

## A STUDY OF THE QUALITY OF SOIL INFILTRATION AT THE DOWNSTREAM OF KURANJI RIVER, PADANG CITY

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**ABSTRACT:** The watershed at the downstream of Kuranji river often experience flooding. This is due to the rainfall runoff and the flat condition of the downstream area. Another factor might be due to low soil infiltration rate. The objective of this research was to analyze the quality of soil infiltration at the downstream of Kuranji River's watershed. Research methodology that had been chosen as a field survey. Soil infiltration rate was measured using double ring infiltrometer. Location of soil sample was selected by purposive random sampling and was analyzed at the Department of Soil Science Andalas University. The data was analyzed using Horton formula to identify the capacity and the cumulative soil infiltration rate. The result showed that the area which often inundated and has high soil water table had a low infiltration rate. The results showed that the bulk density factor, clay fraction and dust significantly affect the capacity of soil infiltration. Moreover, bulk density, clay fraction, and dust influence soil infiltration capacity. Areas that have high infiltration capacity are Gunung Sariak, Aie Pacah, Ampang, Kurao Pagang, and Dadok Tunggul Hitam. Other sampling locations have low infiltration rate due to the high soil water table.

*Keywords: Infiltration capacity, Runoff, Watershed, Watertable*

### 1. INTRODUCTION

Water infiltrates the soil through the soil surface. In the ground, water flows in the lateral direction as the flow between (interflow) to springs, lakes and rivers; or vertically, known as percolation to the groundwater. The motion of water in the soil is affected by the force of gravity and the capillary force [1].

A technical report on Infiltration Characteristics of Soils Under Forestry and Agriculture in the Upper Waikato Catchment has been done due to increasing pressure for conversion of forest to agricultural land within the upper Waikato catchment. The study found that the conversion of forest to agricultural land within the upper catchment area to increase the occurrence of flooding, both of peak and intensity of the flood, and also increase erosion and sedimentation [2].

The special work for advanced study in the assessment of the maximum water storage capacity of soils under different land-use and land-management situations in a real river catchment has been done [3]. The study is done by field measurements of infiltration under several land-use and land-management situations. Then, the development of a modeling approach to estimate the maximum potential water storage capacity also proposed. The study found that due to the change in land-use and land-management could reduce the storage infiltration capacity by 17 percent.

The rainwater absorption in the downstream Kuranji river basin is often impaired due to rapidly saturated soils. As a result, the city of Padang is often flooded and inundated causing houses to be flooded (Figure 1). Factors causing the soil is saturated rapidly due to high groundwater level, soil texture is very smooth and layered consequently inhibit the entry of water into the soil. According to Asdak [4] when the rain falls on the surface of the ground some of the water will be retained by the depressed part of the soil, some of it into the soil and some into the runoff. The rainwater that enters the soil fills the pores of the empty soil until the water reaches the field capacity. Furthermore, the water will move more deeply due to the force of gravity into percolation of water to reach the saturated region. Water in saturated regions can also move horizontally due to plant root uptake and capillary forces. Radke and Berry [5] stated that the vertical entry of water into the soil is closely related to the structure or physical and biological characteristics of the soil. Further, other factors that affect water infiltration is a slope, soil texture, land use, land processing, soil water content and soil organic chart. The state of the soil surface and the number of soil pores will determine the volume of water that can enter into the soil [6]. Soil pores that are numerous and interlocked into the deeper soil will increase the rate of infiltration. Includes pore holes made by roots and soil fauna.



Fig.1 Flooded area at Gunung Pangilun, downstream of Kuranji watershed.

The rate of infiltration decreases because of the changing of soil porosity which blocked by fine particles. The fine particles may come from spatter or from mud brought by the flood. Dense soil surface becomes water resist [4, 7]. This study aims to examine the quality of soil absorption in the downstream Kuranji river basin.

## 2. RESEARCH METHODOLOGY

### 2.1 Location and Time of Research

This research was conducted from March to April 2018 at the downstream Kuranji watershed in Padang City, West Sumatra, Indonesia. Based on the geographical position of the study sites are at 00047'21 "to 00055'57" LS and 100020'31 "to 100033'54" BT, with a height of 0 up to 1859 above sea level. Research location is at Aie Pacah 1, Kurao Pagang, Dadok Tunggul Hitam, Aie Pacah 2, Gunung Sariiek, Ampang, Gunung Pangilun, and Korong Gadang (1-8 locations).

