# INFILTRATION TO CONTROL FLOOD VULNERABILITY

## A Case Study of Rubber Plantation of Dayak Deah Community in Negara Sub-Watershed, South Kalimantan Province

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## ABSTRACT

*The objective of the research was to study the effects of land use and soil texture on infiltration to control flood vulnerability, which was carried out in the rubber plantation of Dayak Deah community in catchment area Jaing. The double ring infiltrometer was used to measure the infiltration on the land use of natural rubber and superior rubber in clay loam texture and sandy loam texture as the treatments with three repetitions for each. Soil sample was analyzed at soil laboratory. The rate, capacity and volume of infiltration was analyzed using Horton's model, and the data of the rate and the volume of infiltration using statistical analysis with factorial design. The result of the analysis indicated that the infiltration rate (fc) of natural rubber reached the average constant higher and longer than the infiltration rate of superior rubber. The average infiltration capacity (f) of natural rubber was 72.185 mm/hour and superior rubber 60.904 mm/hour. The total volume (vt) of infiltration of natural rubber was 970.246 m3/ha/hour and superior rubber 736.031 m3/ha/hour. The total volume of infiltration in sandy loam texture was 965.315m3/ha/hour while in clay loam texture 740.962 m3/ha/hour. The soil texture type and the rubber type were significant to the capacity and the total volume of infiltration, but there was no interaction between soil texture and rubber type. The surface runoff in natural rubber was 32 % of the average precipitation at the research location, while in superior rubber 48 %.*

**Keywords:** Inifiltration, Rubber, Surface Runoff, Watershed

## INTRODUCTION

Watershed is commonly considered a unit of development, mainly in the area depending on water availibity. The major problem of watershed is the increase in population growth and the change in land use, which can decrease the quality and the quantity of water (Kometa, and Ebot, 2012), and watershed is a natural resource (Hernandez-Ram, 2008).

Kusuma (2007), stated that the interaction of components in watershed ecosystem can be described in the form of input and output balance, and it characterizes the hydrologic condition of ecosystem. Asdak (2010), said that ecosystem consists of biotic and abiotic components interacting to each other to form a regular unit. Watershed is devided into two, the upstream area that has characteristics of drainase density, higher slope declivity and certain vegetation types such as forest stands, so it is not the flood-prone area but the area causing flood hazard, and on the other hand, the downstream area is the flood-prone area.

In South Kalimantan Province, there are 761,042.6 ha of critical lands or 20.6 % of total area in 12 regencies/cities (Rahmanto, 2013). Kadir (2011), stated that in Negara sub-watershed there are 194,661 ha of critical lands or 18 % of total sub-watershed area. As many as 82 sub-districts and 550 villages in South Kalimantan including Negara sub-watershed are still vulnerable to flood; therefore, in the future it will be necessary to develop the flood control and management that are well planned and comprehensive (Suryatinah, 2010). Catchment area Jaing is the upstream area of Negara sub-watershed playing a protective role in terms of water system to all parts of the watershed. Socio-economic and cultural activities are the forms of human intervention in the natural system of watershed such as the land development for settlement and cultivated area to increase public walfare.

The rubber plantations occupy 16,737.2 ha or 64.7 % of the total catchment area Jaing (25,852.12 ha). The community of Dayak Deah has cultivated rubber to increase their walfare hereditarily in the catchment area since 1909, inside or outside the forest area. The extention of rubber plants has affected the population of forest species (Meng at al, 2011).

Kometa and Ebot (2012), some villagers in watersheds still reflect the main level of poverty, and lack of food. In order to increase their walfare, they heavily depend on agriculture and natural environment; therefore, it needs to study the indications and implications of environmental degradation in the watersheds. Liu, and Chen (2006), the population growth and the extension of agricultural land in the upstream and the middle of watershed significantly stimulate changes in the ecosystem and cause changes in water volume in the downstream of watershed.

The efforts to improve the economy of the community living around the forestry in the upstream of watershed require supervision and assistance, so that the management of watershed in upstream can function as the water system to control the flood vulnerability. The large amount of floodwater is identified by the amount of precipitation and the characteristics of water catchment area. The characteristics of water catchment area are the water system process such as infiltration and land cover (Paimin, Sukresno, and Pramono, 2009).

Infiltration as one of the factors in hydrologic circle plays an important role in distributing precipitation, so it affects the surface runoff, floods and water availability (Asdak, 2004). The infiltration leading to the storage of water in the soil is generally influenced by soil properties and vegetation. The storage of water in the soil is part of hydrologic circle process (Syed et al., 2008). Generally, the surface runoff only occurs when the intensity of precipitation is greater than the infiltration rate (Yang and Zhang, 2011)

The infiltration rate can be used to estimate the surface runoff that is a source of flooding event, and to make soil and water conservation planning (Arsyad, 2010), as well as to control flood vulnerability (Ruslan, Kadir, and Sirang, 2013). The land cover is the major factor causing the variation of surface runoff, although there is a change in precipitation (Jiang, Huang, and Ruan, 2008).

The research was conducted on the land cover in the rubber plantation of Dayak Deah community in catchment area Jaing of Negara sub-watershed, South Kalimantan Province to determine the effects of the rubber land use and the soil texture on infiltration, and the surface runoff in order to control the flood vulnerability.

