PAPER • **OPEN ACCESS**

Water infiltration rate of illegal mining sites in Bukit Soeharto Forest Park, East Kalimantan Province

To cite this article: M Rafi *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1282** 012025

Water infiltration rate of illegal mining sites in Bukit Soeharto Forest Park, East Kalimantan Province

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Abstract. Infiltration is a component of the hydrological cycle which functions as a source of groundwater, minimizing flooding and distributing water evenly throughout the rainy and dry seasons. This study aims to determine the rate of water infiltration or infiltration and permeability values in 2 (two) land conditions for ex-illegal mining sites, namely at KM 68 and KM 48, and the location of undisturbed land in KM 54 secondary forest area of the Bukit Soeharto Forest Park (BSFP). The research method used a double ring infiltrometer, then tested at the Kalimantan Bioresources Laboratory. Infiltration rate shows that secondary forest area of the KM 54 location was 275.2 mm/hour which was included in the very fast class, while in the former mining sites KM 68 and KM 48 respectively it was 244.6 mm/hour, and 145.7 mm/hour which is included in the fast class. Laboratory analysis shows that the soil permeability value in the secondary forest area of KM 54 location was 6.41 cm/hour which was included in the rather fast class, while the permeability value in the ex-mining land area of KM 68 and KM 48 respectively was 6. 26 cm/hour and 3.66 cm/hour which are included in the medium class. This is due to the physical soil properties such as soil texture, soil structure, bulk density, and soil porosity which are the factors that cause differences in infiltration rates in several land conditions.

1. Introduction

Environmental degradation in Indonesia is a never-ending issue to be discussed considering that development does not only generate benefits but also carries risks [1, 2]. In East Kalimantan Province there are natural resources that are one of the conservation areas, namely the Bukit Soeharto Grand Forest Park (BSFP) which has several potential natural resources but, in its development, has experienced environmental damage and land conversion. The potential natural resources referred to include commercial timber, coal, quite a lot of vegetation, and high biodiversity, namely flora and fauna which are endemic to the island of Kalimantan [3].

The presence of coal mining in the BSFP can cause ecological challenges, including damage, erosion, the landscape, loss of soil fertility, sedimentation, threats to biodiversity, decreased water quality, and decreased air quality [2, 4, 5]. [6] further stated that all these problems ultimately resulted in one or a combination of the following (1) decreased diversity and population of flora and fauna; (2) an increase in open and damaged/degraded areas and conversely a reduction in forest as a due to coal mining; (3) decreased natural aesthetic value of the BSFP: (4) decreased quality and quantity of wildlife habitats. Land clearing continues to be carried out to accommodate the need for land that will be used to build supporting structures in the future in line with technological developments and advances. Implementation of development that ignores the impact of land clearing without being balanced with efforts to preserve the environment will result in a decrease in land use, especially water management.

Coal mining activities in the Bukit Soeharto Forest Park (BSFP) area are increasing from year to year. The amount of land open for coal mining continues to grow. Landscape degradation, loss of soil fertility, sedimentation, water pollution and erosion, are the impacts of coal mining in the BSFP (2). Besides that, the main problem due to mining activities is the loss of vegetation and land cover and changes in the hydrological system which will affect soil morphology, post-mining water quality, and soil capacity as a hydrological system [7]. Vegetation in the BSFP has a role in the process of absorbing groundwater. The BSFP has become a support in the process of groundwater absorption to maintain the preservation of clean water sources in addition to the construction of the transfer of the State Capital in East Kalimantan. The research objective was to determine the differences in infiltration rates on different land conditions and to determine the connection between infiltration rates and soil physical properties in different land conditions in the BSFP area. Research on water absorption in the BSFP is important because there is a need for continuous action to determine the condition of the BSFP so that its sustainability is maintained and its function as hydrological processes.

