs, that exist in the same area, interact with one another and the environment, and exhibit physiognomic (outward) characteristics [9]. Physiognomy, Phenology, Periodicity, Stratification, Abundance, Distribution, Vitality, and Growth Forms are among the qualitative parameters in analyzing plant vegetation. Significant quantitative parameters in vegetation analysis include density, frequency, dominance, importance value index, sum of dominance ratio (SDR), dominance index, diversity index, and similarity index [10].

The purpose of vegetation analysis in forest areas is to identify the vegetation structure, composition of species, and distribution patterns of a specific region [11]. The structure of forest vegetation results from the spatial planning by the constituent components of the stand and life form, stratification, and vegetation cover. Those are obtained through conditions of diameter, height, crown diversity, and spatial distribution of species continuity. Table 1 displays the outcomes of an analysis of vegetation at the seedling level.

Table 1. Important Values Index (IVI) of Seedling Levels Discovered in the Experimental Plot of Nyadeng Lake

No.	Local name	Scientific name	Family	RD (%)	RF (%)	IVI (%)
1	Jambu-jambu	*Syzygium* spp.	Myrtaceae	15.08	21.74	36.82
2	Banitan	*Maranta arundinaceae*	Marantaceae	29.37	4.35	33.72
3	Meranti	*Shorea* sp.	Dipterocarpaceae	12.70	17.39	30.09
4	Mata panah	*Syngonium podophyllum*	Araceae	13.49	4.35	17.84
5	Medang	*Phoebe bournei*	Lauraceae	3.97	13.04	17.01
6	Kunyit	*Curcuma longa*	Zingiberaceae	10.32	4.35	14.67
7	Kopi Hutan	*Cofea* sp.	Rubiaceae	3.17	8.70	11.87
8	Guarana	*Paullinia bracteosa*	Sapindaceae	4.76	4.35	9.11
9	Mali-mali	*Leea indica*	Vitaceae	2.38	4.35	6.73
10	Kayu sirih	*Piper aduncum*	Piperaceae	1.59	4.35	5.94

11	Opor-opor	*Sandoricum koetjape*	Meliaceae	1.59	4.35	5.94
12	Rambutan	*Naphelium lappaceum*	Sapindaceae	0.79	4.35	5.14
13	Kakao	*Theobroma cacao*	Malvaceae	0.76	4.35	5.11

IVI: Important Value Index; RD: Relative Density; RF: Relative Frequency

There are thirteen species plant of seedling vegetation listed in Table 1, and five species that dominate and have the highest Important Value Index (IVI) at the seedling level, including Jambu-jambu (*Syzygium* spp.) with a maximum IVI of 36.82%. The species with the highest IVI are Banitan (*Maranta arundinaceae*) with a value of 33.72 %, Meranti (*Shorea* sp.) with a value of 30.09 %, mata panah (*Syngonium podophyllum*) with a value of 17.84 %, and Medang (*Phoebe bournei*) with a value of 17.01 %.

The existence of vegetation at the seedling level and small vegetation on the soil surface functions as a ground cover to protect the soil surface from the direct impact of rainwater. Plants that cover the ground or floor vegetation protect the soil surface from rainfall's spreading and crushing effect [12]. In the interaction between soil and vegetation in ecological succession, annual species typically grow on the soil where soil texture is loose and aeration conditions are superior [13]. Moreover, it slows surface runoff and protects the surface soil from the abrasive force of surface runoff. Saplings are the next observed step in plant life. Table 2 displays the results of a visual inspection of the vegetation on saplings.

Table 2. Important Value Index for each species at the Sapling Level Discovered in the Experimental Plot of Nyadeng Lake

