Majority Science Journal (MSJ) Vol. 3 No. 4, November 2025
P-ISSN: 0000-0000; E-ISSN: 3025-1990
Available : https://jurnalhafasy.com/index.php/msj DOI: https://doi.org/10.61942/msj.v3i4.499

HYDROLOGICAL ANALYSIS OF EACH LAND USE IN THE JOMPI RIVER WATERSHED, MUNA REGENCY

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Inputed : October 10, 2025 Revised: October 30, 2025
Accepted : November 20, 2025 Published : November 30, 2025

Abstract
This study analyzes the variation of infiltration rates across different land-use types in the upper watershed of the Jompi River Basin, Muna Regency, as an effort to understand hydrological responses to land-use change. Forest ecosystems play a crucial role in regulating water balance through enhanced soil porosity and organic matter accumulation, whereas land conversion often reduces infiltration capacity and increases surface runoff. Using a quantitative cross-sectional design, field measurements were conducted from August to October 2023 on four dominant land-use categories—forest, agriculture, plantation, and settlement. Infiltration was measured using a double ring infiltrometer, while soil physical properties were analyzed through laboratory testing. The results indicate substantial variation in infiltration rates: plantations recorded the highest average value at 24.23 cm/hour, followed by secondary forest at 22.38 cm/hour, settlements at 19.23 cm/hour, and agricultural land at 16.59 cm/hour. These differences are strongly influenced by soil texture, organic matter, and porosity conditions. The findings demonstrate that land-use changes significantly alter soil hydrological behavior, highlighting the need for sustainable watershed management strategies. Further research is recommended to incorporate additional soil parameters such as permeability and to employ alternative infiltration models and rainfall simulators for improved measurement accuracy.

Keywords : *Infiltration Rate, Land Use, Watershed*

Citation :
Zainun M, Yasin A, Hasani U.O, S. 2025. HYDROLOGICAL ANALYSIS OF EACH LAND USE IN THE JOMPI RIVER WATERSHED, MUNA REGENCY. *MSJ: Majority Science Journal*, *3*(4), 282-291.

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P-ISSN: 0000-0000; E-ISSN: 3025-1990
Available : https://jurnalhafasy.com/index.php/msj DOI: https://doi.org/10.61942/msj.v3i4.499

1. Introduction

Forests, as defined in Law Number 41 of 1999, constitute a unified ecosystem consisting of expanses of land dominated by biological resources in the form of trees that have an inseparable ecological relationship with one another (Candra et al., 2023). Conceptually, forests are not only understood as biophysical entities, but also as ecological systems that require sustainability, harmony, and relational balance between humans and their environment (Supriyadi, 2013). Within this framework, the function of forests goes beyond simply providing environmental services; forests act as water regulators that maintain hydrological stability through high infiltration capacity, increased soil porosity, and surface flow dampening by litter and understory vegetation (Kartosapoetra, 2015). Thus, forests can be viewed as ecological entities that have a long-term regulatory function on water dynamics in a landscape.

Hydrologically, infiltration is a fundamental process in the water cycle, as it determines the proportion of rainfall that infiltrates into the soil, is temporarily stored in the surface layer (topsoil), or flows as surface runoff. Infiltration is influenced by various physical properties of the soil, such as texture, structure, aggregate stability, porosity, and environmental variables such as slope and land use (Asdak, 2010). The infiltration mechanism itself involves three interrelated processes: water infiltration through soil pores, water retention within the soil profile, and lateral and vertical water flow toward deeper soil layers (Arianto et al., 2021). High infiltration in forested areas is due to looser soil structure, higher organic matter content, and the presence of litter, which slows runoff, allowing water more time to infiltrate into the soil. Therefore, changes in land cover conditions have the potential to significantly impact the infiltration capacity and hydrological function of an area.

Land use change is an increasingly intense ecological phenomenon in various regions of Indonesia. Population growth, settlement expansion, land conversion for agriculture and plantations, and socio-economic changes have led to the conversion of forest land to other, more intensive uses. This conversion fundamentally alters the biophysical characteristics of the land through reduced vegetation biomass, soil compaction, and soil structure degradation, resulting in reduced infiltration capacity and increased surface runoff. From a watershed hydrology perspective, these conditions can amplify fluctuations in river discharge, reduce groundwater availability, and increase the risk of seasonal flooding and drought.

The theoretical framework for watershed management positions land cover as a key element in maintaining the stability of hydrological systems. Vegetation changes, although local, can have cumulative impacts at the watershed scale through changes in soil structure, reduced water-holding capacity of vegetation, and increased surface runoff. Therefore, assessing infiltration capacity across various land uses is an important approach to understanding the hydrological response mechanisms of a watershed and evaluating its ecological stability.