## RESEARCH METHOD

### Location and Time of Research

The research was conducted in the rubber plantation of Dayak Deah community in catchment area Jaing of Negara sub-watershed, South Kalimantan Province. The measurement of infiltration and the collection of soil sample were conducted on the land use of natural rubber and superior rubber in clay loam texture and sandy loam texture as the treatments with three repetitions. The map of the measurement location is presented in Figure 1.

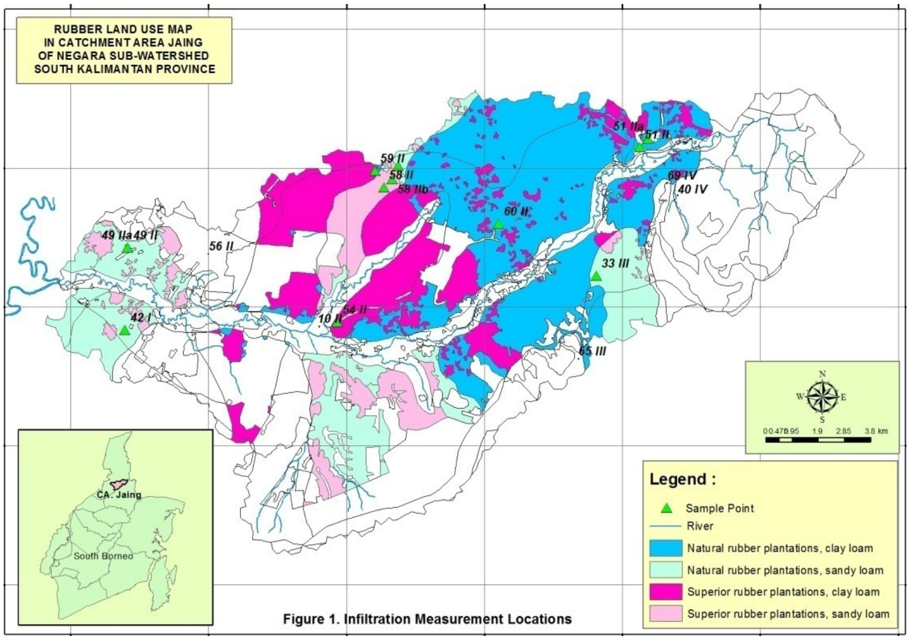


Figure 1. Infiltration Measurement Locations

## Infiltration Measurement

Eze, Eni, and Comfort (2011), the infiltration measurement can use a double ring infiltrometer. The outer ring is 50 cm in diameter and the inner ring 30 cm in diameter, having a height of 30 cm above the ground. Nurmi at al. (2012), the infiltration measurement on the experiment plots uses a double ring infiltrometer method, and the soil sample is analyzed at Soil Laboratory. Sofyan (2006), double ring infiltrometer is a device to measure infiltration. Syukur (2009), the observation of infiltration rate is conducted by using a double ring infiltrometer method.

The infiltration measurement in this research used double ring infiltrometer, where the outer ring is 50cm in diameter and the inner ring 30cm in diameter. The soil samples were collected compositely from 0-20cm into the soil using a ground drill, and were analyzed to determine the soil textures at the soil laboratory of Swampland Agricultural Research Institute, Banjarbaru.

## Infiltration Analysis

1. Exponential model was applied to observe the curve of the relationship between infiltration rate at various land uses and time, like what Wibowo (2011) stated that statistic model of sediment debit and content can use the exponential model. Sofyan (2006), the curve of relationship between infiltration rate (f) and the time of occurance (t) in forestland, moor and agroforestry can be obtained by using the exponential model. The research employed the exponential model of infiltration capacity (f), namely $f = \alpha e^{\beta t}$, where; f : infiltration capacity $\alpha$, $\beta$ : Constant, t : time.
2. Infiltration Capacity (f) and Infiltration Volume (v)

Arsyad (2010) and Asdak (2010), stated that in order to simplify the data interpretation, the infiltration data obtained from the result of the measurement in the field is presented in simplier forms by formulating the data into infiltration equation model, developed by Horton (1968). The determination of the infiltration capacity value (f) and volume (v) of Horton's equation is:

$$f = f_c + (f_0 - f_c)e^{-Kt} \quad \text{and} \quad V(t) = f_c\, t + \frac{f_0 - f_c}{K}(1 - e^{-K\,t})$$

Definition: t is time to reach the constant infiltration (hour); fo is the infiltration capacity at the beginning, infiltration process (mm/hour); fc is the constant of infiltration capacity (when infiltration rate is constant or when t approaches indefinite value (mm/hour); e is 2.718; K is Constant for soil type and land cover (1/hour); vt (the total volume) is the height of water column until constant (mm/hour); and f is the infiltration capacity or the maximum rate of water infiltrating into soil (mm/hour).

3. Variance Analysis of Factorial Design

   Factorial experiment is an experiment that the treatments consist of all possible level combinations of some factors. The purpose of factorial experiment is to find out the interaction between factors being experimented. Variance analysis with factorial design is to determine the significance and the interaction between the treatments, namely the land use of the natural rubber and superior rubber, each in clay loam texture and sandy loam texture on the infiltration capacity using linier factorial model; $Y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + e_{ij}$ . Where; $\mu$ is the average infiltration rate of population, $\tau_i$ is the effect of soil type i (i = 1,2), $\beta_j$ is the effect of rubber type j (j = 1,2), $(\tau\beta)_{ij}$ = the interaction between the factors of soil type i and rubber type j, $e_{ijk}$ is the entire error. To make an hypothesis test, it uses $H_0$ is $\tau_1 = \tau_2 = 0$, $H_1$ is at least one value $\tau_i \neq 0$; $H_0$ is $\beta_1 = \beta_2 = 0$, $H_1$ is at least one value $\beta_j \neq 0$; and $H_0$ is $(\tau\beta)_{ij} = 0$, $H_1$ is at least one value $(\tau\beta)_{ij} \neq 0$).

