Land Covers to Increase Infiltration in Sub-Watershed Mengkaok in South Kalimantan Province

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ABSTRACT

Land cover is a natural resource, which is a component of watershed ecosystem possessing an important role to infiltration and runoff. The objective of this study was to find out the infiltration conditions on various land covers in Sub-watershed Mengkaok in South Kalimantan Province. The determination of the infiltration was carried out using double ring infiltrometer while the analysis of the rate, the capacity and the volume of the infiltration were conducted using the Horton model. The results showed that: a) the very low density land cover of secondary forestor old garden dominated the Mengkaok sub-watershed area of 11716.88 ha; b) the highest infiltration capacity was 113.29 mm/h and the highest infiltration volume 125.70 mm^3, on the high density forest cover while the lowest infiltration capacity was 30.58 mm and the lowest infiltration volume 42.40 mm^3, on the shrub land cover; c) the infiltration classification criteria in Sub-watershed Mengkaok were moderate fast (65-125 mm/h) and moderate (20-65 mm/h); d) based on the conditions of the land covers and the infiltration, it is necessary to take some efforts to increase the density of forest cover in Sub-watershed Mengkaok for the water resource conservation expected to increase infiltration, reduce runoff, and normalize water discharge fluctuation, which in turn can increase the land productivity and improve the community welfare.

Keywords: Infiltration, Land Cover, Sub-Watershed

INTRODUCTION

Land cover is a natural resource formed naturally on the surface of the earth. It is also a component of a watershed ecosystem that has an important role to infiltration and runoff. Kometa et al. (2012), the changes of land cover determine the quantity and quality of water in rainy and dry seasons.

Asdak (2010), infiltration is a component that affects the water cycle in a watershed, which plays an important role in distributing rainfall. The low infiltration with high runoff can cause flooding on the downstream of watershed or sub-watershed.

The rate of deforestation, including the changes in the density of forest cover, is one of the indications that the number of critical lands has been increasing both within and outside the forest area. The Watershed Management Agency of Barito (2013) stated that the critical land in Sub-watershed Mengkaok of Banjar Regency was 112,576.3 ha (24.5% of Banjar area). Degraded land is a factor that can lead to the lack of normal function of land or watershed as the regulator of water system, which can cause flooding.

The Regional Research and Development Agency of South Kalimantan (2010) stated that in the period from 2007 to 2010 the floods in Sub-watershed Mengkaok of Banjar Regency

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occurred in 10 districts and 65 villages. The Regional Development and Planning Agency of Banjar Regency and the Forestry Faculty of Lambung Mangkurat University (2013), the results of the analysis and the field survey showed that there were 10 (ten) districts in Banjar Regency that were prone and very prone to flooding.

This study on land cover and infiltration was conducted in Sub-watershed Mengkaok South Kalimantan Province to find out the relevance of various land covers to infiltration. It was expected to be a reference in order to control the flood vulnerability.

RESEARCH METHOD

Location and Time of Study

The study was carried out in Sub-watershed Mengkaok South Kalimantan Province, and the infiltration measurements were performed on various land covers: a) High Density Forest; b) Low Density Secondary Forest; c) Medium-Low Density Secondary Forest; d) Very Low-density Secondary Forest/Old Garden; e) Old Thickets; f) Young Secondary Forest/Young Garden; and g) Young Shrubs. The map of the study locations presented in Figure 1.

