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RESEARCH PAPER

A Preliminary Study on Rainfall Interception Loss and Water Yield Analysis on Arabica Coffee Plants in Central Aceh Regency, Indonesia

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Abstract - Rainfall interception loss from plants or trees can reduce a net rainfall as source of water yield. The amount of rainfall interception loss depends on kinds of plants and hydro-meteorological characteristics. Therefore, it is important to study rainfall interception loss such as from Arabica Coffee plantation which is as main agricultural commodity for Central Aceh Regency. In this study, rainfall interception loss from Arabica Coffee plants was studied in Kebet Village of Central Aceh Regency, Indonesia from January 20 to March 9, 2011. Arabica coffee plants used in this study was 15 years old, height of 1.5 m and canopy of 4.567 m^2. Rainfall interception loss was determined based on water balance approach of daily rainfall, throughfall, and stemflow data. Empirical regression equation between rainfall interception loss and rainfall were adopted as a model to estimate rainfall interception loss from Arabica Coffee plantation, which the coefficient of correlation, r is 0.98. In water yield analysis, this formula was applied and founded that Arabica Coffee plants intercept 76% of annual rainfall or it leaved over annual net rainfall 24% of annual rainfall. Using this net rainfall, water yield produced from Paya Bener River which is the catchment area covered by Arabica Coffee plantation was analyzed in a planning of water supply project for water needs domestic of 3 sub-districts in Central Aceh Regency. Based on increasing population until year of 2025, the results showed that the water yield will be not enough from year of 2015. However, if the catchment area is covered by forest, the water yield is still enough until year of 2025.
Keywords: Net rainfall, hydro-meteorological characteristics, water balance, empirical regression equation, water needs domestic

Introduction

Rainfall interception loss from vegetation surface is defined as the rain water that is retained on the vegetation canopies and lost to the atmosphere as water vapor (Rao, 1987). This interception loss from vegetation surfaces becomes important when their ratio to the rainfall is high. Caldier (1979) and Gash *et al.* (1980) reported that there could be a reduction in water yield to almost a zero level after forestation of grassland of Great Britain. This is due to higher interception losses from forest than from short vegetation such as grasses. On the other hand, Rao (1987) has reported that a reverse impact could occur due to conversion of forest into agricultural lands in India. Yoshida *et al.* (1993) reported that annual rainfall interception loss in the Shirakawatani forested experimental basin in Japan is about 13% of annual rainfall. The tree of this basin consists of Cryptomeria Japonica and natural broad-leaved forest. Asdak (2004) reported that rainfall interception loss in the tropical rain forests is 11% of total rainfall. This rainfall interception loss depends on kind of plant. Therefore, it is important to study rainfall interception loss from various kind of plant in study of water yield.

Central Aceh Regency is one of regencies in Aceh Province of Indonesia where the main agricultural activity of the farmers is Arabica Coffee plantations. This activity has caused a conversion of forests to offee plantation. This conversion influences water yield that resulted due to difference rainfall interception loss from forests and from plantation. Therefore, it is important to study rainfall interception loss from Arabica Coffee plants in Central Aceh Regency which the results can be used in study of water yield that resulted from net annual rainfall.

In this study, measurement daily data of rainfall interception loss was obtained based on water balance analysis which its component consists of daily measurement data of rainfall, throughfall, and steamflow. A model of rainfall interception loss estimation was developed using linear regression equation which its independent variable is daily rainfall and its dependent variable is throughfall, and steamflow. . This model was applied to obtain rainfall interception loss of observed daily rainfall data of Bebesen rainfall station in Central Aceh Region. Annual rainfall interception loss was obtained from sum of daily rainfall interception loss. Finally, net annual rainfall as water yield can be derived from calculating the difference between annual rainfall and annual rainfall interception loss.

Materials and Methods

This study was carried out in Kebet Village of Central Aceh Regency, Indonesia from January 20 to March 9, 2011. Arabica coffee plant that used in this study was 15 years old, stand height of 1.50 meter and canopy coverage about 4.567 m^2. Rainfall interception loss was determined based on water balance approach, as shown in Formula 1(Yoshida *et al.*, 1996; and Yulianur, 1999).

$$I = R - (Tf + Sf) \quad (1)$$

Where: *I* = rainfall interception loss (mm); *R* = rainfall (mm); *Tf* = throughfall (mm); *Sf* = steamflow (mm).