### 2.2 Tools and Materials

The tool used in this study is a set of computers with ArcView / ArcGIS program, Microsoft Excel, Global Positioning System (GPS) and infiltrometer. Materials used in this study are Digital Elevation Model (DEM) data in the form of Triangulated Irregular Network (TIN), a map of Kuranji watershed administration, land use map, soil type map, and monthly rainfall data.

### 2.3 Data Collection

The data collected were 1) soil parameters (texture, soil structure, soil permeability, and soil effectiveness), 2) infiltration capacity measured directly in the field using double ring infiltrometer (Figure 2). Soil sampling is done purposively (purposive sampling), which is based on the consideration of spatial distribution and areas that often get flooded during the rain at 8 locations. The examples of soil taken are examples of intact soils and disturbed soil samples. The soil samples were

used for the analysis of soil physical characteristics (BD/bulk density, TRP/total pore space, organic C, permeability, texture, etc.), and soil samples were disturbed for soil organic C-analysis. Infiltration measurements were performed at each location of the soil sampling point.



Fig. 2 Measuring soil infiltration capacity on the field

Figure 3 and Figure 4 shows laboratory analysis of dust fraction.



Fig 3. Soil texture analysis

### 2.4 Data Calculation and Analysis

1. The soil texture parameters were analyzed by using triangle texture to determine the soil texture class.



Fig 4. Dust fraction analysis using a shaker

2. Hydraulic conductivity set by using the Deboodt method using Darcy's legal principle.
3. Establish infiltration capacity using double ring infiltrometer, and data are analyzed using Horton formula ie  $F = f_c + (f_0 - f_c) e^{-kt}$ .
4. Analyze the result of soil physics characteristics from a laboratory in statistical analysis with correlation analysis and Principal Component Analysis (PCA) or main component analysis with Minitab 17 software. So it can be selected the main factor most determine infiltration capacity at Kuranji downstream basin.

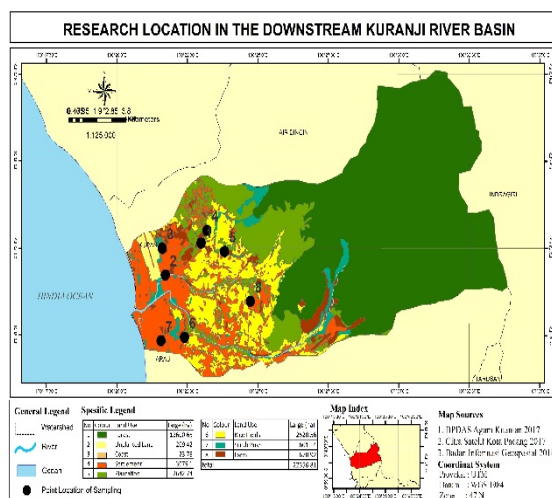


Fig.5 Research location in the downstream Kuranji watershed.

### 3. RESULT AND DISCUSSION

#### 3.1 The Main Factors of Soil Physical Characteristics That Affect the Infiltration Capacity

The results of the principal of component analysis (PCA) [8] on soil physical characteristics, showed that eigenvalue is greater than one ie. PC1 (principal component1) and PC2 (principal component2). On the PC most variable values affect the infiltration capacity is greater value on PC1 is bulk density (BD) 0.417, clay fraction 0.416. While on PC2 is 0.445 dust fraction (Table 1). Based on this selected variable hence can be made graph relation between variable and infiltration capacity.

Table 1 Determination of the main component

Eigenvalue	3.9644	1.2777
Proportion	0.566	0.183
Cumulative	0.566	0.749
Variable	PC1	PC2
BD	<b>0.417</b>	-0.370
TRP	-0.417	0.370
C Organik	0.056	-0.648
Permeability	-0.349	-0.238
Sand	-0.462	-0.227
Dust	0.374	<b>0.445</b>
Clay	<b>0.416</b>	-0.023

Based on PCA result analysis, a simple regression relationship between infiltration capacity with soil physical characteristics variable and sampling point location was made.