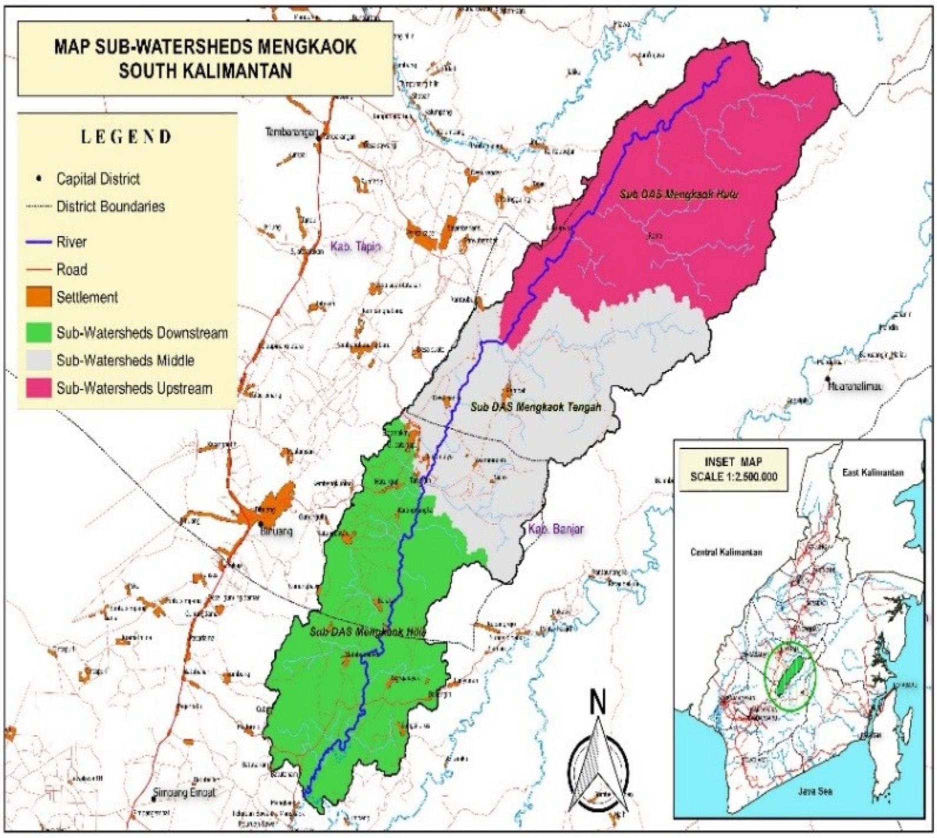

Figure 1. Sub-watershed Mengkaok in South Kalimantan Province

Measurements

The infiltration measurements on various land covers in Sub-watershed Mengkaok employed double ring infiltrometer, like what Eze et al. (2011) stated that the data of infiltration on land covers were obtained using double ring infiltrometer consisting of: a) the outer ring diameter of 50 cm; b) the inside ring diameter of 30cm; and c) the ring height of 30cm. Furthermore, Kadir (2013) suggested that the infiltration measurement on rubber land cover could be carried out using infiltrometer.

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Infiltration Analysis

1. Exponential model was used to observe the infiltration rate curves on various land covers with time, as Wibowo (2011) stated that the statistical modeling of relationship between discharge and sediment content can employ the exponential model. Kadir (2013), infiltration rate curve (f) and time (t) on various land covers can be obtained using the exponential model. The infiltration curve was on the land cover and occurrence time. This study employed the exponential model of infiltration capacity (f), namely f = α e $^{\beta t}$ where; f: infiltration capacity α, β: Constanta: time

2. Capacity (f) and volume (v) of infiltration Arsyad (2010) and Asdak (2010), to facilitate the data interpretation, data obtained from the measurements of infiltration on the field were presented in a simpler form by formulating these data into infiltration equation model developed by Horton (1968). The determination of infiltration capacity (f) and volume (v) in Horton (1968) equation is:

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

   Description: ***t***is the time needed to reach a constant infiltration (h), ***fo*** is the infiltration capacity at the beginning the process of infiltration (mm /h), ***fc*** is constant infiltration capacity (when the infiltration rate has been constant or when ***t*** approaches infinity value (mm / h), ***e***is 2.718, ***K*** is a constant for land cover classification (1/h), ***vt*** (total volume) is the height of the water column up to a constant (mm/h), and ***f*** is the infiltration capacity or the maximum rate of water infiltrating the soil (mm/h).

RESULTS AND DISCUSSION

Land Cover

Zhang and Wang (2007) state that the land covers in accordance with the intended use in a watershed or a sub-watershed will provide optimum benefits, for water management. The land covers in Sub-watershed Mengkaok are presented in Table 1.

Table 1. Land Covers in Sub-watershed Mengkaok South Kalimantan

No	*Land Cover*	*Symbol*	*Sub-watershed Mengkaok (Ha)*			*Total (Ha)*
			Down Stream	*Central*	*Up Stream*	
1	High Density Forest	HDF	0.27	-	-	0.27
2	Low Density Secondary Forest	LDSF	155.59	836.61	2,131.80	3,124.00
3	Medium-Low Density Secondary Forest	MLDSF	1.95	7.61	62.27	71.63
4	Very Low Density Secondary Forest/Old Garden	VLDSF	1,299.27	3,990.15	6,427.46	11,716.88
5	Old Thickets	OT	2,491.02	1,450.96	789.39	4,731.37
6	Young Secondary Forest/Young Garden	YSF	2,257.07	3,009.15	2,641.66	7,907.79
7	Young Shrubs	YS	1,727.35	626.16	248.47	2,601.99

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Table 1 shows that the land cover of very low density secondary forest/old garden dominated Sub-watershed Mengkaok area of 11,716.88 ha whereas the less land cover was medium-low density secondary forest area of 71.63 ha. Changes in the density of forest cover can occur because of the high rate of population growth settled at this sub-watershed, in accordance with Liu and Chen (2006), the higher the population growth in a watershed, the more increasing the expansion of agricultural cultivation.