No.	Local name	Scientific name	Family	RD (%)	RF (%)	IVI (%)
1	Kayu Batu	*Rhodamnia* sp.	Myrtaceae	17.74	21.43	39.17
2	Jambu-jambu	*Syzygium* spp.	Myrtaceae	24.19	14.29	38.48
3	Meranti	*Shorea* spp.	Dipterocarpaceae	14.52	10.71	25.23
4	Kakao	*Theobroma cacao*	Malvaceae	4.84	7.14	11.98
5	Mengerawan	*Hopea mengerawan*	Dipterocarpaceae	8.06	3.57	11.63
6	Nyatoh	*Palaquium* spp.	Sapotaceae	3.23	7.14	10.37
7	Kayu sirih	*Piper aduncum*	Piperaceae	6.45	3.57	10.02
8	Jabon	*Anthocephalus cadamba*	Rubiaceae	3.23	3.57	6.80
9	Kayu manis	*Cinnamomum* sp.	Lauraceae	3.23	3.57	6.80
10	Malapari	*Pongamia pinnata*	Leguminosae	3.23	3.57	6.80
11	Kedarai	*Ellipanthus beccari*	Connaraceae	3.23	3.57	6.80
12	Jelutung	*Dyera costulata.*	Apocynaceae	1.61	3.57	5.18
13	Blangkan	*Vitex pinnata*	Lamiaceae	1.61	3.57	5.18
14	Bintanong	*Trema cannabina*	Ulmaceae	1.61	3.57	5.18
15	Matoa	*Pometia pinnata*	Sapindaceae	1.61	3.57	5.18
16	Medang	*Phoebe bournei*	Lauraceae	1.61	3.57	5.18

IVI: Important Value Index; RD: Relative Density; RF: Relative Frequency

Table 2 illustrates the presence of 16 species of vegetation at the sapling level. Of these 16 species, five species dominate the greatest number and have the highest Important Value Index at the sapling level, with kayu batu (*Rhodamnia* sp.) having the highest IVI at 39.17%. The second-highest IVI for jambu-jambu species (*Syzygium* spp.) is currently 38.48%. Meranti (*Shorea* spp.) ranks third with an IVI of 25.23%. The fourth is kakao (*Theobroma cacao*), with an IVI of 11.98%, and the fifth is Mengerawan (*Hopea mengerawan*), with an IVI of 11.63%.

The majority of plants existing at the stage of saplings are pioneer species, including *Piper aduncum, Trema cannabina*, and *Anthocephalus cadamba*, among others. Pioneer species are prevalent; pioneer species typically colonize first in newly opened areas. The presence of pioneers will progressively improve the condition of the forest's surroundings, the microclimate, and the site. After this, primary types were beginning to appear. Primary forest varieties have begun to dominate, with Meranti (Shorea sp.) in third place with an IVI of 25.23% and Mengerawan (*Hopea mengerawan*) in fifth place with an IVI of 11.63%.

Furthermore, the level of plant life observed was pole size. Table 3 illustrates the vegetation analysis results for plants above the poles.

Table 3. Important Value Index for each species at the Pole Level Discovered in the Experimental Plot of Nyadeng Lake

No.	Local name	Scientific name	Family	RD (%)	FR (%)	RDo (%)	IVI (%)
1	Jambu-jambu	*Syzygium* spp.	Myrtaceae	30	30	33.24	93.24
2	Meranti Putih	*Shorea agami*	Dipterocarpaceae	15	15	18.84	48.84
3	Meranti merah	*Shorea johorensis*	Dipterocarpaceae	10	10	10.80	30.80
4	Nyatoh	*Palaquium* spp.	Sapotaceae	10	10	6.29	26.29
5	Meranti kuning	*Shorea acuminatissima*	Dipterocarpaceae	5	5	7.15	17.15
6	Bebane	*Hibicus tiliaceus*	Malvaceae	5	5	5.23	15.23
7	Terap	*Artocarpus odoratissimus*	Moraceae	5	5	5.05	15.05
8	Medang	*Phoebe bournei*	Lauraceae	5	5	4.56	14.56
9	Kayu sirih	*Piper aduncum*	Piperaceae	5	5	4.05	14.05
10	Blangkan	*Vitex pinnata*	Lamiaceae	5	5	2.56	12.56
11	Mersawa	*Anisoptera* sp.	Dipterocarpaceae	5	5	2.22	12.22

RD: Relative Density; RF: Relative Frequency; RDo: Relative Dominance; IVI = Importance Value Index

Table 3 illustrates 11 species of vegetation at the pole level. Of all of these 11 species, five are the most dominant and have the highest Important Value Index at the pole level, specifically jambu-jambu (*Syzygium* spp.) with the first highest IVI of 93.24%, the second highest IVI is the white Meranti (*Shorea agami*) with a value of 48.84%, the third highest is the red Meranti (*Shorea johorensis*) with an IVI of 30.80%, the fourth is the Nyatoh (*Palaquium* spp.) with an IVI of 26.29%, and the fifth is Yellow Meranti (*Shorea acuminatissima*) with an IVI of 17.15%.