4. Surface runoff

   Indarto (2010), run-off is part of rainwater infiltrating into soil, flowing on the ground surface to the river. Asdak (2010), runoff is part of precipitation flowing on the ground surface to the river, lake, and sea, which is expressed by the formula: AP = P – I. Where: AP = Surface runoff (mm), P= Precipitation (mm), I = Infiltration (mm).

## RESULT AND DISCUSSION

### Infiltration Rate

The measurement of the infiltration capacity was conducted on the land use of natural rubber and superior rubber with three repetitions for each in clay loam texture and sandy loam texture. The curve of the infiltration capacity was built from the data of the infiltration measurement using Horton's model (1938). Horton admitted that the infiltration capacity decreased with the increasing time until approaching the constant value. He stated his point that the decline in the infiltration capacity was controlled by factors operating on the soil surface more than on the flow process in the soils. Lado at al. (2005), the infiltration of sandy soil texture and clay soil texture can be presented in the form of infiltration curve as the function of precipitation.

The graphic of the infiltration capacity of each measurement on various land uses and soil textures is presented in Figure 1-4. The curve of the infiltration rate illustrates in Figure 1: the land use of natural rubber in clay loam texture that reached constant (fc) at 65.33 mm/hour in average, in Figure 2: the land use of superior rubber in clay loam texture reached constant (fc) at 43.09 mm/hour in average, in Figure 3: the land use of natural rubber in sandy loam texture reached constant (fc) at 74.86 mm/hour in average, in Figure 4: the land use of superior rubber in sandy loam texture reached constant (fc) at 70.94 mm/hour in average.

Nurmi at al. (2012), the infiltration rate and the surface runoff as the responses to the treatments of vegetative conservation in cacoa planting decrease until constant with the increasing time and until average constant at the 60th minute. Wirosoedarmo, Suharto, and Hijriyati (2009), infiltration in the land use of corn, eucalyptus and vacant land decrease until constant, and the difference between infiltration rates is due to the porocity difference. Syukur (2009), the infiltration rate at each time can indicate the curve of the relationship between infiltration rate IR (cm) and observation time T (hour), and reach constant at about the 45th minute. Wibowo (2010), the effect of time on the infiltration is great; the longer the time of the infiltration measurement the less the rate of the infiltration.

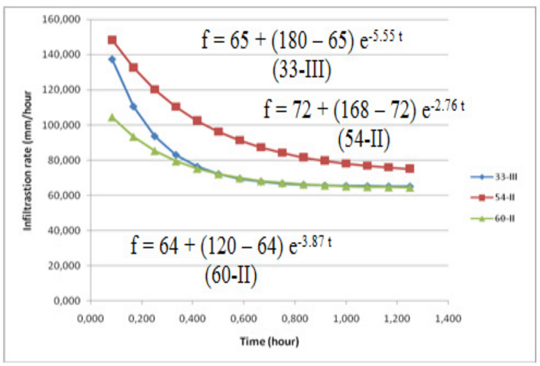


Figure 1. The infiltration rate of the land use of natural rubber in clay loam texture

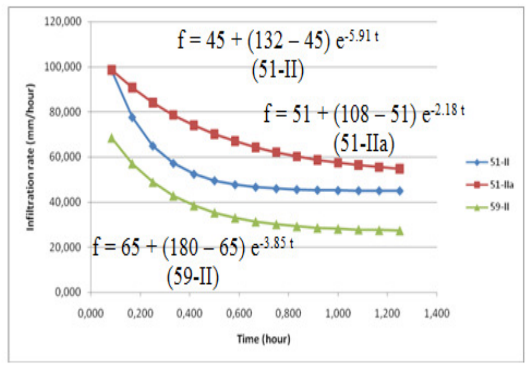


Figure 2. The infiltration rate of the land use of superior rubber in clay loam texture

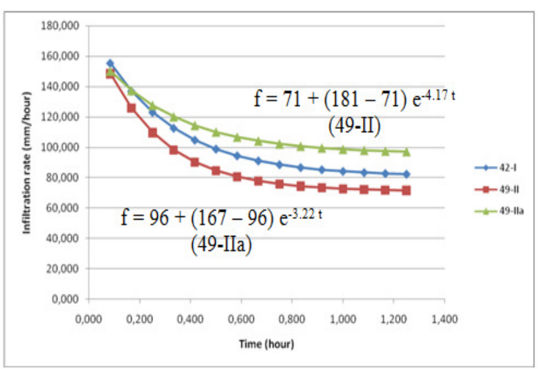


Figure 3. The infiltration rate of the land use of natural rubber in sandy loam texture