Meng et al. (2011), people who live in a watershed or sub-watershed do farming, reduce the density of forest cover, and make changes to improve their welfare. The changes in land covers at a watershed or sub-watershed can be responsible for the low infiltration and make the runoff higher in rainy season, which can result in abnormal fluctuation of discharge and flooding (Zhao et al., 2012).

Capacity and Volume of Infiltration

The capacity and the volume of infiltration on various land covers already measured were analyzed using Horton equation model (1938). The results of the analysis are presented in Table 2.

Table 2. Capacity and volume of infiltration on various land covers in Sub-watershed Mengkaok

No.	*Land Cover*	*fc*	*fo-fc*	*e*	*k*	*Infiltration (mm/mm^3)*	
						Capacity (f)	*Volume (v)*
1	High Density Forest	113	70	2.72	5.49	113.29	125.70
2	Low Density Secondary Forest	87	88	2.72	6.58	87.12	100.28
3	Medium-Low Density Secondary Forest	56	110	2.72	2.57	64.42	95.52
4	Very Low Density Secondary Forest/Old Garden	47	109	2.72	2.38	57.09	88.56
5	Old Thickets	51	102	2.72	6.40	51.17	66.91
6	Young Secondary Forest/Young Forest	38	42	2.72	2.99	40.11	51.34
7	Young Shrubs	29	47	2.72	3.39	30.58	42.40

The infiltration capacity and volume are the process of water infiltrating into the soil that occurs as part of distributed rainfall reaching the ground. It can be seen in Table 2 that the highest infiltration capacity was 113.29 mm/h and the highest infiltration volume 125.70 mm^3 on the land cover of high density forest while the lowest infiltration capacity was 30.58 mm and the lowest infiltration volume 42.40 mm^3 on the land cover of shrubs. It is showed in Figure 2 that the higher the infiltration capacity, the more increasing the infiltration volume. It indicated that the physical properties of the soil potentially affected the high infiltration capacity directly proportional to the infiltration volume. Lado et al. (2005), changes in infiltration capacity are determined more by factors operating at ground level than the flow process in the soil.

The vegetation of forest cover consumes large amounts of water through infiltration process so as it tends to reduce the flow of river, which can control the incidence of flood. Liu et al. (2008) states that the deforestation reduces the density of forest cover, resulting in low amounts of carbon storage and infiltration capacity.

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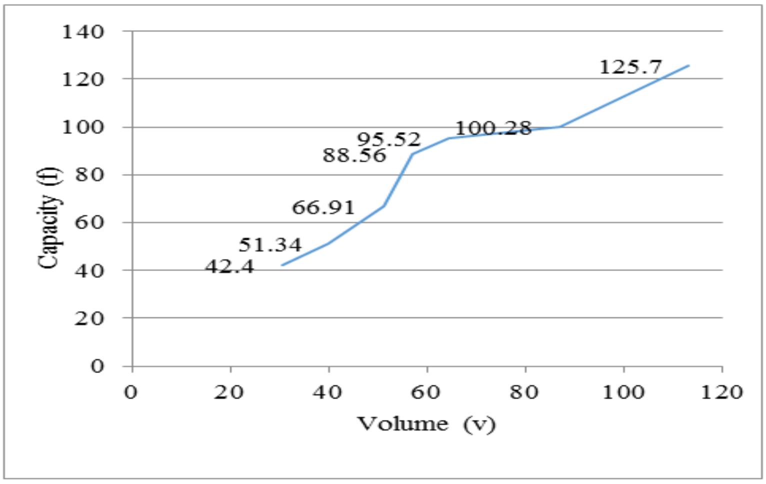

Figure 2. Capacity and volume of infiltration

Table 3. Infiltration capacity and width on various land covers in sub-watershed Mengkaok

No	*Land Cover*	*Symbol*	*Average Infiltration Capacity (mm/h)*	*Width (Ha)*
1	High Density Forest	HDF	113.29	0.27
2	Low Density Secondary Forest	LDSF	87.12	3124
3	Medium-Low Density Secondary Forest	MLDSF	64.42	77.34
4	Very Low Density Secondary Forest/Old garden	VLDSF	57.09	11716.88
5	Old Thickets	OT	51.17	4731.37
6	Young Secondary Forest/Young Garden	YSF	40.11	7907.79
7	Young Shrubs	YS	30.59	2601.99

Table 3 shows that the high density forest had the highest average infiltration capacity of 113.29 mm/h while the shrubs had the lowest infiltration capacity of 30.59 mm/h; therefore, it can be inferred that the higher the density of the forest cover, the higher the infiltration capacity, as shown in Figure 2, because the denser the forest cover, the higher the soil pores due to the greater number of the roots and plant remains as well as the physical properties of soil supporting the increase in infiltration capacity. Ladoet al. (2005) stated that the physical properties of the soil in each area can affect the infiltration capacity. Furthermore, Kadir (2013) stated that the physical properties of the soil with clayey loam texture have lower infiltration capacity compared to the soil with clayey sandy texture.