Similar to the sapling stage, primary species have begun to dominate the pole stage, especially from the group of Dipterocarpaceae. Meranti putih (*Shorea agami*) has the second highest IVI with a value of 48.84%, followed by Red Meranti (*Shorea johorensis*) with an IVI of 30.80% in the third position and Yellow Meranti (*Shorea acuminatissima*) in fifth position with an IVI of 17.15%.

The most recently observed level of plant life was the tree level. The results of the vegetation analysis of tree-level plants are displayed in Table 4 below.

Table 4. Important Value Index for each species at the Tree Level Discovered in the Experimental Plot of Nyadeng Lake

No.	Local name	Scientific name	Family	RD (%)	FR (%)	RDo (%)	IVI (%)
1	Meranti merah	*Shorea johorensis*	Dipterocarpaceae	20	20.83	61.27	102.10
2	Jambu-jambu	*Syzygium* spp.	Myrtaceae	20	20.83	17.40	58.23
3	Meranti Kuning	*Shorea acuminatissima*	Dipterocarpaceae	8	8.33	3.71	20.04
4	Meranti putih	*Shorea agami*	Dipterocarpaceae	8	8.33	2.56	18.89
5	Medang	*Phoebe bournei*	Lauraceae	8	4.17	1.67	13.84
6	Kayu gubal	Unidentified	Unidentified	4	4.17	3.27	11.44
7	Terap	*Artocarpus odoratissimus*	Moraceae	4	4.17	3.25	11.42
8	Ulin	*Eusideroxylon zwageri.*	Lauraceae	4	4.17	1.74	9.91
9	Dara-dara	*Dehaasia caesia*	Lauraceae	4	4.17	1.74	9.91
10	Mata kucing	*Dimocarpus* sp.	Sapindaceae	4	4.17	1.49	9.66
11	Kapur	*Dryobalanops* sp.	Dipterocarpaceae	4	4.17	1.38	9.55
12	Jelutung	*Dyera costulata.*	Apocynaceae	4	4.17	0.64	8.81
13	Binuang	*Duabanga moluccana*	Lythraceae	4	4.17	0.58	8.75
14	Dungun	*Heritiera littoralis*	Sterculiaceae	4	4.17	0.53	8.70
15	Daun emas	Unidentified	Unidentified	4	4.17	0.50	8.67

RD: Relative Density; RF: Relative Frequency; RDo: Relative Dominance; IVI = Importance Value Index

Table 4 illustrates the presence of 15 different kinds of tree-level vegetation. Of these 15 types, five types of tree-level vegetation are dominant and have the highest Important Value Index at the tree level. Red Meranti (*Shorea johorensis*) has the highest IVI at 102.10%, followed by jambu-jambu (*Syzygium* spp.) at 58.23%, Yellow Meranti (*Shorea acuminatissima*) at 20.04%, White Meranti (*Shorea agami*) at 18.89%, and Medang (*Phoebe bournei*) at 13.84% respectively.

Tree-level vegetation is still dominated by plants that are part of the Dipterocarpaceae family, red Meranti (*Shorea johorensis*) with the maximum IVI (102.10%); Yellow Meranti (*Shorea acuminatissima*) with an IVI of 20.04%; and White Meranti (*Shorea agami*) with an IVI of 18.89%. The dominant species have high values regarding both density and frequency. The particular type of *Syzygium* spp., which has the greatest number of species in the field compared to other types, is also equitably distributed in almost all observation plots and has a high density. IVI value is dependent on population density, frequency, and dominance. The greater a species' IVI, the higher its dominance in communities where it grows up.

Several tree species is dominant in primary and logged-over forest observation sites at each growth stage. Determining a dominant species is based on an index that is a combination of three values: density value, frequency value, and dominance value. A dominant species refers to a species that is abundant, evenly distributed, and has a large diameter in the area in question, which is highly accurate. A species is prevalent in a community if it utilizes more of the available resources than other species.