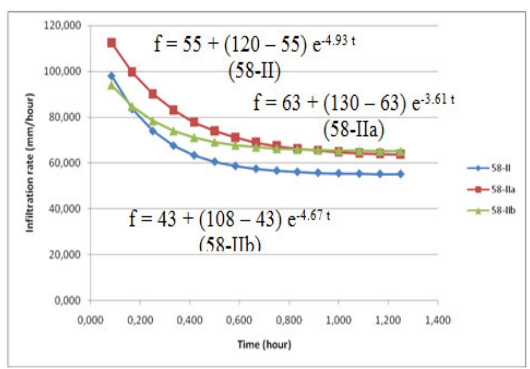


Figure 4. The infiltration rate of the land use of superior rubber in sandy loam texture

Based on the curve of the infiltration rate in Figure 1- 4 and other results of the research, it can be stated that the infiltration rate decreased until constant with the increasing time of the measurement. The infiltration rate of natural rubber reached the average constant 70.095 mm/hour at the 64.13th minute, while the superior rubber was 57.01 mm/hour at 54.20th minute. The infiltration rate reaching the constant on the land use of natural rubber was higher and longer than on the land use of superior rubber because the location unity of natural rubber was denser and there were intercrops that increase the capability to store water, so the infiltration rate was higher. It can also be caused by the large amount of evapotranspiration.

The infiltration measurement in this study was conducted at each five minutes, like Madrid at al. (2006), stated that the infiltration measurement used a circular metal ring with the interval of five minutes on the gradients of 17 – 27 %.

The infiltration measurement in this study was conducted only in the rubber land cover, so it required the infiltration measurement in other land covers in catchment area Jaing of Negara sub-watershed in order to determine the time of the constant rate of infiltration in all land covers. It became the reference for the analysis of the initiation time of surface runoff in all land covers. Catchment area, there are 9 types of land cover types in addition to rubber closure.

## Effects of Land Use and Soil Texture on Infiltration

The capacity and the the volume of infiltration in various land uses and soil textures were analyzed using Horton's equation model (1938). The significance of the rubber land use and soil texture on the capacity and volume of infiltration were analyzed using factorial design.

### *Capacity Rate and the Volume of Infiltration*

The analysis result of the capacity and the volume of infiltration based on land cover and soil texture is presented in Table 1.

**Table 1. Capacity and the volume of infiltration based on land cover and soil texture in Catchment areaJaing of Negara sub-watershed**

| *No.* | *Location/Repetition* | *fc* | *fo-fc* | *e* | *k* | *f* | *vt* |
|---|---|---|---|---|---|---|---|
| | | | *Natural rubber, clay loam texture* | | | | |
| 1 | 33.III | 60.000 | 115.000 | 2.718 | 5.550 | 60.260 | 84.080 |
| 2 | 54.II | 72.000 | 96.000 | 2.718 | 2.760 | 78.078 | 104.581 |
| 3 | 60.II | 64.000 | 56.000 | 2.718 | 3.870 | 65.169 | 78.168 |
| | Average | 65.333 | 89.000 | | 4.060 | 67.835 | 88.943 |
| | | | *Superior rubber, clay loam texture* | | | | |
| 4 | 51.II | 48.913 | 87.000 | 2.718 | 5.910 | 49.325 | 60.931 |
| 5 | 51.II-a | 51.000 | 57.000 | 2.718 | 2.180 | 57.445 | 74.190 |
| 6 | 59.II | 29.348 | 57.000 | 2.718 | 3.850 | 31.142 | 42.626 |
| | Average | 43.087 | 67.000 | | 3.980 | 45.971 | 59.249 |
| | | | *Natural rubber, sandy loam texture* | | | | |
| 7 | 42.I | 75 | 99.000 | 2.718 | 3.420 | 77.282 | 107.136 |
| 8 | 49.II | 60.684 | 110.000 | 2.718 | 4.170 | 61.399 | 93.375 |
| 9 | 49.II-a | 88.889 | 71.000 | 2.718 | 3.220 | 90.920 | 115.786 |
| | Average | 74.858 | 93.333 | 2.718 | 3.603 | 76.534 | 105.106 |
| | | | *Superior rubber, sandy loam texture* | | | | |
| 10 | 58.II | 66.265 | 65.000 | 2.718 | 4.930 | 76.284 | 104.755 |
| 11 | 58.II-a | 75.904 | 67.000 | 2.718 | 3.610 | 79.939 | 84.243 |
| 12 | 58.II-b | 70.652 | 43.000 | 2.718 | 4.670 | 71.289 | 74.872 |
| | Average | 70.940 | 58.333 | | 4.403 | 75.837 | 87.957 |

In Table 1, describing the natural rubber in clay loam texture, the average capacity rate of infiltration was 67.835 mm/hour and the volume of infiltration was 88.943 mm/hour or 889.429 $m^3$/ha/hour. The average capacity rate of infiltration of the superior rubber in clay loam texture was 45.971 mm/hour and the volume of infiltration was 59.249 mm/hour or 592.494 $m^3$/ha/hour. The average capacity rate of infiltration of the natural rubber in sandy loam texture was 76.125 mm/hour and the volume of infiltration was 105.106 mm/hour or 1,051.062 $m^3$/ha/hour. The average capacity rate of infiltration of superior rubber in sandy loam texture was 75.792 mm/hour and the volume of infiltration was 87.957 mm/hour or 879.569 $m^3$/ha/hour.

Nurmi, at al. (2012), the research location having a low capacity of infiltration was caused by the high level of clay soil indicated by the analysis result of soil texture. Wirosoedarmo, Suharto, and Hijriyati (2009), constant infiltration rate of land cover eucalyptus was 9.477 mm/minute, while on vacant land was 7.330 mm/minute. The high infiltration rate was affected by soil porosity and texture. Wibowo (2010), the infiltration rate was increasingly smaller, because the soil becomes more saturated and most of soil cavity is filled by soft soil.

