Jurnal Kejuruteraan Awam 15(1): 24-33(2003)

THROUGHFALL, STEMFLOW AND INTERCEPTION LOSS OF OLD RUBBER TREES

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Abstract: An interception study of old rubber trees was carried out in Skudai, Johor. Out of 35 rainfall events recorded, only 28 produced measurable throughfall and stemflow. Throughfall and stemflow comprised 87% and 1.1% of the total rainfall, respectively. These resulted in interception loss of 12.1% of the rainfall. Both throughfall and stemflow showed strong linear correlations against daily rainfall with r^2 values of 0.99 and 0.84, respectively. The wettest month of November registered the highest interception, both in term of actual value and as the percentage of rainfall. The canopy storage capacity (S_t), trunk storage capacity (ρ_t) and the fraction of rainfall that goes to trunk (ρ_s) were 0.11 mm, 0.017 mm and 6.45 mm, respectively.

Keywords: *Throughfall; Stemflow; Interception Loss; Canopy Storage Capacity; Trunk Storage Capacity.*

Abstrak: Kajian pintasan curahan ke atas pokok getah tua telah dijalankan di Skudai, Johor. Dari 35 kejadian hujan yang direkod, hanya 28 menghasilkan curahan terus dan lelehan batang. Sebanyak 87% dan 1.1% dari jumlah curahan membentuk curahan terus dan lelehan batang, masing-masing. Ini menghasilkan jumlah pintasan sebanyak 12.1% dari curahan. Kedua-dua curahan terus dan lelehan batang menunjukkan kaitan yang kuat terhadap curahan dengan nilai r^2 masing-masing 0.99 dan 0.84. Bulan yang paling basah (November) menghasilkan nilai pintasan tertinggi dari segi jumlah sebenar dan nilai peratusan hujan. Nilai kapasiti simpanan kanopi (S_t), kapasiti simpanan dahan (ρ_t) dan pecahan hujan yang mengalir ke batang (ρ_s), masing-masing 0.11 mm, 0.017 mm and 6.45 mm.

Katakunci: *Curahan Terus; Lelehan Batang; Kehilangan Pintasan; Kapasiti Simpanan Kanopi; Kapasiti Simpanan Batang.*

1. Introduction

Interception is a process whereby rainfall is intercepted by vegetation or buildings before reaching the ground surface. This is an important component in hydrological analysis and modelling. Interception also determines catchment water yield and runoff generation processes (Schellekens, 2000). In the tropics the source of water entering a catchment system is virtually from rainfall, except in the case of coastal fog belt and montane belt forests (Bruijnzeel, 1990). When the rainfall is intense enough and exceeded the canopy storage capacity, the excess rainwater drips off as throughfall and along branches and stem as stemflow. Depending on the canopy characteristics, a significant amount of rainwater could be intercepted and immediately evaporated back to the atmosphere once the rain has ceased. This fraction of rainwater is termed interception loss. Rainfall interception studies in the tropics have been confined mostly to natural and plantation forest ecosystems (e.g. Herwitz, 1985; Bruijnzeel and Wiersum, 1987; Zulkifli et al, 2003). With rapid conversion of natural forest to other landuse, reliable estimates of interception loss from other major landuse are equally important. This could contribute to a better scientific understanding leading to sound management of water and land resources.

In Malaysia, rubber (*Hevea brasiliensis*) plantation is still one of the major landuse after forest and oil palm. Besides producing latex, rubber wood is used for making high quality furniture, mainly for export. Despite the large contribution of rubber industries to socio-economic development, very little work has been documented on the hydrological impacts of rubber plantation. The aim of this paper is to provide an estimate of interception loss from old rubber stands. The results are put in perspective by comparing interception values from other plantations and forested sites.

2. Methodology

This study was carried out over three months between October and December 2001. The site is located within the UTM's campus at Skudai, Johor. The rubber trees were about 35 years old. Throughfall and stemflow were measured in a small plot (11 m x 13 m), consisting of 11 rubber trees. Each tree was numbered and seven of them were randomly selected for stemflow measurement. The plot was further divided into 143 grids for measuring throughfall. Nine sets of throughfall collectors were randomly located within the 143 grids (Photo 1). Each set consists of a 2002 mm diameter funnel with 5 cm rim and a collecting tank. These devices were roved to different grids every biweekly to account for spatial variation in throughfall (Llyord and Marques-Filho, 1998). Stemflow was intercepted using a rubber collar, spirally fitted along the stem and routed into a 25 liter collecting tank (Photo 2). The tanks were inspected and emptied on a daily basis and the volume of rainwater was measured. Rainfall in the open space was also measured using the similar device for throughfall measurement.

