Infiltrated Water and Runoff at Four Gradient Slopes at Smallholder Oil Palm Plantation in Dry Season in Jambi, Indonesia

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Since water balance is considered as a major constituent in the environmental issue for sustainability of oil palm production system, particularly as significant biomass contributor, runoff water as water loss and infiltrated water for oil palm consumption play the most significant role for the explanation of water status and should be exposed comprehensively. In case of water inefficiency in oil palm cultivation system, problem-solving solutions are to be identified and recommended. The purpose of the experiment was to approach the value of infiltrated water at smallholders oil palm plantation in Jambi at 4 gradient slopes category i.e. plain (0-5%), slight (6-10%), moderate (11-21%) and heavy slope (24-33%). The experiment was conducted at dry season from June to October 2013 in 4 replications. Water throughfall from September-October amounted to 35-39 mm from the total precipitation value of 97.1 mm. Infiltrated water from the water throughfall amounted to 32.3 mm at the slight gradient slope and 6.8 mm at the heavy gradient slope. Runoff rate at heavy gradient slope reached the value of 82.7 mm per 100 mm of total throughfall value. Canopy covering rate measured by sunlight transmission ranging from 11.9% - 13.5% had no significant effect on throughfall value at all of gradient slopes category.

Key Words
Runoff, infiltration, Oil palm, Slope gradient, Throughfall

1. Introduction

Since water balance is considered as a major constituent in the environmental issue for sustainability consideration of oil palm production system, particularly as significant biomass contributor, runoff water as water loss and infiltrated water for oil palm consumption play the most significant role for the explanation of water status and should be exposed comprehensively. The various field conditions, including mostly undulating oil palm area in Jambi and generally in Indonesia, contribute diverse water balance status 1) 2). The vigorous development of oil palm growing area is associated with the positive economic impact 3) 4) and reduction ecosystem service 4). A minimum of 30% forest cover is required for sustainable ecosystem services 5).

The requirement of water by oil palms grown on smallholder farms at 4-24 years old measured by transpiration in Jambi is relative low with average value of 1.5 mm day⁻¹ 6) 7) with its value is equivalent with other tree species including rubber, jungle rubber and forest trees 8) at the value ranging 1.0-1.4 mm day⁻¹ 9). Annual water requirement represented as evapotranspiration value of large scale mature oil palm plantation of PTPN6 in Jambi reached to 1216 ± 34 mm yr⁻¹. At the same time immature smallholder farmer showed evapotranspiration value of 918 ± 46 mm yr⁻¹ 10). Irrespective of this difference, a main problem of water balance in the oil palm ecosystem is, that the rate of infiltration and its capability are very low under 3 cm h⁻¹ 7).

However, the real infiltrated water in the area in
the previous research publications was less discussed nor approached in the previous findings. In previous report water infiltration was measured for saturated stabilized value after 4 hours. During the time until the 4-hour time measurement to reach the constant \( K_s \) value as saturated hydraulic conductivity, which presents the maximum value of infiltration rate, there is a quantity of water succeeded in infiltrating into the soil with higher infiltration rate at unsaturated hydraulic conductivity. The infiltrated water from precipitation in unsaturated soil condition, especially during 4-hour infiltration time is very important to contribute soil moisture required by the growing plant.

To find out the real infiltrated water into the soil, field experiment was installed. In case of any findings regarding of water inefficiency in oil palm cultivation system, problem-solving solutions are to be identified and should be recommended.

2. Experimental

Field research was conducted at smallholder oil palm plantation at Harapan Forest adjacent, Jambi Province in dry season from June to October 2013. Four gradient slopes category i.e. plain (0-5%), slight (6-10%), moderate (11-21%) and heavy slope (24-33%) were observed with 4 replications. The distance between the plain area at the ridge position to the valley position was 100 m. Total observed area covered 4 ha measurement.

Annual precipitation in the year of 2001-2016 was averagely 2229 ± 308 mm (stdev) ranging from 1637-2612 mm with average temperature of 26.7 ± 0.2 °C according to the data of Indonesian Board of Meteorology, Climatology and Geophysics (BMKG) - Airport Sultan Thaha, located around 35 km from the study site, 2017. Precipitation data in dry season is presented at Table 1. Soil type is red-yellow podzolics as not wetland soil type in the group of acid soil ultisol. Coordinate of site location is 103°16′14″ E and 1°51′28″ S at 48 m above sea level. The study area belongs to a smallholder farmer.