Hasrullah (2009), the infiltration capacity in clay soil was greater than in sandy soil because the volume change of soil cavity was greater with increasing soilwater content. On the other hand, in sandy soil the water content is lower because of the less-absorbent nature of sand that the number of pore is also small and the change of volume, due to the presence of water, does not make the soil expand. Nurmi at al. (2012), the result of the research on the infiltration and the surface runoff as the responses to the treatments of vegetative conservation on cocoa plants stated that the volume of infiltration (vt) of cocoa land cover was 17.31 mm and 18.69 mm.

For the importance of water system, clay soil is better than sandy soil since it stores more water. This is in accorandce with Wakindiki and Ben-Hur (2002), clay soil has greater aggregate proportion than sandy soil. Kim, Chon, and Lee (2004), the clay soil has a smooth texture, while the sandy soil has a rougher texture. The infiltration rate declines with increasing bulk density and with decreasing in air-filled porosity. Therefore, a great number of macro pores increase the infiltration rate and decrease the surface runoff (Yang and Zhang, 2011). In the location with high enough precipitation the infiltration occur 500 - 850 mm/year even in higher location the infiltration 1,500 – 2000/year (Scozzafava and Tallini, 2001).

The result of the study indicated that the average capacity rate and the volume of infiltration of natural rubber were 72.185 mm/hour and 970.246 $m^3$/ha/hour, greater than superior rubber 60.904 mm/hour and 736.031 $m^3$/ha/hour, respectively. It was due to the denser stands of natural rubber and other plants with their roots expanding and enlarging the soil pores. According to Lee category (1986), the clasification of the average capacity rate of infiltration indicated that the natural rubber is categorized rather fast (65-125 mm/hour), while superior rubber moderate (20-65 mm/hour).

The average capacity rate and the volume of infiltration in sandy loam texture were 76.185 mm/hour and 965.315 $m^3$/ha/hour greater than in clay loam texture 56.903 mm/hour and 740.962 $m^3$/ha/hour, respectively. Asdak (2010), the infiltration rate is affected by gravitational forces that is limited by the diameter of soil pores. Moreover, it is stated that the texture affects the infiltration process. Rayes (2007), clay loam texture belongs to a group of rather smooth texture, while sandy loam texture belongs to a rather rough texture group. The classification of the average capacity rate of infiltration in sandy loam texture was categorized rather fast (65-125 mm/hour), while in clay loam texture moderate (20-65 mm/hour).

Infiltration is a part of hydrologic cyrcle playing an important role in reducing the surface runoff that can cause the flood vulnerability in the downsteam of watershed. It is apparent from the result of study that natural rubber has larger capacity and volume of infiltration than superior rubber. Therefore, in order to clear the land for rubber plantation it is suggested to prioritize the natural rubber type because in addition to its function as the better regulator of water system the rubber plantation cultivated by Dayak Deah Community can also be planted with fruit crops and other intercrops.

### *Significance*

The factorial design using SPSS to analyze the significance of the land use and the soil texture to the capacity and the volume of infiltration is presented in Table 2 – 3.

**Table 2. Dependent Variable of the infiltration capacity**

| *Source* | *Type III Sum of Squares* | *df* | *Mean Square* | *F* | *Sig.* |
|---|---|---|---|---|---|
| Type_Texture | 858.707 | 1 | 858.707 | 7.288 | .027 |
| Type_Rubber | 1692.829 | 1 | 1692.829 | 14.367 | .005 |
| Type_Soil * Type_Rubber | 11.177 | 1 | 11.177 | .095 | .766 |

**Table 3. Dependent variable of the total volume of infiltration**

| *Source* | *Type III Sum of Squares* | *df* | *Mean Square* | *F* | *Sig.* |
|---|---|---|---|---|---|
| Type_Texture | 903.467 | 1 | 903.467 | 6.204 | .037 |
| Type_Rubber | 5502.327 | 1 | 5502.327 | 37.781 | .000 |
| Type_Soil * Type_Rubber | 193.708 | 1 | 193.708 | 1.330 | .282 |

It was stated in table 2 and 3 that the soil texture was significant to the capacity and the volume of infiltration because the significance value was < α (0.05) each 0.027 and 0.037. Moreover, the rubber type was significant to the capacity and the volume of infiltration because the significance value was < α (0.05), each 0.005 and 0.000. Table 2-3 showed that there was no interaction between the soil texture and the rubber type for the capacity and the volume of infiltration. Therefore, the natural rubber type at the measurement location in either clay loam texture or sandy loam texture still had greater value than superior rubber. According to Cho at al. (2009), the statictic analysis of the effect of the measurement location on the land use with soil type in watershed was not significant.

Since the land use of rubber type has the significance to the infiltration, it is suggested that the open land and the sloping land are used as the natural rubber plantation that can increase the infiltration and reduce the sediment. According to Zhang at al. (2008), the effective step in reducing the sediment debit is when the vegetation cover is extended in sloping agricultural land and open land.