Since the canopy of the trees are dense enough and almost entirely enclosed the aerial view of the plot, throughfall in unit depth (mm) was obtained by simply dividing the volume of collected water by the receiving area of the funnel. The values for all the nine throughfall sets were then averaged out on a daily basis. Stemflow was calculated based on the following formula (Bo et al, 1989)

$$S = 1/2\left[\left(D_1 + D_2\right)/D_1 + \left(B_1 + B_2\right)/B_1\right]\left(V_c / A\right) \tag{1}$$

Where S is stemflow (mm)
D_1 is total number of trees in the plot
D_2 is number of uncollared trees
B_1 is total basal area of all trees (m^2/plot)
B_2 is basal area of uncollared trees (m^2/plot)
Vc is total volume of stemflow (liter/plot)
A is plot size (m^2)

Photo 1: Interception plot under old rubber stands at UTM's campus.

Photo 2: Spirally fitted rubber collar for intercepting stemflow.

3. Results and Discussion

Out of 35 rainfall events recorded during the study period, only 28 events produced measureable throughfall and stemflow. Total rainfall between October and December, 2001 was 548 mm with November being the wettest month, recorded 262 mm or 47.9% of the total rainfall (Table 1). The daily rainfall was positively skewed with values of less than 10 mm constituted about 46% of the total event (Figure 1). As such the median values were also computed in addition to the mean and standard deviation. Throughfall comprises 86.7% of the rainfall or 475.2 mm. Only very small fraction of the rainwater appeared as stemflow that was 6.23 mm or 1.14% of the rainfall. Interception loss, calculated as the difference between the sum of throughfall and stemflow from the total rainfall was 66.5 mm. This made up about 12% of the rainfall.

Table 1: Summary statistics of rainfall, throughfall and stemflow between October and December 2001.

	Rainfall (mm)	Throughfall (mm)	Stemflow (mm)
No of event	35	28	28
Mean	19.6	17.0	0.22
Median	18.0	14.9	0.10
Standard deviation	13.7	12.3	0.20
Range	1.0 -54.4	1.8-48.4	0.01 -1.03
Total	548.0	475.3	6.23
% of rainfall		86.7	1.14

Table 2: Monthly rainfall, throughfall and stemflow under old rubber trees.

	Oct	Nov	Dec	Total
Rainfall (mm)	152.6	262.3	133.0	548.0
Stemflow (mm)	2.02	3.29	0.91	6.22
Throughfall (mm)	132.6	224.7	118.0	475.3
Interception (mm)	18.05	34.33	14.12	66.5
Interception as % of rainfall	11.8	13.1	10.6	12.1

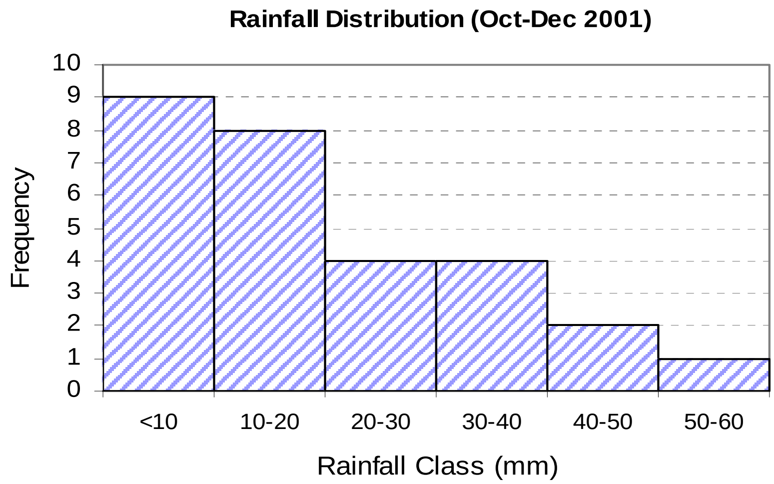

Figure 1: Rainfall distribution at the study site between October and December 2001.

Daily throughfall and stemflow were strongly correlated against rainfall with r^2 values of 0.99 and 0.85, respectively (Figures 2 & 3). This suggests that throughfall and stemflow at the present site can be comfortably predicted from rainfall data alone using the following equations:

Throughfall : $T = -0.551 + 0.895P$ (2)
(n =28, r^2= 0.99, p <0.001)
Stemflow: $S = -0.11 + 0.017P$ (3)
(n = 28, r^2 = 0.85, p <0.001)

The amount of rainfall required to saturate the canopy before throughfall starts is termed as canopy storage capacity (Gash and Morton, 1979). The value can be determined by regressing throughfall against daily rainfall. A canopy storage capacity of 0.62 mm was obtained, derived from the intercept value on the throughfall axis when rainfall is equal to zero. Estimates of canopy storage capacity vary with the density and the structure of the canopy, the presence of epiphytes, the leaf area and the amount of woody surface area of the bark (Herwitz, 1985; Pathak et al, 1985; Veneklas and van Ek, 1990). Reported values of canopy storage capacity for tropical forest range between 0.6 and 0.9 mm (e.g. Jackson, 1975; Llyod and Marques-Filho, 1988; Wong, 1991; Zulkifli et al, 2003). Smaller estimates of 0.5 to 0.6 mm were found under young *Acacia auriculiformis* plantations in Java (Bruijnzeel and Wiersum, 1987).