The data of rainfall, through fall and steam flow were daily data. The rainfall data were measured using daily rainfall gauge (Figure 1a). Referring to the Calder and Rosier (1976), the through fall data was measured using a plastic carpet that spread under the canopy plants (Figure 1b). Referring to Yoshida *et al.,* (1993), the steam flow data was measured using a zinc plat that wrapped around the trunk of plants (Figure 1c). Each installation of these instruments is shown in Figures 1 below. These daily data were measured every rainy day at 07.00 am.

a. Daily rainfall gauge b. Through fall measurement c. Steam flow measurement

Figure 1. Instruments of rainfall interception loss measurement consist of daily rainfall gauges (a); daily through fall measurement (1b); and daily steam flow measurement (1c).

Empirical regression equation between rainfall interception loss and rainfall that has been used world-wide was adopted as a model to estimate rainfall interception loss from Arabica Coffee plants in Central Aceh Regency, Indonesia. The empirical regression was developed using 32 rainy day data. The range of daily rainfall data was 0.1 – 50.0 mm. The data of daily rainfall interception loss was obtained by applying the observation data of daily rainfall, daily throughfall, and daily steamflow in formula 1.

Results and Discussion

Based on correlation between observed daily data of rainfall and rainfall interception loss, the model of rainfall interception loss estimation from Arabica Coffee plants was developed. The model is described as Formula 2 and the correlation between rainfall interception loss and rainfall is shown in the Figure 2.

$$I = 0.78\ R - 0.23 \quad (2)$$

Where: I = daily rainfall interception loss (mm); R = daily rainfall (mm)

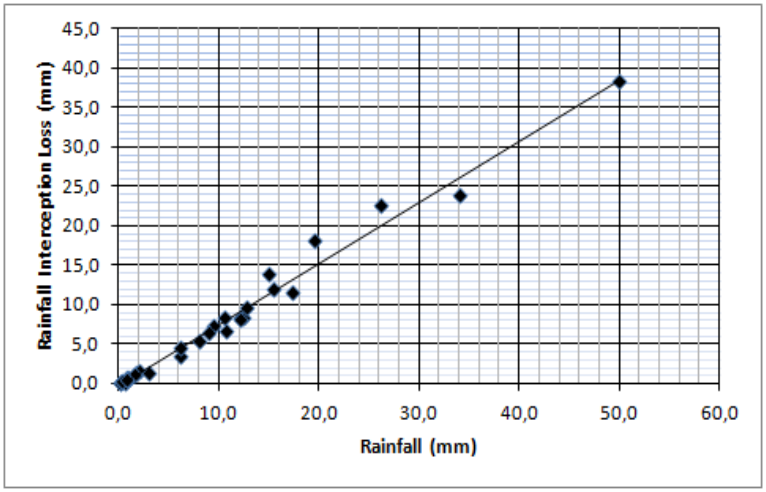

Figure 2. Correlation between daily rainfall interception loss and daily rainfall

The formula 2 expresses that only rainfall up to 0.30 mm can be applied in this formula and around 78% of daily rainfall will be intercepted by Arabica Coffee plant. Figure 2 shows that good correlation between daily rainfall interception loss and daily rainfall was obtained, which the coefficient of correlation, *r* is 0.98. There are many critical for usage of regression equation which its explanatory only daily rainfall, while meteorological effect such as evaporation rate in the process of rainfall interception loss is not considered. However, 0.98 of coefficient of correlation that obtained in this study is sufficient to use this formula for estimating daily rainfall interception loss by using daily rainfall data without considers meteorological effect. It might be caused to influence of meteorological aspects was not significance.

The net annual rainfall is required for water yield analysis of water available in a region. Net rainfall is derived from a calculation where net rainfall is equal to rainfall minus rainfall interception loss. In this study, water yield of Central Aceh

Regency was examined based on net annual rainfall resulted from abstracting daily rainfall interception loss from Arabica Coffee plants to daily rainfall. Annual rainfall data used in this analysis was 10 years recorded data from 1999 until 2008 at Bebesen Rainfall Station in Central Aceh Regency. By using formula 2, daily rainfall interception loss of every recorded daily rainfall was determined. Then daily net rainfall was derived by abstracting daily rainfall interception loss to recorded daily rainfall. After that, net annual rainfall was determined by summing daily net rainfall. The results are shown in table below. In average, Arabica Coffee plants intercept 76% of annual rainfall and it leaved over annual net rainfall 24% of annual rainfall.