In this context, the Jompi Watershed in Muna Regency is one area that exhibits intense land cover changes. This area covers 2,288.18 hectares and serves as a protected forest that supports the Jompi spring. This spring is classified as a perennial spring, a type of spring that produces year-round flow and has low sensitivity to seasonal fluctuations (Verbrianti et al., 2019). The continuity of the spring's hydrological function is highly dependent on the condition of the catchment area, which is covered by diverse vegetation. However, ecosystem degradation due to land use changes—including the conversion of forest to plantations, agriculture, and settlements—has altered soil and vegetation characteristics, potentially reducing infiltration capacity in the area.

Land cover transformation in the Jompi watershed includes decreased vegetation density, soil compaction due to anthropogenic activities, and reduced litter that serves as an infiltration buffer. These changes have direct implications for water flow patterns, increasing surface runoff, reducing the soil's water-holding capacity, and increasing fluctuations in river discharge. These conditions, in turn, can impact land productivity and the well-being of communities dependent on the stability of water resources (Harjianto, 2016). Therefore, an empirical study of infiltration rates based on differences in land use in the Jompi watershed is

P-ISSN: 0000-0000; E-ISSN: 3025-1990
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urgently needed to gain a more comprehensive understanding of the region's hydrological conditions.

Based on these conditions, research is needed that specifically assesses variations in infiltration rates across land uses in the Jompi Watershed as a scientific basis for sustainable watershed management. This research aims to provide up-to-date information on infiltration capacity across various land uses, thus supporting future soil and water conservation planning and hydrological degradation mitigation efforts.

2. Method

This study used a quantitative approach with a cross-sectional design to analyze variations in infiltration rates across various land uses in the upstream Jompi Watershed (DAS). This design was chosen because it allows for measurement of hydrological characteristics over a single observation period without requiring tracking of changes over time. The study was conducted from August to October 2023 in the upstream Jompi Watershed, Muna Regency, which was chosen as the research location because it is a water conservation area experiencing land cover changes.

The study population covered the entire upstream area of the Jompi Watershed, covering 2,288.18 ha. The sample was determined using purposive ground-based sampling, selecting observation points based on representative land use categories, including forests, plantations, agriculture, and settlements. Each sample point was selected based on land cover uniformity and accessibility for instrument installation.

Primary data were obtained through direct measurements of infiltration rates using a 4-inch Double Ring Infiltrometer and by recording the coordinates of observation points using GPS. A graduated ruler, stopwatch, and soil auger were used to support the measurements and the collection of intact soil samples for laboratory analysis. Secondary data were obtained from publications, agency reports, and academic references related to infiltration, soil physical properties, and watershed conditions.

Infiltration measurements were performed by installing infiltrometers concentrically on the soil surface, filling both rings with water, and recording the decrease in water level at specific intervals until a constant infiltration rate was reached. Each location was measured twice to ensure data reliability. Soil samples were then analyzed to determine texture, structure, porosity, organic matter, bulk density, and particle density.

The data were analyzed in two stages. First, the infiltration rate was calculated using the Horton Model to obtain the initial infiltration capacity, constant, and shrinkage constant. Second, soil physical properties were analyzed to identify the relationship between soil characteristics and infiltration values for each land use. The results of the analysis were used to interpret the effect of land cover changes on the hydrological conditions of the Jompi Watershed.

3. Results and Discussion

This section presents the results of the analysis of infiltration rates and soil physical properties in various forms of land use in the upstream area of the Jompi River Basin (DAS) along with their scientific interpretation within the framework of hydrology and land ecosystem dynamics. The research results are presented systematically to show differences in infiltration characteristics between land uses, then analyzed critically by referring to infiltration theory, soil biophysical characteristics, and empirical findings from previous studies. The discussion is conducted to interpret the relationship between land biophysical conditions, surface hydrological processes, and soil infiltration capacity, so as to obtain a comprehensive understanding of the implications of land use changes on the hydrological stability of the Jompi Watershed.