### Surface Runoff

The study of the surface runoff and the infiltration on the land use of natural rubber and superior rubber in clay loam texture and sandy loam texture was conducted in 2,623,793 ha or 49 % of the total catchment area Jaing of Negara sub-watershed (25,852.12 ha), with the average precipitation of 141.710 mm. Asdak (2010), the amount of water infiltrating into the soil through infiltration process is affected by several factors, such as the soil texture and structure, vegetation type and under storey. The analysis result of the surface runoff as part of the precipitation and the infiltration is presented in Table 4.

**Table 4. Infiltration capacity and the surface runoff on each use in Negara sub-watershed**

| *No* | *Precipitation (mm)* | *Land use* | *Total volume of Infiltration (m3/ha/hour)* | *Surface runoff* | |
|---|---|---|---|---|---|
| | | | | *(m3/ha/hour)* | *%* |
| 1 | 141.710 | Natural Rubber | 970.246 | 446.764 | 32 |
| 2 | 141.710 | Superior Rubber | 736.031 | 680.979 | 48 |

The total volume of infiltration in natural rubber was 446.764 m3/ha/hour while in superior rubber 736.031 m3/ha/hour; therefore, if the precipitation was 141.710 mm, the surface runoff was 446.764 m3/ha/hour or 32 %, greater than the superior 48 % (Table 4). The canopy cover and the number of roots in natural rubber were greater than superior rubber, which could expand the infiltration and reduce the surface runoff. Dayak Deah community is used to cultivating natural rubber, and other crops (fruit crops, under storey or other intercrops) among the natural rubber crops.

Carlson and Toby (2004), the increase in population followed by the increase in the land cover development can increase the surface runoff. The more the rainwater infiltrates into the soil the less the surface runoff occurs, so that the magnitude of flooding can be reduced. The improvement of the quality of soil and canopy cover results in the decrease in surface runoff and erosion (Suprayogo et al., 2004). The change in urban soil properties as the result of the population growth affects the infiltration and the environment that can cause flood; the infiltration is at the criteria of slow and very slow due to the soil compaction while the amount of surface runoff is greater (Yang and Zhang, 2011). Nurmi at al. (2012), the infiltration process is the event of the entry of water into the soil through the soil surface. The more the rainwater infiltrates into the soil, the more water is available and the less water flows as runoff.

The natural rubber plantation increases the surface runoff 32 % of precipitation, lower than the superior rubber plantation 48 % because in natural rubber plantation there are a number of intercrops, including grasses with roots and litter that increase the infiltration and reduce the surface runoff. Grasses have the very important capability to reduce the surface runoff and to control the soil erosion (Rachman et al., 2004). The decline in surface runoff occurs 40 – 60 % in the presence of grass as the buffer zone (Caron at al., 2010). The vegetation of land cover is more effective to reduce the volume of surface runoff and to increase the infiltration (Self-Davis at al., 2003). Madrid at al., (2006), the logging or the reduction of forest cover can increase the surface runoff.

The wisdom of Dayak Deah community in upstream of Negara sub-watershed is for the environment sustainability and the improvement of their walfare through natural rubber plantation. Moreover, the natural rubber plantation can decrease the surface runoff, greater than the superior rubber plantation, to control the flood vulnerability in the downstream of Negara sub-watershed. Hence it is necessary to make regulation and technology adoption of natural rubber plantation. Barungi et al. (2013), the improvement of agricultural sector requires the technology adoption to reduce the land degradation that could have an impact on the environmental damage. According to Bin at al. (2008), the surface runoff in agricultural land and grassland occurs more quickly than in forestland and the amount of surface runoff in the forest was the lowest, indicating that the forest has greater capacity of water conservation than the grassland and the agricultural land.

## CONCLUSION

1. The curve of the infiltration rate (fc) of natural rubber reached the average constant of 70.095 mm/hour at the 64.13$^{th}$ minute, higher and longer than superior rubber 57.01 mm/hour at the 54.20$^{th}$ minute.
2. The average infiltration capacity (f) of natural rubber was 72.185 mm/hour, greater than superior rubber 60.904 mm/hour. The average infiltration capacity (f) of sandy loam texture was 76.185 mm/hour, greater than clay loam texture 56.903 mm/hour. The soil texture type and rubber type was significant to the capacity and the volume total of infiltration, but there was no interaction between soil type and rubber type.
3. The average total volume (vt) of the infiltration of natural rubber was 970.246 $m^3$/ha/hour, greater than superior rubber 736.031 $m^3$/ha/hour. The average total volume of infiltration of sandy loam texture was 965.315$m^3$/ha/hour, greater than clay loam texture 740.962 $m^3$/ha/hour.
4. The surface runoff in natural rubber was 32 % of the average precipitation at the research location, while the surface runoff in superior rubber was 48 %. Therefore, it can be concluded that as the flood vulnerability control and the water management regulator, the natural rubber is better than the superior rubber.

## ACKNOWLEDGEMENTS

The author would like to express the sincere gratitude to Prof. Dr. Ir. H. Zaenal Kusuma, M.Sc., Prof. Dr. Ir. H. M. Ruslan, M.S., Prof. Dr. Ir. M. Lutfhi Rayes, M.Sc. for their guiandce and suggestions throughout the period of the study on flood control. Special thanks to Ichsan Ridwan, S.Si., M.Kom., Agus D Rahmanto, S.Hut., Syam'ani, S.Hut, M.Si. for their assistance in mapping to support the research through GIS program; Rezza Ryanda and Hiskia Simatupang for their help in conducting the infiltration measurement using double ring infiltrometer; Ir. Karta Sirang, M.S and Badaruddin, S.Hut, M.P. for the infiltration analysis using Horton model; Dewi Sri Susanti, S.Si, M.Si, and M.Ahsar Karim, S.Si, M.Sc. for statistic analysis to determine the significance of the land use and the soil texture; Khaerana Hamdat, S.Pd. for her encouragement and infinite patience until the acquision of the knowledgement of the flood vulnerability control.