2. Materials and Methods

2.1. Site description

The locations used for research include disturbed land on former illegal coal mining land, namely at KM 68 and KM 48, while undisturbed land is at KM 54.

a. Former Illegal Coal Mining Land KM 68

The location points for collecting data on infiltration, permeability and soil samples is the former illegal coal mining area KM 68 in Batuah Village, Loa Janan District, which is located at 117°4ʹ44.557″ E - 0°48ʹ36.638″ S. Based on the map of the mine opening area resulting from the interpretation of Landsat imagery in 2015, this area is already open to illegal coal mining activities. The former illegal coal mining area KM 68 is estimated to have been abandoned for more than 5 years considering the condition of succession in the form of reeds, grass, shrubs, and several revegetation trees, namely Acacia trees (*Acacia mangium*) and there are former mining holes.

b. Former Illegal Coal Mining Land KM 48

The location points for collecting infiltration, permeability and soil sample data were on the former illegal coal mining area KM 48 in Bukit Merdeka Village, Samboja District, which is located 117°6ʹ28.956″ E - 0°53ʹ48.557″ S. Based on the map of the mine opening area resulting from the interpretation of Landsat imagery in 2015, this area is already open to illegal coal mining activities. The former illegal coal mining area of KM 48 is estimated to have been abandoned for less than 5 years considering the condition of the succession which is still open land and only a few revegetation trees were found, namely Acacia trees (*Acacia mangium*), Sengon trees (*Albizia chinensis*) and there are former mining pits.

c. Undisturbed Land at KM 54

The location points for collecting data on infiltration, permeability and soil samples was on undisturbed land KM 54 in Bukit Merdeka Village, Samboja District, which is located 117°00ʹ59.9″ East Longitude - 0°52ʹ36.0″ South Latitude. This location is a location that has dense land cover and is dominated by the vegetation types of Damar (*Agathis dammara*), Jabon (*Neolamarckia cadamba*), Meranti (*Shorea* sp), Mahogany (*Swietenia mahagoni*), Ironwood (*Eusideroxylon zwageri*) and Sengon (*Albizia* *chinensis*). The dominant soil type in this research location is district cambisol, 44.95% chromic podzolic with sandstone as the parent material.