In this study, the affect of forest conversion to Arabica Coffee plantation in association with water yield was analyzed based on applying the average annual net rainfall into a planning of water supply project for water needs domestic in Central Aceh Regency, Indonesia. The project will be planed to supply water needs domestic of 3 sub-districts. Estimation of water needs domestic of bulge in population from year of 2009 until 2025 that was obtained from study of Benara (2012) was used as shown in table below. Based on catchment area of Paya Bener River is 12.55 km^2, water needs domestic in mm/year was obtained. The results were compared to applying average annual net rainfall caused due to rainforest as reported by Asdak (2004) where tropical rainforest was intercepted 11% of annual rainfall or leaved over 89% annual net rainfall.

Comparison among annual water needs domestic, annual net rainfall due to Arabica Coffee plantation, and net rainfall due to tropical rainforest are shown in Figure 3. The results show that if Paya Bener river catchment area is conversed from forest to Arabica Coffee plantation, net rainfall as water yield is only enough to supply water needs domestic in 1999 until 2010, but not enough in 2015 until 2025. On contrary, water yields are sufficient to supply water needs domestic when catchment area is still forest. These results indicate that it is important to consider conversion forest to Arabica plantation where the water sheet of a river is water source of water needs domestic. However, regarding to the main agricultural activity in Central Aceh's farmers is Arabica Coffee plantation; a spatial planning in the catchment area that has been converted to Arabica Coffee plantation is needed

Table 1. Annual rainfall interception loss and net rainfall due to Arabica Coffee plants

No.	Year	Annual Rainfall (mm)	Annual Interception (mm)	Annual Net Rainfall (mm)
1.	1999	2188.65	1663.36	525.29
2.	2000	1887.60	1428.92	458.67
3.	2001	1825.30	1381.87	443.43
4.	2002	1647.65	1247.98	399.67
5.	2003	1879.75	1427.79	451.96
6.	2004	1822.26	1379.42	442.84
7.	2005	1656.20	1251.27	404.93
8.	2006	1664.05	1257.85	406.20
9.	2007	1936.71	1471.83	464.88
10.	2008	1670.75	1262.31	408.44
Average		1817.89	1377.26	440.63
Percentage to Annual Rainfall			76%	24%

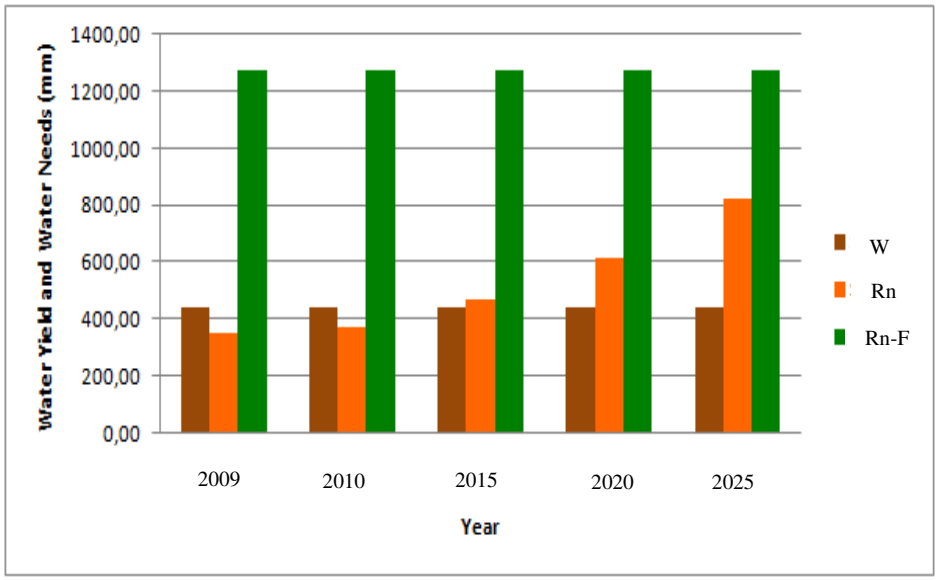

Figure 3. Comparison among water needs domestic (W), annual net rainfall in Arabica Coffeeplantation (Rn-C), and annual net rainfall in rainforest (Rn-F)

Conclusions

Arabica Coffee plantation intercepts 76% of annual rainfall in Central Aceh Regency, Indonesia. An annual net rainfall as source of water yield is 24% of annual rainfall. Using this net rainfall, water yield produced from Paya Bener River that its catchment area covered by Arabica Coffee plantation was analyzed in a planning of water supply project for water needs domestic of 3 sub-districts in Central Aceh Regency, Indonesia. Toward domestic consumption needs prediction based on increasing population until 2025, the water yield will be not enough from 2015. However, if the catchment area is covered by forest, the water yield is still enough until 2025. Therefore, it is important to consider a spatial planning of the catchment area by reducing the conversion of land use to Arabica Coffee plantation.

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