## REFERENCES

Arsyad, S. (2010). *Water and Soil Conservation* (Second Edition, Second Print). Bogor: IPB Press.

Asdak, C. (2010). *Hidrology and Watershed Management* (The Fifth Print (revision)). Yogyakarta: Gadjah Mada University Press.

Barungi, M., Ng'ong'ola, D. H., Edriss, a., Mugisha, J., Waithaka, M. & Tukahirwa, J. (2013). Factors Influencing the Adoption of Soil Erosion Control Technologies by Farmers along the Slopes of Mt. Elgon in Eastern Uganda. *Journal of Sustainable Development*, *6*(2), 9–25. **doi:10.5539/jsd.v6n2p9**

Bin, F., Yu-kuan, W., Yi, R., Cheng, L. & Pei, X. (2008). Study on rain-runoff process in the peripheral mountainous area of the Sichuan Basin. *Chinese Journal of Geochemistry*, *27*(2), 183–188 **doi:10.1007/s11631-008-0183-2**

Cho, Huidae, Olivera & Francisco. (2009). Effect of the spatial variability of land use, soil type, and precipitation on streamflows in small watersheds1. Journal of the American Water Resources Association, 45*(3), 673-686.*

Carlson & Toby, N. (2004). Analysis and Prediction of Surface Runoff In An Urbanizing Watershed Using Satellite Imagery1. *Journal of the American Water Resources Association, 40*(4), 1087-1098.

Caron, E., Lafrance, P. & Auclair, JC. (2010). Impact of Grass and Grass with Poplar Buffer Strips on Atrazine and Metolachlor Losses in Surface Runoff and Subsurface Infiltration from Agricultural Plots. *Journal of Environmental Quality, 39*(2), 617-629.

Eze, E. B., Eni, D. I. & Comfort, O. (2011). Evaluation of the Infiltration Capacity of Soils in Akpabuyo Local Go Infiltration can be considered as the process by which water from the surface moves into the groundvernment Area of Cross River. *Nigeria*, *3*(1), 189-199. **doi:10.5539/jgg.v3n1p189.**

Hasrullah. (2009). Study on Impacts of Rainwater Infiltration on Stability of Slope. University of Borneo Tarakan. *Journal of Technical Science – system*, *5*(2), 5-13.

Hernandez-Ramirez, G. (2008). Emerging Markets for Ecosystem Services: A Case Study of the Panama Canal Watershed. *Journal of Environment Quality*, *37*(5), 1995. **doi: 10.2134/jeq2008.0010br**

Horton R. I. (1938). Interpretation and application of runoff plot experiments with reference to soil erosion problems. *J. Soil Science Society of America Proceedings, 3*, 340–349.

Indarto. (2010). *Hydrology Theory Fundament and Aplication Model of Hydrology* (First Print). Jakarta: Bumi Aksara.

Jiang, X., Huang, C. & Ruan, F. (2008). Impacts of land cover changes on runoff and sediment in the Cedar Creek Watershed, St. Joseph River, Indiana, United States. *Journal of Mountain Science*, *5*(2), 113–121. **doi:10.1007/s11629-008-0105-0**

Kadir, S. (2011). Study on Characteristics of Negara Sub-watershed of Barito Watershed, South Kalimantan Province. *Proceeding of National Seminar PERTETA, Roles of Agriculture in Supporting Sustainable Industrial Agriculture*, Jember, 21 to 22 July 2012, (pp. 656 – 665). http://repository.ipb.ac.id/bitstream/handle/123456789/64460/Jember2011_RKH1.pdf

Kim, J. G., Chon, C. M. & Lee, J. S. (2004). Effect of structure and texture on infiltration flow pattern during flood irrigation. *Environmental Geology*, *46*(6-7), 962–969. **doi:10.1007/s00254-004-1108-y**

Kometa, S. S. & Ebot, M. A. T. (2012). Watershed Degradation in the Bamendjin Area of the North West Region of Cameroon and Its Implication for Development. *Journal of Sustainable Development*, *5*(9), 75–84. **doi:10.5539/jsd.v5n9p75**

Kusuma, Z. (2007). *Development of Watersheds. Postgraduate Program* (First Print). Malang: University of Brawijaya.

Lado, M., Ben-Hur, M. & Assouline, S. (2005). Effects of Effluent Irrigation on Seal Formation, Infiltration, and Soil Loss during Rainfall. *Soil Science Society of America Journal*, *69*(5), 1432-1439.

Lee. R. (1986). *Forest Hydrology*. Yogyakarta: Gadjah Madah University Press.

Liu, Y., & Chen,Y. (2006). Impact of population growth and land-use change on water resources and ecosystems of the arid Tarim River Basin in Western China. *International Journal of Sustainable Development and World Ecology, 13*(4), 295-305.

Madrid, A., Fernald, A. G., Baker, T. T. & VanLeeuwen, D. M. (2006). Evaluation of silvicultural treatment effects on infiltration, runoff, sediment yield, and soil moisture in a mixed conifer New Mexico forest. *Journal of Soil and Water Conservation*,*61*(3), 159-168.