Dominant species are those that are capable of utilizing their environment more effectively than other species in the same location. In forest vegetation, the species with the highest IVI value is dominant. A species is considered important if the IVI value for seedlings and saplings is ≥10% and for poles and trees ≥ 15% [14].

Infiltration is the process by which rainfall penetrates the soil via capillary and gravitational forces, allowing water to penetrate deeper into the soil. Infiltration is also defined as water movement into the earth through soil and rock fissures and pores toward the groundwater table.

3.2. The Capacity of Vegetation to Promote the Infiltration Process

Soil water content can be affected by vegetation density in a given area. The following table illustrates vegetation density at the study site.

Table 5. Individual Vegetation Density in Research Sites

No.	Plant stages	Individual Density in Each Plot (Individu.Ha^{-1})					
		1	2	3	4	5	6
1	Seedling	100,000	390,000	90,000	150,000	150,000	380,000
2	Sapling	7,200	1,600	2,800	7,600	2,400	3,200
3	Poles	300	200	600	400	400	200
4	Trees	17	13	29	21	46	8
	Total	107,517	391,813	93,429	158,021	152,846	383,408

The individual densities in the study sites at the seedling, sapling, pole, and tree levels are shown in Table 5. The density of vegetation affects the rate of infiltration. Due to the presence of gravitational potential, infiltration is the process of water percolating vertically into the soil. Several physical factors influence infiltration, including soil type, soil density, soil moisture, and the plants that grow on the soil. The infiltration rate in the soil is decreasing as soil moisture levels rise.

Infiltration is the process by which rainwater penetrates the soil due to capillary and gravitational forces so that water can penetrate deeper into the soil. Infiltration refers to water movement into the earth through soil and rock cracks and pores toward the groundwater table. Increasing groundwater requires vegetation because the roots of vegetation influence the absorption or transmission of water through the soil. Thus, vegetation's effect on the infiltration rate can be observed. Figure 5 illustrates the infiltration rate in each research plot.