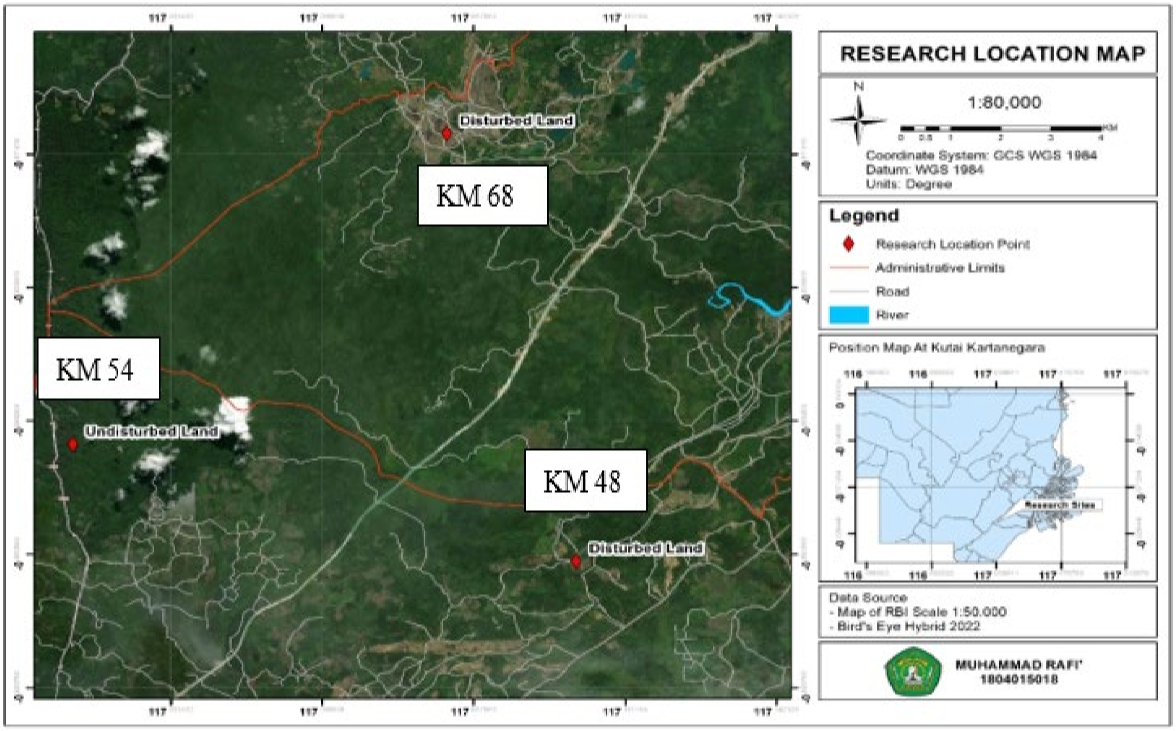

Figure 1. Map of the research point area on BSFP

Figure 2. Conditions of succession in the ex-mine area of Kilometers 68

Figure 3. Conditions of succession in the ex-mine area of Kilometers 48

2.2. Research procedure

This study uses materials and equipment, namely double ring infiltrometer and ring sample. This research began with conducting field observations to determine measurement points for each land condition, namely former illegal coal mining land and undisturbed land. After that, a double ring infiltrometer was used to measure the infiltration rate, and soil samples were taken at each measurement point to analyses the soil's physical properties and permeability values in the laboratory. The physical parameters observed were soil structure, bulk density, soil porosity, and soil texture.

2.3. Processing and analysis of data
Results of research infiltration rate measurements in the field and results of soil physical analysis in the laboratory are tabulated and described graphically and analysed descriptively qualitatively and quantitatively.

3. Results and Discussion

3.1. Infiltration rate
Infiltration rate is the process of water seepage from the soil surface to the subsurface which can determine the absorption capacity of an area. Infiltration is a component of the hydrological cycle that functions as a source of groundwater, minimizes flooding, and distributes water evenly throughout the rainy and dry seasons [8]. The measurement results show that the highest infiltration rate is in undisturbed land Kilometers 54 at 275.2 mm per hour, then the second highest infiltration rate is in the former illegal coal mining land Kilometers 68 at 244.6 mm per hour, and the lowest infiltration rate is on Kilometers 48 former illegal coal mining land of 145.7 per hour. In open land, the soil was more likely to meet direct sunlight, causing evaporation which can accelerate the rate of infiltration. This is supported by [9] who state that factors affect the rate of direct infiltration namely bulk density, initial soil water content, fraction clay, and soil porosity. Affect indirect infiltration, namely by forming soil physical properties that can support increased infiltration, strata, tree and canopy density, as well as ground cover plants. This is demonstrated in Kilometers 68 and 48 illegal coal mine land which belongs to the very fast and fast class. The physical properties and permeability of the soil at the study site are also factors that cause differences in infiltration rates in several land conditions. Meanwhile, according to [10], the infiltration rate with a small value indicates that the soil conditions in the area have been saturated and the water saturation will cause water surface and will result in surface runoff. The smaller the infiltration value, the greater the food runoff water. In mining activities, the value of the infiltration rate affects soil conditions besides that affects the water runoff that occurs in the mining area.

Table 1. Infiltration rate at 3 measurement points

No.	Location name	Infiltration rate (mm/hour)	Class
1	undisturbed land Kilometers 54	275.2	very fast
2	land of former illegal coal mine Kilometers 68	244.6	fast
3	land of former illegal coal mine Kilometers 48	145.7	fast

3.2. Permeabilities
The measurement results show that the highest permeability value is in undisturbed land Kilometers 54 with a value of 6.41 cm/hour which belongs to the rather fast class and the second highest permeability is in the land of former illegal coal mining Kilometers 68 with a value that is not much different by 6.26 cm/hour which is included in the medium class and the lowest permeability is found in Kilometers 48 land of former illegal coal mining land with a value of 3.66 cm/hour which is included in the medium class. Several affecting soil characteristics of soil permeability are unit weight, porosity, soil texture, pore size distribution, and aggregate stability [11, 12, 13, 14, 15].