Analysis of Soil Physical Properties

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The results of the analysis of the physical properties of the soil for various uses in the upstream area of the Jompi watershed were obtained as follows:

Table 1. Elemental composition of sampling sites

NO	Land Use	Average Infiltration Rate (Cm/Hour)	Class
1	Plantation	24. 23	Very fast
2	Secondary Forest	22. 38	Fast
3	Settlement	19. 23	Currently
4	Agriculture	16. 59	Slow

Based on the results of laboratory analysis of the physical properties of the soil, it shows that settlements are classified as porous porosity class with a percentage of 0.66%, having a dusty sandy clay texture with 2.32% organic material, while the use of secondary forest land is classified as porous porosity class with a porosity percentage of 0.74%, having a clayey dusty sand soil texture, 3.96% organic material, agricultural land use is classified as good porosity with a porosity percentage of 0.61%, having a dusty clayey sand soil texture, 2.50% organic material, plantation land use is classified as a less good porosity class with a porosity percentage of 0.54%, having a clayey dusty sand soil texture, 1.78% organic material. Measurement of infiltration rate and soil physical properties was carried out in the Jompi Watershed, Muna Regency, the submission of the infiltration rate using a double ring infiltrometer.

Infiltration Rate Analysis

The measurement results that have been used on various types of land use in the Jompi Watershed are as follows.

Table 2. Infiltration Rate in Various Types of Land Use in the Jompi Watershed

No	Land Use	Average Infiltration Rate	Soil Texture	Organic Materials	Porosity
1.	Forest	22.38	Dusty Clay	2.23%	0.74%
2.	Agriculture	16.59	Dusty Clay Loam	3.96%	0.66%
3.	Plantation	24.23	Dusty Look	2.50%	0.61%
4.	Settlement	19.23	Dusty Clay	2.23%	0.74%

BeBased on the average infiltration rate for various 4 land uses, the highest value is in forest land, namely cm/hour with a medium infiltration rate class category and the lowest value is in land with a slow infiltration rate class category.

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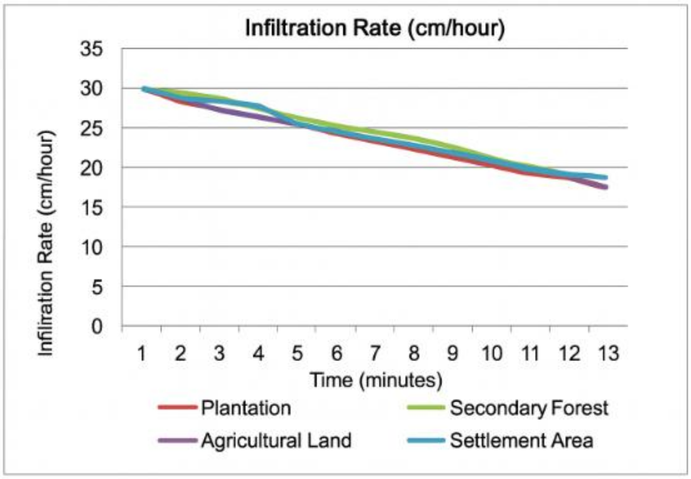

Figure 1. Infiltration Rate Graph (cm/hour)

BeFigure 1 shows that the infiltration rate in various land uses varies over time. In this case, land use is defined as the interval (intervention) of humans on the land to fulfill their material and spiritual needs. The results of the infiltration rate analysis using the Horton method in the upper reaches of the Jompi watershed indicate that plantations are the land use with the highest infiltration rate capacity, namely 24.23 cm/hour, with a moderate infiltration rate classification. This is because plantations have good ground cover vegetation compared to other land uses.

The results of the infiltration rate analysis using the Horton model in the Jompi River Basin (DAS) in Muna Regency, show that plantations are the land use with the highest infiltration rate capacity, namely 24.23 cm/hour with a medium infiltration rate classification. This is because plantations have good ground cover vegetation compared to other land uses. This is in line with research conducted by Mujiyani. A. (2022), where forest land use is more capable of absorbing more water compared to other types of land use.

PePlantations have high water holding and infiltration capacities, therefore surface runoff is rare on plantation land. The high infiltration rate in plantations is due to the presence of litter. Decomposed litter can loosen the soil, allowing water to easily penetrate. Litter and undergrowth can also temporarily retain rainwater. When the rain stops, the retained water evaporates or infiltrates into the soil. This process can restrain or reduce the rate of surface runoff. When it does occur, high rates of surface runoff are limited to areas where the soil surface has been disturbed, such as fires that have cleared the forest floor of litter and undergrowth. Because of the numerous pores in the soil, most of the water flows as rapid flow, contributing to peak river flows (Widiyanto, 2010).

