Journal of Engineering and Applied Sciences 12 (21): 5572-5577, 2017
ISSN: 1816-949X

Preliminary Study on Tropical Forest Canopy Interception

[1]Azinoor Azida Abu Bakar and [2]Muhammad Khairudin Khalil
[1]Faculty of Civil Engineering, Universiti Teknologi MARA, Cawangan Johor,
Kampus Pasir Gudang, Bandar Seri Alam, 81750 Masai, Johor, Malaysia
[2]Department of Irrigation and Drainage, Bangunan Dato' Muhamad Ibrahim Munsyi,
Pusat Pentadbiran Kota Iskandar, 79626 Nusajaya, Johor, Malaysia

Abstract: The rainfall interception loss in a tropical forest was investigated in this study. The 9 month data was collected with 78 rainfall events, 73 events with throughfall and 72 events produced stemflow. Two study plots were selected at Bukit Lagong Forest Reserve, Kepong, Selangor. The measured interception losses are compared with the calculated intercepted losses compute by using original Gash Model. The study show that the measured interception loss for Plot 11 and 12 is 305.8 mm and 269.11 and the calculated interception loss is 364.27 and 318.8 mm, respectively.

Key words: Gash Model, interception loss, rainfall, stemflow, throughfall, compared

INTRODUCTION

Studies had been done on interception loss for a few decades. In hydrological studies, interception loss is a major characteristic with effects on site and catchment water balance (Dijk and Bruijnzeel, 2001). Interception loss can be categorised as interception loss in forest due to the canopy structure and interception loss of building structure. This study focus on the interception loss due to the canopy structure in the tropical forest. Interception loss can be referred to the amount of rainfall intercepted, stored and evaporated from the canopy (Deguchi *et al*., 2006). In other word, interception loss can be defined as rain that fall to vegetation and evaporates without reaching the ground.

In this study, the Gash Model is used to compute the interception loss. The model was developed to make the prediction of interception loss on rainfall and canopy characteristics (Deguchi *et al*., 2006). The storm-based analytical model described by Gash (1979) demonstrated that the evaporation of rainfall intercepted by forest canopies can be estimated from the forest structure, the mean evaporation and rainfall rates and the rainfall pattern (Gash *et al*., 1995).

There are several parameters that have to be determined in order to adapt Gash Model to compute the interception loss. Precipitation is among the important parameters where it is influenced by the canopy structure. Changes in canopy structure will alter the canopy Storage capacity S direct throughfall fraction (p) and the ratio of Evaporation to the Rainfall intensity ($\bar{E}/\bar{R}$) that influences the interception Loss (l) (Pypker *et al*., 2005).

The focus of this study is to gain information on interception loss of canopy structure by the tropical forest in Malaysia. The finding will be compared with the calculated value determine from original Gash Model (Gash and Morton, 1978).

MATERIALS AND METHODS

Study area: This study was conducted at Bukit Langong Forest Reserve at Forest Institutional Research Malaysia (FRIM) reserve forest Kepong, Selangor. Geographical location is 3°15'N latitude and 101°37'E longitude. The FIRM forest compound is 485 ha equally to 4,850,000 m^2 and it is covered with primary lowland mixed dipterocarp forest and 78% of this forest reserve planted forest. Figure 1 shows the boundary of Bukit Lagong forest belongs to FRIM and the shaded area which is denoted of Plot 11 and 12 indicated the locations of the study area.

The 2 plots (Plot 11 and 12) were then measured in an area of 400 m^3 (20×20 m) where the interception loss canopy cover study was being conducted. Within the area of study for both locations, trees above 10 cm dbh (diameter at breast height) were identified, tagged and numbered. For Plot 11, 21 trees have dbh greater than 10 cm whereas Plot 12, 20 trees. Plot 11 is dominated by *Kulim* species while Plot 12 is occupied with several species, namely *Keladan, Keruing, Simpoh* and *Mempisang*.