Similar to throughfall, stemflow can only be generated after rainfall has exceeded a certain amount. For stemflow, this is represented by the trunk storage capacity (S_t) which can be estimated from a linear function of stemflow on incident rainfall (Gash and Morton, 1978). A trunk storage capacity of 0.11 mm was found, that is the extended stemflow value when gross rainfall is set to zero. The slope coefficient of the regression line represents the conversion rate for the fraction of rainfall in the canopies that goes to the trunk, denoted as ρ_t. In this study a ρ_t value of 0.017 was obtained. Another related parameter is the antecedent rainfall for initiating stemflow which is given by the gross precipitation value when stemflow is equal to zero (Woo et al, 1989). On average, a gross rainfall of 6.45 mm is required to fully wet the canopies and trunk before stemflow is produced.

The difference between the sum of throughfall and stemflow from the gross rainfall represents the interception loss or the portion of rainwater that is returned back to the atmosphere immediately after the rain has ceased. Monthly interception loss ranged from 10.6% to 13.1% of the rainfall. The highest interception loss was recorded in November which was the wettest month and the lowest in the drier month of December. For incident rainfalls of greater than 5 mm, the interception loss ranged from 4% to 28%. The interception tended to be higher for smaller storms and decreases with storm size (Figure 4). This suggests that for a similar amount of total rainfall, months with more frequent rain but with smaller intensity would produce higher percentage of interception loss compared to in months with less frequent but more intense rainfall.

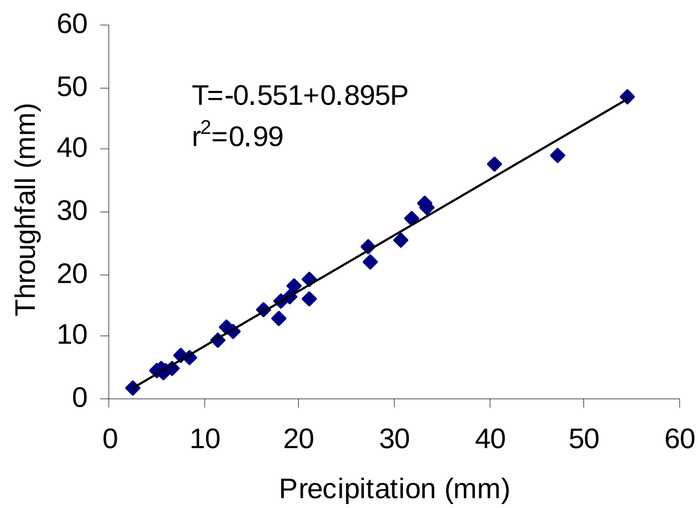

Figure 2: Regression of throughfall against rainfall.

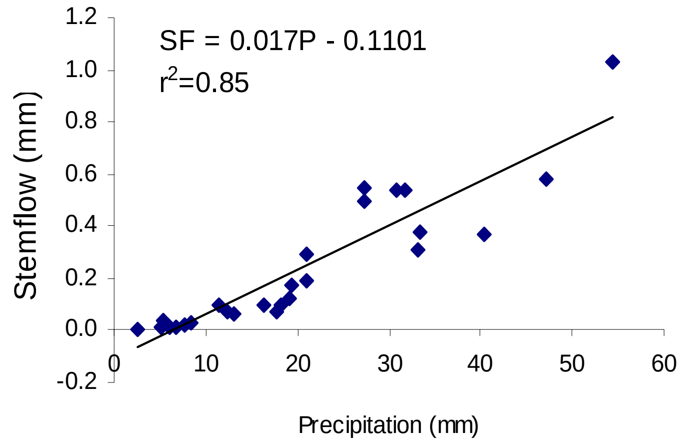

Figure 3: Regression of stemflow against rainfall.