#### 3.2 The Correlation of Infiltration Capacity to the Location of Flood Affected Areas

The infiltration capacity with some flood-affected sites has an exponential relationship (Figure 5 and Figure 6). The closeness of the relationship between the infiltration capacity and the location of the flood is quite strong with the value of  $R^2$  equal to 0.9297. It means that flood-affected locations affect infiltration capacity by 93 percent. This is because the locations affected by the flood caused a change in the characteristics of soil physical characteristic that affect the maximum ability of the soil in the water. Floods generally carry a lot of sediment loads of very fine sand fractions, dust, and clay. The results of Huria [9] show that the Batang Kuranji river carries the sediment 194.08 mg / l. The sediment material comes from forest exploitation, mixed gardens, shrubs, and settlements. The sediment material carried to the floodplain will affect the physical characteristics of the soil, especially the



composition of the fraction and the pores of the soil in the soil layer.

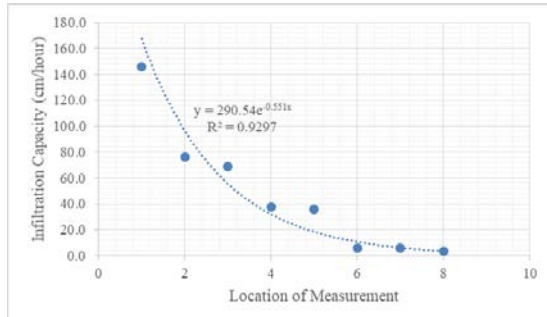


Fig. 6 Correlation of infiltration capacity with research location in downstream Kuranji watershed in Padang.

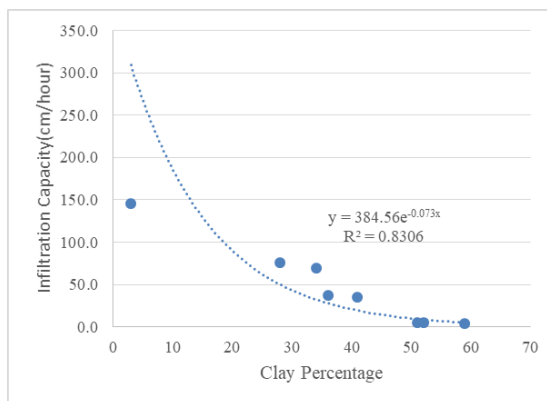


Fig. 7 Correlation of infiltration capacity with the percentage of clay content in downstream Kuranji watershed in Padang.

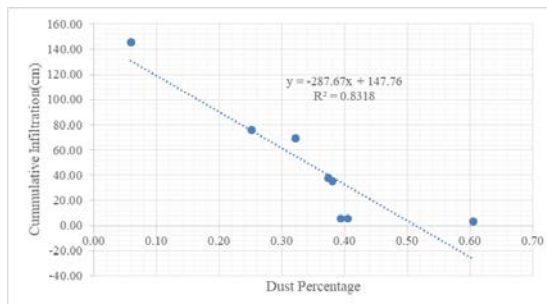


Fig. 8 Correlation of infiltration capacity with the percentage of dust in downstream Kuranji watershed in Padang.

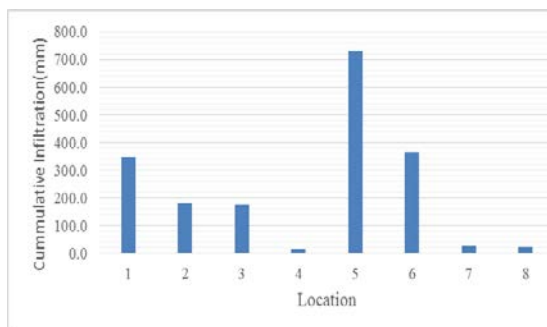


Fig. 9 Correlation of cumulative infiltration with the research location in the downstream watershed in Padang.