Table 2. Permeability values at 3 measurement points

No.	Location name	Permeability (cm/hour)	Class
1	undisturbed land Kilometers 54	6.41	rather fast
2	land of former illegal coal mine Kilometers 68	6.26	currently
3	land of former illegal coal mine Kilometers 48	3.66	currently

3.3. Soil physical properties

3.3.1. Soil density. Soil density is the ratio of volume soil and weight of dry soil and the volume of soil which is an indication of soil density. The denser the soil, the higher the density of lindak which means it is more difficult for water to pass through (16). The bulk density value at the study site has a value of 1.07 gr/cm3 for Kilometer 54 undisturbed land, 1.26 gr/cm^3 for Kilometer 68 land of former illegal coal mine, and 1.34 gr/cm^3 for Kilometers 48 land of former illegal coal mine. Measurement of the combined results of the relationship between the infiltration rate and the specific gravity of the soil turns out to be inversely proportional, that is, the greater the infiltration rate, the smaller the soil-specific gravity [17].

3.3.2. Soil porosity. Soil porosity is closely related to the level of soil density (bulk density). the smaller the porosity of the soil, the denser the soil, and the more difficult it is for water to absorb. Conversely, the easier it is for the soil to absorb water, the greater the porosity of the soil [18, 19]. Soil porosity values at 3 measurement points of undisturbed land Kilometers 54, land of former illegal coal mine Kilometers 68, and Kilometers 48 respectively were 58.51%, 51.20%, and 48.26%. The highest soil porosity value is at Kilometer 54 undisturbed land which is caused by the soil texture which is rich in sand fraction.

3.3.3. Soil texture. [20] stated that characteristic soil physics consists of structure and texture. Soil texture consists of silt, clay, and the size fraction of sand. Basically, related to the state of the larger the pores, the greater the infiltration capacity and the soil pores. The results of the soil sample tests that have been carried out show that the texture of the soil is loamy clay (32% silt, 30% clay, 38% sand) for Kilometers 54 undisturbed land, loamy loam (32% silt, 36% clay, 32% sand) for land of former illegal coal mine Kilometers 68, and dusty clay (65% dust, 27% clay, 8% sand) for land of former illegal coal mine Kilometers 48. Soil dominated by sand will have a lot of macro pores (large), soil dominated by dust will have a lot of meso pores (medium) while those dominated by clay will have micropores [21]. Thus, the soil that has larger pores has an infiltration rate value that is included in the fast class category as shown in undisturbed land Kilometers 54 and land of former illegal coal mine Kilometers 68.

3.3.4. Soil structure. The arrangement of soil particles that form soil aggregates consists of dust, sand, and clay particles bound by organic matter, iron oxidation, and the like. Soil aggregates very in shape, size, and stability. A granular soil structure is a soil structure that is good at passing water, this is shown in the undisturbed land Kilometers 54 and for land of former illegal coal mine land Kilometers 68 which has a granular soil structure so that it has an infiltration rate value that belongs to the very fast class. This is because soil with a high sand content has the property of easily passing water so that it rapidly decomposes organic matter and has good aeration. Soils with massive structures have lower porosity than soils with granular/crumb structures [22]. Furthermore, [23] stated that soil with good structure (granular, crumbs) has an air system well, and nutrients are more readily available and easy to process.

Table 3. Soil physical properties at 3 measurement points

No.	Location name	Soil texture	Soil structure	Bulk density (gr/cm^3)	Porosity (%)
1	undisturbed land Kilometers 54	Clayey clay (32% silt, 30% clay, 38% sand)	granular	1.07	58.51
2	land of former illegal coal mine Kilometers 68	Clayey clay (32% silt, 36% clay, 32% sand)	granular	1.26	51.20
3	land of former illegal coal mine Kilometers 48	Dusty loam (65% silt, 27% clay, 8% sand)	block	1.34	48.26

4. Conclusion

The rate of water infiltration and permeability values at the 3 measurement points tend to vary due to various factors such as available vegetation and soil surface conditions as well as the fraction of the structure of each soil. The infiltration rate class at 3 measurement points is still good because it is included in the category of very fast and fast, However, if left for a long period of time, the land will become critical, so revegetation or replanting efforts are needed to repair and restore damaged and lost vegetation in order to restore the land to its proper function.

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