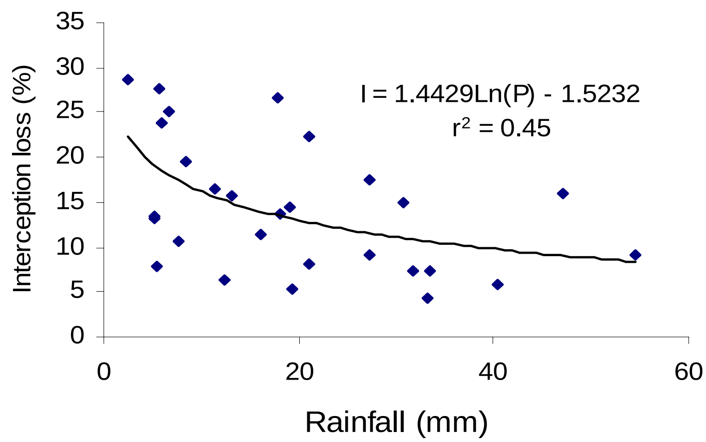

Figure 4: Percentage of interception against rainfall.

The relationship between interception loss against daily rainfall was tested using three regression models namely, linear, quadratic and logarithmic. Interception loss was only moderately correlated against rainfall with r^2 for the three models range from 0.45 to 0.49. The following logarithmic model was selected because interception, *I* tends to reach a constant value as the rainfall size, *P* increases (Figure 4).

$$I = 1.443\ln(P) - 1.523 \quad (4)$$

($n=28$, $r^2=0.45$, $p<0.001$)

Table 3: Interception losses in forested and plantation sites in Malaysia.

Location	Vegetation type	T_f (%)	S_f (%)	I (%)	A.P (mm)
1. Pasoh, Negri Sembilan	Lowland rain forest	77.6	0.6	21.8	2381
2. Ulu Gombak, Selangor	Lowland hill forest			<18	2000
3. Puchong, Selangor	Secondary lowland rain forest	72.2	0.89	26.9	
4. Berembun, Negri Sembilan	Lowland rain forest	73.0	0.4	26.6	3786
5. Danum Valley, Sabah	Lowland rain forest	80.7	1.9	17.4	3276
6. Danum valley, Sabah	Lowland rain forest	81.0		19.0	3257
7. Bukit Tarek, Selangor	Secondary lowland rain forest	85.1	1.3	13.6	2698
8. Kemasul, Pahang	*Acacia mangium*				
	62 months	56.5	4.3	39.3	2000
	56 months	61.5	3.6	35.4	
9 Negri Sembilan	*Hevea brasiliensis*	80.8	0.4	15.2	2000
		82.8	1.5	15.7	
10. This study	*Hevea brasiliensis*	86.73	1.13	12.14	545 (3 months)

Notes: T_f = throughfall; S_f = stemflow; I = interception loss; A.P. = annual precipitation

References**:** 1.Manokaran (1979); 2. Kenworthy (1969); 3. Nik *et al*., (1979); 4. Baharuddin (1989); 5. Wong, (1991); 6. Burghouts (1993); 7. Zulkifli et al, 2003; 8. Lai and Osman (1989); 9. Teoh (1977)

Based on the reported studies in Malaysia, the interception loss at the present site seemed to be the lowest (12.2%) (Table 3). However, this value is close to the interception losses in rubber plantations (15.2% and 15.7%) as reported by Teoh (1977). In general, interception loss in rubber plantation is lower than in forested sites (13.5% to 26.9%). Apparently young stands of *Acacia mangium* recorded the highest interception loss, up to 39.3% of the rainfall (site 8, Table 3). Besides rainfall, the large variation in the interception loss could be attributed to the structure and density of the canopy. The higher interception loss for tropical forests is rather expected due to their thick and multilayer canopy structure that is capable of storing larger rainwater before throughfall and stemflow can be initiated. Conversely, rubber plantation is basically a single crop with less dense and quite uniform canopy structure.

While such a large variation in interception loss could be real, Bruijnzeel (1990) cautioned that the diversity and inconsistency of methods employed for measuring throughfall and stemflow in forested and plantation sites could contribute to discrepancy in the interception values. He concluded that interception estimates could be improved by frequently shifting throughfall measurement devices.

4. Conclusion

Despite a rather short observation period, the throughfall, stemflow and interception values obtained from this study are comparable with earlier findings for rubber trees. About 87% of the rainwater reaches the ground surface as throughfall and only a minor fraction (1.2%) as stemflow. The remaining 12% of the rainfall was intercepted by the canopy and evaporated back to the atmosphere. As throughfall and stemflow were strongly correlated against daily rainfall, it is possible to extrapolate interception loss for a longer duration. However, it would be interesting to prolong the observation period as interception loss may show significant temporal variation. Rubber trees are known to shed leaf around February to April every year, therefore may intercept less rainfall during this time. Another relevant aspect to be examined is the interception loss by undergrowth and litter layer. In view of the various clone of rubber tree currently planted, it is worthwhile to replicate interception study to cover a wider range of clone and planting density.

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