The oil palm age was 8-year old with total area about 5 ha. The area was also joined with oil palm plantation area of neighbour farmer with 3 ha covering area. Total area of the oil plantation spot area of the both farmers is about 8 ha. The existing plantation was a conversion culture from previously rubber plantation. In rainy season glyphosate herbicides was applied at the rate of 2.4 L active ingredient per ha. The farmer did not apply any additional fertilizer, lime nor insecticides during the growing and productive period.

At plant spacing of 9 m × 9 m × 9 m with equilateral triangle spacing in oil palm cultivation system, a single triangle consisted of 3 oil palm trees has an area of 70.1 m². Sampling area position base on the equilateral triangle of oil palm tree position has been supposed to have equivalent opportunity to be drawn as sampling area. Further, this triangle area was divided to 6 equal right triangles drawn from the center of the equilateral triangle, which the 6 smaller triangles also have equivalent opportunity to be drawn as sampling area. Each smaller right triangle has the same dimension area of 4.5 m × 2.6 m × 5.2 m = 11.7 m². This smaller right triangle area was set for sample measurement area of sunlight transmission rate measurement through oil palm canopy. This small right triangle area is supposed to be the smallest representative sampling area in oil palm plantation system.

At the triangles area, mini erosion plot with a dimension of 3.6 m × 1 m under oil palm trees and with a 50 L water tub for runoff collector was installed as unit plot. The plot position was started at upper tree (tree 1 in the unit plot) and directed to center of the equilateral triangle tree spacing. Each unit plot was installed 4 times under 4 oil palm trees to obtain average value of the collected data for a single slope gradient and single replication.

Throughfall of precipitation transmitted through canopy to the soil surface was collected with simple ombrometer with diameter measurement of 11 cm. 16 ombrometers were positioned at each unit plot with a distance of 45 cm from the other 2 trees (tree 2 and tree 3 in the unit plot) to the central equilateral triangle tree spacing. To collect rainwater stemflow, water tub with volume of 10 L was installed at each sample tree, which represented an area of 70.1 m². PVC sheet was installed at the trunk at the height of 0.5-1.0 m above the bottom for collection of flowing down water and then finally reached to the tub. Without the installed PVC catcher, the water would have reached soil surface. Totally there were 64 unit plots, 64 runoff water tubs, 192 stemflow tubs and 1024 simple throughfall ombrometers. Runoff water, throughfall water and stemflow water were collected after every rainfall.

To find out the explanation about the relation between throughfall with the canopy covering rate, the

| Year 2001-2016 | Year 2013 | Min | Max | Stdev. |
|---------------|-----------|-----|-----|--------|
| May | 173 | 62 | 332 | 86 |
| Jun | 102 | 28 | 197 | 45 |
| Jul | 125 | 52 | 253 | 63 |
| Aug | 172 | 26 | 397 | 91 |
| Sep | 172 | 15 | 356 | 83 |

Table 1 Monthly precipitation data in Jambi in dry season according to the data of BMKG 2017
sunlight transmission through canopy was measured with Lightmeter Licor Li-250A with photometric sensor Li-210. An equivalent measurement area was also set under plant spacing of $9 \times 9 \times 9$ m at the equilateral triangle. Sample measurement point was set from tree 1, 2 and 3 of each unit plot. The observation points were positioned at the area of 11.7 m$^2$ right triangle. Distance between each observation point was 45 cm. There were 28 sunlight measurement points at each right triangle or 84 measurement points at each unit plot. During the experiments time sunlight measurement was repeated 24 times.

### 3. Results and Discussion

At the plain and slight gradient slope it exhibited similar pattern of canopy density and the value of sunlight transmission amounted to 11.6 and 11.9\% respectively. The domination of transmission rate was at the transmission rate value in 15-20\% and 5-10\%. However, at the moderate slope, it was found that more sunlight was transmitted to the soil surface and the density value was 13.3\%. It was lower than at the top ridge and slight gradient slope (Fig. 1).