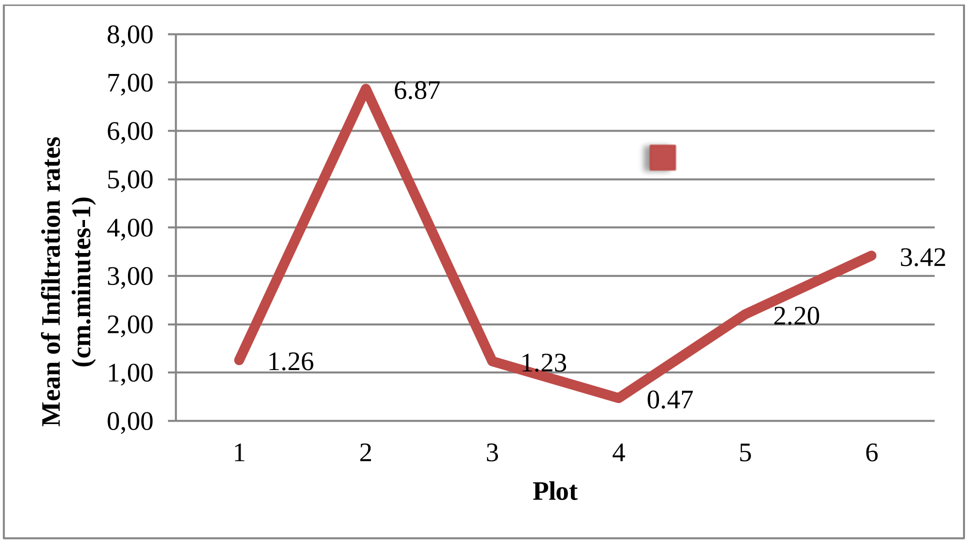


Figure 5. The Average Rate of Infiltration in Each Research Plot

Figure 5 illustrates the highest infiltration rate in plot 2 with a value of 6.87 cm.minutes^{-1} with vegetation density of various levels, the first level beginning with the seedling density of 390,000 individuals.Ha^{-1}, followed by the sapling density of 1,600 individuals.Ha^{-1}, the pole density of 200 individuals.Ha-1, and the tree density of 13 individuals.Ha^{-1}. In the fourth plot, the infiltration rate is the lowest at 0.47 cm.minutes^{-1}, and the seedling density is 150,000 individuals.Ha^{-1}, the sapling density was 7,600 individuals.Ha-1, the pole density is 400 individuals.Ha^{-1}, and the tree density is 21 individuals.Ha^{-1}. The fourth allocation has a relatively high vegetation density despite having the lowest infiltration rate. This is due to the condition of the land in the part area, where a bowl-shaped basin has formed on the surface of the soil, presumably as a result of the basin's ability to collect water. Below the surface of the basin, so that infiltration is extremely gradual.

The infiltration rate of each observation plot with a distinct decline time interval is depicted in Figure 5. Several factors, including vegetation in the area and the soil texture, can impact the infiltration rate. The factors influencing the infiltration rate are soil texture, soil moisture content, and vegetation. The protection provided by the litter layer to the soil's surface increased the soil's ability to absorb water. Furthermore, differences in vegetation and soil management have the potential to influence soil infiltration [15]. Several structural, physicochemical, and environmental factors, such as soil type, vegetation cover, initial soil moisture condition, soil compaction, etc., affect the infiltration rate. Increasing soil compaction will drastically reduce the infiltration rate [16].

The influence of topography on erosion can be eliminated by excellent ground cover vegetation, such as thick grass and dense forests. Therefore, vegetation is required to increase groundwater, as the roots of vegetation influence the capacity of soil to absorb or transmit water. The growth of plant roots compresses the soil around the roots but causes the pores to enlarge, allowing water to flow slightly farther [17].

The individual densities in the study sites at the seedling, sapling, pole, and tree levels are shown in Table 5. The density of vegetation influences the rate of infiltration. Figure 5 depicts the highest infiltration rate in plot 2 with a value of 6.87 cm.minutes^{-1} and vegetation density of various levels, the first level beginning with the seedling density of 390,000 individuals.Ha^{-1}, followed by the sapling density of 1,600 individuals.Ha^{-1}, the pole density of 200 individuals.Ha^{-1}, and the tree density of 13 individuals.Ha^{-1}. In the fourth plot, the infiltration rate is the lowest at 0.47 cm.minutes^{-1}, and the seedling density is 150,000 individuals.Ha^{-1}, the sapling density is 7,600 individuals.Ha^{-1}, the pole density is 400 individuals.Ha^{-1}, and the tree density is 21 individuals.Ha^{-1}. Despite having the lowest infiltration rate, the fourth allotment has a relatively high vegetation density. This is due to the condition of the land in the part area, where there is a bowl-shaped basin on the surface of the soil, presumably as a result of water deposits caused by the basin. Below the basin's surface, so that infiltration is very slowing down. Figure 6 below illustrates the correlation between infiltration rate and plant density.