LaInfiltration rates also depend heavily on soil type and its ability to absorb water. Sandy soils generally allow water to pass through quite easily, while clay soils restrict water movement (Karnisah et al., 2017). Plantations with silty clay loam soil texture absorb more water than other land uses. This is in line with research conducted by Mujiyani, A (2022), whose results showed that the infiltration rate in forest land use is relatively high with silty clay loam soil texture compared to other land uses. In plantation land with silty clay loam texture, organic matter forms aggregates that can increase the number of macropores and facilitate aeration, which increases the soil's ability to pass water. Plantation land has vegetation as surface cover in the form of hard trees whose roots can penetrate the soil and form pores between soil particles, making it easier for water to infiltrate into the soil. In addition, the litter that is formed is thick enough to protect the surface of the soil so that water is retained and has more time to seep into the soil and also makes the soil fauna in it get enough food so that the soil becomes loose.

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PSoil porosity also influences the infiltration rate. High soil porosity in plantations is due to the lack of tillage activities, thus preventing soil compaction. Furthermore, the root system in forest land significantly improves soil pores, thus increasing the infiltration rate. This is in line with research conducted by (Nuraida et al., 2021). High soil porosity in plantations is due to infrequent tillage, thus preventing soil compaction. The opposite occurs in plantation and agricultural land uses, where these land uses have lower porosity than forests because plantations and residential areas have undergone tillage, which causes the destruction of soil aggregates and increases soil density, which inhibits the infiltration rate.

The analysis of the infiltration rate on agricultural land showed an average infiltration rate of 16.59 cm/hour, classified as a rather slow infiltration rate. This is influenced by the physical properties of the soil and the type of vegetation growing on the surface. Based on the analysis of the physical properties of the soil, the agricultural land has a dusty clay loam texture, organic matter content of 2.50, and a porosity percentage of 0.61%, classified as very poor. Suprayoga (in Ali and Asmirullah, 2020) stated that the organic matter content comes from leaves, twigs, and branches that fall on the surface of the soil, and dead roots in the soil will provide organic matter input.

FaThe dominant physical property of soil affecting infiltration is soil texture. Sandy clay loam textures have lower infiltration rates than sandy loam textures. This indicates that the coarser the soil texture, the faster water infiltrates, and conversely, the finer the soil texture, the slower water infiltrates. Furthermore, differences in soil texture composition between sand, silt, and clay will also result in different infiltration rates (Yunagardasari et al., 2017).

Forest land has a porosity value of 0.66% with a very poor porosity class. This is influenced by the texture of the silty clay soil in the silty clay soil, the porosity is very diverse because the soil alternately expands, contracts, clumps, disperses, solidifies, and cracks. This is as stated by Bintoro et al., (2017), that in general, forest land in some land uses has a relatively very poor soil porosity value, one of which is forest land. This shows that the easier the soil absorbs water, the greater the potential for permeability to arise, the higher the porosity.

The results of the infiltration rate analysis on plantation land use showed an average infiltration rate of 24.85 cm/hour with a moderate infiltration classification. The results of the analysis of the physical properties of the soil on the plantation land showed that it had a dusty clay loam texture, organic matter with a value of 1.78% and very poor soil porosity with a porosity percentage of 0.54%.

PVery poor porosity indicates that the soil does not have the ability to absorb water well so it easily releases water. Soil with very poor porosity is not suitable for all types of land use. This is in line with research conducted by Rizal, et., al (2022) Soil porosity is influenced by organic matter content, organic matter increases the porosity value and affects the soil pore space. Pores in good porosity have a large number so that it makes it easier for water to absorb into the soil.

The analysis of the infiltration rate in the settlement showed an average infiltration rate of 19.23 cm/hour, classified as rather slow. The analysis of the physical properties of the settlement's soil showed a dusty clay texture, 2.23% organic matter, and a very poor porosity class with a porosity of 0.74%. In addition to soil texture, high organic matter is one of the factors that influence infiltration in a land area.

4. Conclusions and Suggestions

The results of the study indicate that the infiltration rate across various land uses in the Jompi Watershed (DAS) in Muna Regency varies significantly. Plantation land use recorded the highest average infiltration rate, at 24.23 cm/hour, followed by secondary forest at 22.38 cm/hour. Meanwhile, residential areas showed an infiltration rate of 19.23 cm/hour, and agricultural land use had the lowest infiltration rate, at 16.59 cm/hour. These findings indicate that the biophysical characteristics of each land use have different effects on the soil's ability to absorb water, so that changes in land cover have the potential to affect the overall hydrological stability of the Jompi Watershed.

P-ISSN: 0000-0000; E-ISSN: 3025-1990
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Based on these results, further research is recommended to expand the analysis parameters by adding other soil physical property variables, such as permeability, to obtain a more comprehensive hydrological picture. Furthermore, the use of alternative infiltration models other than the Horton Model, as well as the use of rainfall simulation methods such as a constant-head rainfall simulator, is expected to provide more in-depth comparisons of results and strengthen the validity of infiltration rate measurements across various land uses.

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