### 3.3 The Correlation of Infiltration Capacity with Clay Fraction

The highest percentage of clay fraction is found in Aie Pacah area, Gunung Sariék and Ampang. The clay content of the soil will increase the soil micro pore from the micro pores. The percentage of this pore affects the movement that enters the soil. Based on the results of the major component analysis (PCA) clay fraction is one of the variables that determine the infiltration capacity in the lower Kuranji river basin. Based on a simple regression analysis of clay correlation with infiltration capacity very closely with value  $R^2 = 0.8306$  (Figure 7). This means that 83 percent infiltration capacity is influenced by clay fraction. It is also stated by Foth [10] that clay-textured soils will be dominated by micro pores and unlike sandy terraces will be dominated by micro pores. The infiltration capacity is not determined by the micro pores but is the macro pore. In macro pore, the infiltration capacity will be greater than slow-moving micro pores. Soil fraction or soil texture, also called soil grain, is one of the most important properties of the soil. This is because soil fractions are closely related to the movement of water and solutes, air, heat movement, weight of soil volume, specific surface area, compressibility, etc. [11].

### 3.4 Correlation of Infiltration Capacity with Dust Fraction

The correlation between the fraction of dust and the infiltration capacity was strongly correlated, with the  $R^2$  value of 0.8318 (Figure 8). This means that 83 percent of the infiltration capacity is affected by dust fraction. When compared to the size of the dust with clay, then illite is smoother than dust so there is a difference in the relationship between infiltration capacity between dust and clay.

According to Hardjowigeno [12], soil texture shows the comparison of grains of sand ( $2\text{mm}-50\ \mu$ ), dust ( $50-2\ \mu$ ) and clay ( $< 2\ \mu$ ) in the soil. The soil texture class is divided into 12 classes, namely: sand, clay sand, sandy clay, clay soil, dusty clay, dust, clay-clay, sandy clay loam, dusty clay-clay, sandy clay-clay, dusty clay, clay. Based on its size, the soil solid material is classified into three particles of sand, dust, and clay. Sandy soils are sand  $> 70$  percent, low porosity ( $< 40$  percent), most of the pore space is large, resulting in good aeration of rapid water conductivity, but the ability to hold water and low nutrients. The soil is called textured clay if the clay content is  $> 35$  percent, the porosity is relatively high (60 percent), but most of it is small pore, water conductivity is very slow and air circulation is substandard [13]. In the sand soil

texture, the percolation rate will be very fast, in the clay soil texture the percolation rate is moderate to fast and in the clay texture, the rate of percolation will be slow [14].

### 3.5 Cumulative Infiltration in Frequently Flooded Area

Cumulative infiltration at various sampling sites showed that the largest cumulative infiltration was located at location 1. Aie Pacah1, 5. Gunung Sariiek, and 6. Ampang (Figure 9). It means that these locations have more ability to absorb water than other locations. Areas that have larger cumulative infiltration can be used as surface water absorption areas.

The difference in infiltration capacity between the sample sites is due to the differences of soil physical properties of the soil. Based on the analysis of PCA has sorted out the variable of soil physical properties that are very influential are bulk density, clay fraction and dust fraction. The different soil properties on sampling locations caused by the influence of the material cumulative floods (fine fractions). This means that the location is often inundated gradually so the nature of the soil will experience changes, especially the bulk density nature of the increasing tendon and reduce the movement of water into the soil. According to research results Mukhtar et al. [9] and Aprisal et al. [15], finds the infiltration rate which tends to fall due to the surface which always hit the raindrops causing the soil to become slippery and smooth.

### 4. CONCLUSIONS

Based on the research, it can be concluded, that;

1. The main factors affecting the capacity of infiltration capacity in flooded areas are bulk density, clay fraction, and dust.
2. The magnitude of infiltration capacity is influenced by soil physical properties having the first high correlation with clay fraction ( $R^2 = 0.83$ ) and dust has a negative correlation ( $R^2 = -0.83$ ).
3. Areas that have high water absorption or cumulative rate of infiltration capacity in the location are 5. Gunung Sariiek, 6. Ampang, 1. Aie Pacah1, 2. Kurao Pagang, and 3. Dadok Tunggul Hitam.

### 5. ACKNOWLEDGMENTS

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