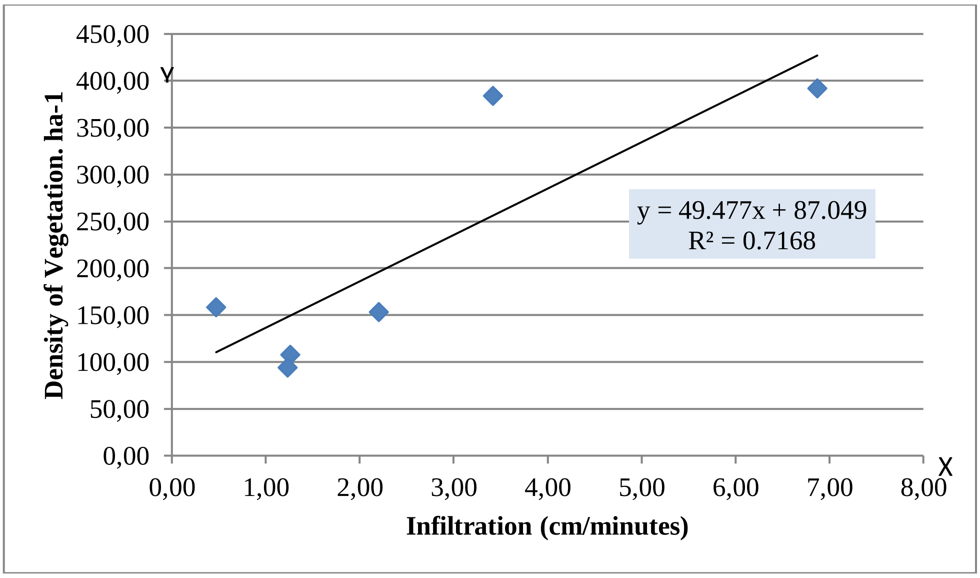


Figure 6. Correlation between infiltration rate and density of vegetation

The above graph is the result of model identification with the X variable (vegetation density) and the Y variable (infiltration), based on the correlation category 0.00-0.199 (very low); 0.20-0.399 (low); 0.40-0.599 (medium); 0.60-0.799 (strong); 0.80-1.00 (very strong). According to the estimation results, the effect of density on the infiltration rate has a constant value of (a) = 87.049 and a positive regression coefficient of (b) = + 49.477, indicating that the value of the infiltration rate will increase as the density of vegetation increases. The coefficient of determination (R2) can be calculated by squaring the correlation coefficient. Based on the above results, the coefficient of determination (R2) = 0.7168. A coefficient of determination of 72% indicates that the presence of vegetation determines 72% of the infiltration capacity, while the rest (28%) is affected by other variables. Thus, it could be justified to classify the correlation between infiltration and vegetation density as strong. The correlation between plant age or plant stage and infiltration rate was positive [18]. In addition, the level of plant life influences the infiltration rate because of the differences in the soil's root layer.

The presence of aboveground plant growth influences the infiltration rate. The roots of plants offer the ability to increase the porosity of soil, consequently promoting water infiltration into the soil structure. The roots of plants have the ability to contribute to the stabilization of soil structure. The foliage and stems of plants can retain rainwater prior to its contact with the ground (known as interception), thereby mitigating the intensity and consequences of rainfall on the soil. The accumulation of fallen leaves and plant twigs on the ground, known as the litter layer, can absorb precipitation and mitigate evaporation. The presence of a litter layer has the potential to serve as a protective barrier against soil erosion while simultaneously contributing to an increase in soil organic matter content. Hence, one might argue that the presence of soil vegetation can enhance the water penetration rate through mechanisms such as increasing soil capacity and permeability, mitigating the severity and consequences of rainfall, and sustaining soil moisture levels.

Accordingly, it is known that the higher the density of vegetation, the greater the infiltration rate. A high and diverse vegetation density can improve the soil's physical conditions for infiltration. Due to the availability of organic matter and environmental improvements, a closer canopy cover promotes an increase in soil surface biological activity. Crown thickness, crown area, and vegetation density affect the effectiveness of vegetation in mitigating runoff and erosion. The importance of vegetation can inhibit the saturated hydraulic conductivity of soil, suggesting that increasing the erodibility of soil can inhibit movement development, which in turn hinders the development of macropore flow [19].

By dissipating the kinetic energy of rainfall through the crown, branches, and stems, vegetation plays a significant role in shielding the soil from its direct impact. The litter that it drops will form humus, which is useful for increasing the soil's infiltration capacity. Indirectly, the condition of the various layers or strata of the canopy in mixed stands is also responsible for the high infiltration rate. This is supported by the assertion that the presence of trees increases the soil's capacity to absorb water, thereby increasing infiltration and soil permeability [20]. The influence of plant species vastly improves predictions of infiltration capacity compared to those that only depend on physical factors [21].

4. Conclusion

The coefficient of determination, with a value of 72%, indicates that vegetation influences the infiltration ability to a significant degree. Therefore, there exists an intense connection between infiltration and vegetation density. Soil vegetation can increase the water infiltration rate by increasing soil capacity and permeability, reducing the intensity and impact of rainwater, and maintaining soil moisture.

A high density of vegetation within a field will lead to a substantial quantity of organic matter being deposited into the ground, thereby yielding a favourable impact on the pore space of the soil. As a result, the soil's infiltration rate will be increased. Compared to tree species with deep roots, the ability of understory plants to absorb and retain water and form channels for water to penetrate the soil is very low.

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