Canopy structure measurement

Gross rainfall (P_g) measurement: Gross rainfall defines as the precipitation drops into the catchment or in an

Corresponding Author: Azinoor Azida Abu Bakar, Faculty of Civil Engineering, Universiti Teknologi Mara, Cawangan Johor, Kampus Pasir Gudang, Bandar Seri Alam, 81750 Masai, Johor, Malaysia

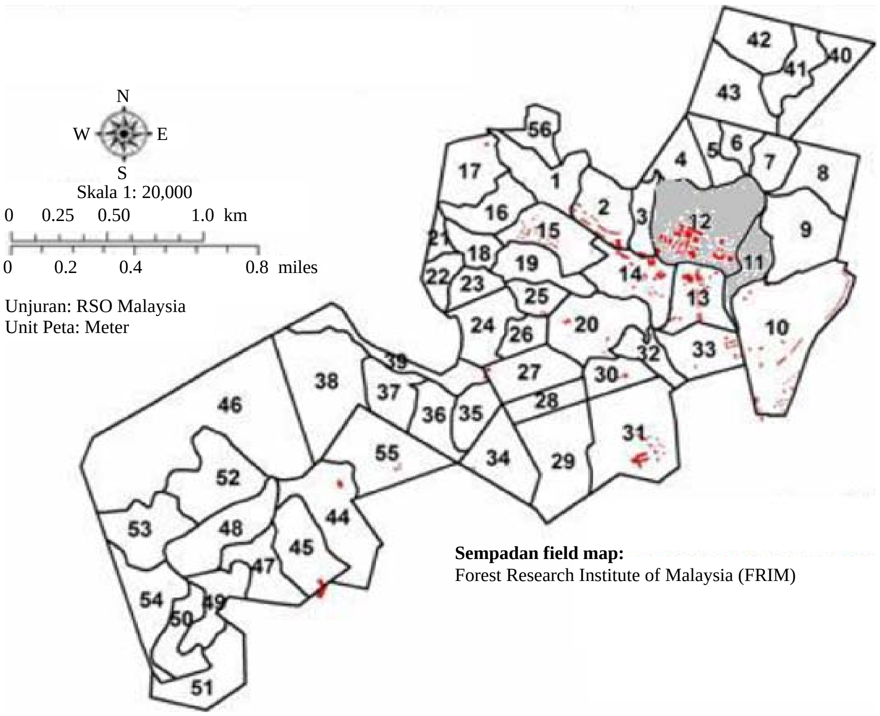

Fig. 1: Location of the study area and FRIM forest boundaries

open area. In this study, the gross rainfall measured using the manual collector system where rain gauges were placed within 30 m from the study area and the rainfall data were collected in daily basis.

Throughfall (T_f) measurement: The throughfall was measured by using 25 collectors with 225 mm diameter and 200 mm deep for both plots. The collectors of throughfall were placed at each of the plot grids with 5 m interval. The volume of throughfall was measured by using measuring cylinder and it was collected on daily basis.

Stemflow (S_f): The measurement of stemflow was done at the same plots as throughfall measurement. Total 15 trees for each plot were randomly selected based on the dbh and the eased of access in setting up the stemflow collar. The collar method was adapted in measuring the stemflow where selected trees were fitted with spiral rubber collar.

There were some problems occurred during the study period where on 14 April 2012 there is some changes in stemflow tank collector which actual tank collector capacity of 5.5 L was changed to 10 L tank and replaced again with 25 L tank capacity due to the overflow of stemflow from the selected trees for this study. In August 2012 there was no data collection in both sites because the research assistance was on leave:

$$\text{Stemflow}, S_f = \frac{1}{2}\left(\frac{(D_1+D_2)}{D_1}+\frac{(B_1+B_2)}{D_2}\frac{V_c}{A}\right) \quad (1)$$

Where:
D_1 = Total number of trees inplot
D_2 = Total number of uncollared trees
B_1 = Total basal area of all trees (m^2/plot)
B_2 = Basal area of uncollared trees (m^2/plot)
V_c = Total basal area of all trees
A = Plot size (m^2)

RESULTS AND DISCUSSION

Gross rainfall, P_g: There are 78 events of gross rainfall recorded in both locations (Plot 11 and 12). Out of 78 events of gross rainfall only 73 events in (Plot 11) and 72 in (Plot 12) events are produce measured throughfall and stemflow in and are producing measured throughfall and stemflow. The minimum gross rainfall recorded is 1.4 mm on September 28 whereas the extreme rainfall event recorded is 109.7 mm on April 18, 2012.