Meng, L. Z., Martin, K., Weigel, A. & Liu, J.-X. (2011). Impact of rubber plantation on carabid beetle communities and species distribution in a changing tropical landscape (southern Yunnan, China). *Journal of Insect Conservation*, *16*(3), 423–432. **doi:10.1007/s10841-011-9428-1**

Nurmi, Haridjaja, O., Arsyad, S. & Yahya,S. (2012). Infiltration and Runoff as Response of Vegetative Conservation Treatments in Cocoa Plantation. Agricultural Faculty of Gorontalo University. *JATT*, *1*(1), 1-8.

Paimin, Sukresno & Pramono, I.B. (2009). *Mitigation Technigues of Flood and Soil Erosion*. Center of Reseach and Development of Forest and Natural Conservation. Institute of Forest Research and Development. Tropenbos Internasional Indonesia, Balikpapan. www.tropenbos.org/file.php/337/tehnik-mitigasi-and-tanah-longsor

Rahmanto, A. D. (2013). *Updating Spatial Data of Critical Land*. Work Area of Institute of Barito Watershed Management 2009. http://www.bpdasbarito.or.id/index.php?option=com_content&view=article&id=79:lahan-kritis-2009&catid=37:keadaan-umum-wilayah&Itemid

Rachman, Achmad, Anderson, Gantzer, S. H. & Thompson, C. J. AL. (2004). Influence of Stiff-Stemmed Grass Hedge Systems on Infiltration. *Soil Science Society of America Journal, 68*(6), 2000-2006.

Rayes, M. L. (2006). *Inventaritation Methods of Natural Resources* (1st Ed.). Yoyakarta: CV Andi Offset.

Ruslan, M., Kadir, S. & Sirang, K. (2013). *Managemnet of Barito Watershed* (First Print). Banjarmasin: Lambung Mangkurat University Press.

Scozzafava, M. M. & Tallini, M. M. (2001). Net infiltration in the Gran Sasso Massif of central Italy using the Thornthwaite water budget and curve-number method. *Hydrogeology Journal, 9*(5), 461-475.

Self-Davis, M. L., Moore, P. A., Jr., Andiel, T. C. & Nichols, D. J. (2003). Forage species and canopy cover effects on runoff from small plots. *Journal of Soil and Water Conservation, 58*(6), 349-359

Sofyan, M. (2006). Effects of Various Land Uses on Infiltration Rate. *Study Program of Soil Science*. Institut Pertanian Bogor: Bogor.

Siradz, S. A., Kertonegoro, B. D. & Handayani, S. (2000). Roles of Test *In Situ* of Infiltration Rate in Management of Grindulu-Pacitan Watershed. Proceeding of National Seminar "Agricultural Environment Polution Control through Approaches of Integrated Watershed Management" *Surakarta, March* 28, 2006. UNS-Surakarta.

Suriatinah. 2010. 550 Villages in South Kalimantan Flood Vulnerability. http://sijaka.wordpress.com/2010/12/29/550-desa-di-kalsel-rawan-banjir.

Syed, T. H., Famiglietti, J. S., Rodell. Chen, M, J. & Wilson, C. R. (2008). Analysis of terrestrial water storage changes from GRACE and GLDAS. *Water Resour. Res*., 44, W02433, **doi:10.1029/2006WR005779**

Syukur, S. (2009). Infiltration Rate and Its Roles in Management of Allu-Bangkala Watershed. *Journal of Agroland*, *16*(3), 231 – 236.

Suprayogo, D., Widianto, Purnomosidi, P., Widodo, R. H., Rusiana, F., Aini, Z. Z., Khasanah, N. & Kusuma, Z. (2004). Degradation of Soil Physical Nature as Result of Land Use Change of Forest into Monocultural Coffee System: Study on Soil Macroporosity Change. *Journal of Agricultural Science*, Agrivita, *26*(1), 60-68.

Wakindiki, I. I. C. & Ben-Hur, M. (2002). Soil Mineralogy and Texture Effects on Crust Micromorphology, Infiltration, and Erosion. *Soil Science Society of America Journal*, *66*(3), 897-905. **doi:10.2136/sssaj2002.0897**

Wibowo, M. (2011). Statistic Modelling of Relation of River Debit and Sediment Content. Case Example in Citarum– Nanjung Watershed. *Journal of Environmental Technology, 2*(3), 255-260.

Wibowo, H. (2010). Infiltration Rate in Peat Land Affected by Soil Water (Case Study in Sei Raya Dalam of Sei Raya Sub-district of Kubu Raya Regency). *Journal of Belian*, *9*(1), 90–103.

Wirosoedarmo, R., Suharto, B. & Hijriyati, W. R. (2009). Evaluation of Infiltration Rate of Horton in Coban Rondo Sub-wareshed, Malang Regency. *Journal of Agricultural Technology*, *10*(2), 88–96.

Yang, J. & Zhang, G. (2011). Water infiltration in Urban soils and its effects on the quantity and quality of runoff. *J. Soils Sediments*, *11*(5), 751–761. **doi:10.1007/s11368-011-0356-1**

Zhang, X., Yu, X., Wu, S. & Cao, W. (2008). Effects of changes in land use and land cover on sediment discharge of runoff in a typical watershed in the hill and gully loess region of northwest China. *Frontiers of Forestry in China*, *3*(3), 334–341. **doi:10.1007/s11461-008-0056-1**