Infiltration Classification

The infiltration classification was a result of the data analysis of measurements on various land covers in Sub-watershed Mengkaok, as Arsyad (2010) and Asdak (2010) stated that in order to find out the infiltration of land covers, it is necessary to conduct measurement son the field presented in a simpler form by formulating the data through infiltration equation model developed by Horton (1938). The infiltration classification of land covers in Sub-watershed Mengkaok according to Lee (1986) and Kohnke (1968) is presented in Table 4.

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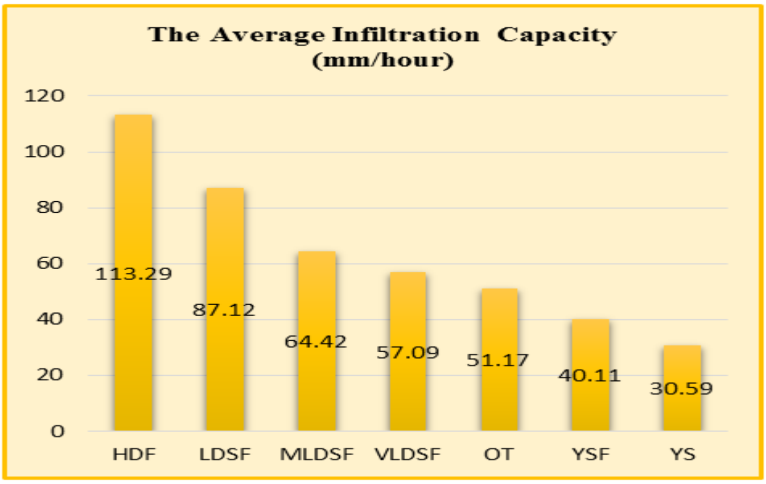

Figure 3. . the average infiltration capacity (mm / hour)

Table 4. Classification of Infiltration and width on various land covers in Sub-watershed Mengkaok

No	*Land Cover*	*Classification*	
		Infiltration (mm/h)	*Criteria*
1	High Density Forest	65 -125	Moderate Fast
2	Low Density Secondary Forest		
3	Medium-Low Density Secondary Forest	20 - 65	Moderate
4	Very Low Density Secondary Forest/Old Garden		
5	Old Thickets		
6	Young Secondary Forest/Young Garden		
7	Young Shrubs		

Table 4 shows that there were two criteria for the classification of infiltration in Sub-watershed Mengkaok, namely: a) moderate fast (65-125 mm/h); and b) moderate (20-65 mm/h). The land covers had different infiltration capacity based on the density and the roots. According to Nurmi *et al*. (2012), the infiltration rate on land cover decreases to constant with the increasing time and the average constant at the 60th minute. Furthermore, Wirosoedarmo, Suharto and Hijriyati (2009) state that the infiltration rate on the land covers decreases to constant and the difference of infiltration is due to the porosity difference on the land covers.

Direction of Land Covers to Increase Infiltration

The infiltration values obtained were the reference to improve the carrying capacity of Sub-watershed Mengkaok as the water management regulator, as Arsyad (2010) stated that the infiltration capacity can be utilized in the planning of water resource conservation and in estimating the surface runoff. In addition, the data on the infiltration capacity on various land covers become the reference for the planning of the implementation of the flood vulnerability control (Ruslan, Kadir and Sirang, 2013).

Based on the conditions of the land covers and the infiltration, it is necessary to take some efforts to increase the density of the forest cover in Sub-watershed Mengkaok as the conservation of water resources expected to increase infiltration, reduce runoff, normalize water discharge fluctuation, which in turn can increase the land productivity and improve the community welfare in Sub-watershed Mengkaok. It is in accordance with Zhan et al. (2007), the conservation of water resources on open land can increase infiltration capacity.

CONCLUSION

1. The land covers of very low density secondary forest/old garden dominated Sub-watershed Mengkaok area of 11,716.88 ha, and the lowest density was on the land cover of high density forest area of 0.27 ha.
2. The highest infiltration capacity was 113.29 mm/h and the highest infiltration volume 125.70 mm^3 on the land cover of high density forest while the lowest infiltration capacity was 30.58 mm and the lowest infiltration volume 42.40 mm^3 on the land cover of shrubs; the criteria of infiltration classification in Sub-watershed Mengkaok were moderate fast (65-125 mm/h) and moderate (20-65 mm/h);
3. Considering the conditions of the land covers and the infiltration, it is necessary to take some efforts to increase the density of forest cover in Sub-watershed Mengkaok as the conservation of water resources expected to increase infiltration, reduce runoff, normalize water discharge fluctuation, which in turn can increase the land productivity and improve the community welfare.

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