In the dry season there were only 97.1 mm precipitation value during 7 September - 2 October 2013 in 6 rain days. During the dry period 4 mm runoff water was collected at plain area. There was no runoff difference value between plain and slight gradient slope. However, at moderate and heavy gradient slope, it was found that the runoff value was much higher with 16.6 mm and 32.6 mm water loss, those represent 17.1\% and 33.6\% of total precipitation respectively. Irrespective the water loss values correspond to 47.0\% of the total precipitation reaching the soil surface or throughfall at moderate gradient slope and even its loss amounts to 82.7\% of the total precipitation reaching the soil surface at heavy gradient slope. This significant water loss phenomenon could be higher in rainy season, whereas lower infiltrated water would be exposed due to low water infiltration capacity in oil palm plantation.

The low infiltration capacity at oil palm plantation at the stabilized saturation value of $K_s$ was less than 3 cm h$^{-1}$ (11). The lower rate of infiltrated water problem at the oil palm cultivation should be resolved for example by application of soil cover management and controlling of lower vegetation strata. The appropriate application techniques should be further identified and developed properly.

Average throughfall value under the oil palm canopy indicated no difference at the various gradient slopes. It ranged between 35.3-39.4 mm of the total observed precipitation. The throughfall values correspond to 36.4-40.1\% of the total observed rainfall in the dry season. The throughfall ratio to total precipitation in wet season could be higher due to the wetting capacity of crown or canopy interception.

The stemflow at oil palm plantation was very low less than 0.2 mm and corresponds to less than 2\% of total precipitation. The very low value of stemflow at all of observed oil palm trees could be associated with the low precipitation value in the dry season, whereas more precipitated water was absorbed by plant canopy as interception water than throughfall. Subtracted by throughfall, the value of canopy interception in dry season ranged 57.7-61.8 mm per 97.1 mm rainfall, which represents 59.4-63.6\% of total precipitation. This result was similar to measurement at the same region (11) located about 15 km far away from this experiment site. It was informed that the stemflow value at rainy season from November 2012-March 2013 with monthly precipitation value of 171-490 mm ranged from 0.84-3.07\% of total precipitation. Value of runoff, throughfall, stemflow, sunlight transmission rate and the infiltrated water during the observation time is presented at Table 2.

![Sunlight transmission rate through oil palm canopy](image-url)

Fig. 1 Schematic distribution of sunlight transmission rate through oil palm canopy by 12 equivalent right triangles per oil palm tree at four gradient slopes category
A relative high crown interception value was associated with the dry season condition.

Based on average evapotranspiration at oil palm at the equal site in the value of 4.7 mm day$^{-1}$, average water deficit of oil palm consumption at the observation site from precipitation rate was exposed to -0.9 mm day$^{-1}$ during 26 observation days. The contribution to supply of water is to be explored at the dynamics of soil moisture status and the groundwater status.

The distribution pattern of throughfall density under the palm canopy was associated with the distance from the oil palm trunk to the middle position among the trunks. The position closer to the trunk showed a lower throughfall value than in the middle position among the 3 trunks. To simplify the distribution pattern (Fig. 2), the following equation (1) shows the relation between the distance of the observation point with its throughfall value:

$$Y = 0.002x^2 + 0.1467x + 14.994$$

where $Y$ represents the value of throughfall passing through the oil palm canopy (mm) and $x$ represents the distance from the oil palm trunk (cm) from the total precipitation value of 97.1 mm.

### 4. Conclusion

Infiltrated water and runoff water as well at oil palm plantation indicate a major problem for the environment for biomass and bio-oil production. Infiltrated water amounted to 32.3 mm at the slight gradient slope and only 6.8 mm at the heavy gradient slope was exposed from total precipitation value of 97.1 mm in dry season. Total throughfall in average value of 38.1 mm at all gradient slopes showed a critical value for water balance consideration. The runoff at heavy gradient slope reached the value of 82.7 mm per 100 mm of throughfall value or the total precipitation reaching the soil surface. Canopy covering rate with sunlight transmission ranging from 11.9% - 13.5% had no significant effect on throughfall value at all of gradient slopes category. Problem-solving for the higher rate of runoff and lower rate of infiltration requires further quality improvement of oil palm cultivation system.

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