Figure 2 shows that the monthly summary of gross rainfall, throughfall, stemflow and interception loss within the study period. The wettest seasons was recorded on October until December which contributes to 1941 mm of total rainfall within the study periods. Figure 2 shows the bar chart of monthly gross rainfall for both plots. The

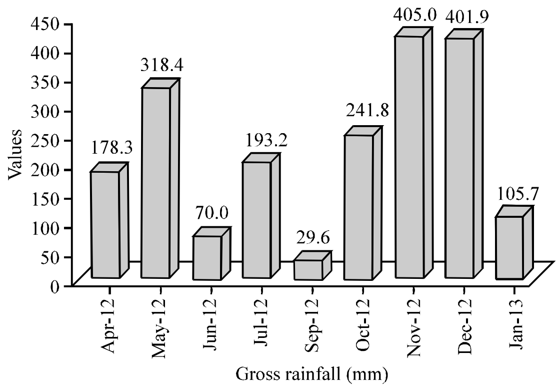

Fig. 2: Monthly gross rainfall bar chart Plot 11and 12

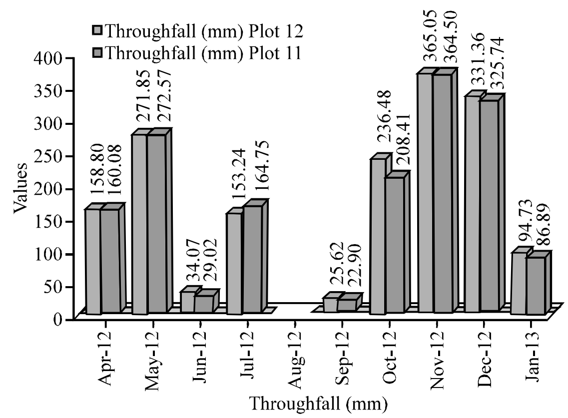

Fig. 3: Monthly throughfall bar chart of Plot 11 and 12

highest monthly rainfall recorded was 405 mm in November, 2012 whereas the lowest was 70 mm in June.

Throughfall coefficient, p: Throughfall coefficient, p was determined by using linear regression of gross rainfall against throughfall where the slope indicate prediction of p. The highest troughfall recorded for Plot 11 and 12 was on April 18, 96.33 and 98.24 mm whereas the small value was recorded as 0.13 and 0.11 mm, respectively. Total throughfall for Plot 11 and 12 recorded within this study period was 1635 or 84.2 and 1671.2 mm or 86.1% of the gross rainfall. The monthly throughfall data is shown in Fig. 3.

In the regression analysis, the threshold value of throughfall is >3 mm which assume sufficient enough to saturate the canopy (Carlyle-Moses and Price, 1999). The threshold value for this study is higher than the other study because tropical forest canopy cover structure is larger, therefore contributes to high interception loss (Asdak *et al*., 1998).

Figure 4-7 show the linear regression between these two components of interception loss. Based on the regression, the r^2 value for Plot 11 and 12 was 0.8626 and 0.8449, respectively. The value of throughfall coefficient, p was 0.9269 for Plot 11 and 0.8378 for Plot 12. The present site can be comfortably predicted by Eq. 2 and 3:

$$p_g = 0.9269T_f + 7.5 \text{ for plot11} \left(r^2 = 0.8626\right) \quad (2)$$

$$P_g = 0.9692T_f + 4.122 \text{ for plot 12} \left(r^2 = 0.8449\right) \quad (3)$$

Canopy Storage capacity, S: Canopy storage capacity was obtained from linear regression of throughfall and gross rainfall. The negative interception of the regression

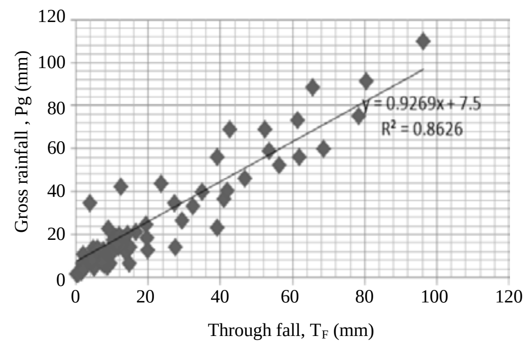

Fig. 4: Linear regression of gross rainfall against throughfall to predict the throughfall coefficient for Plot 11

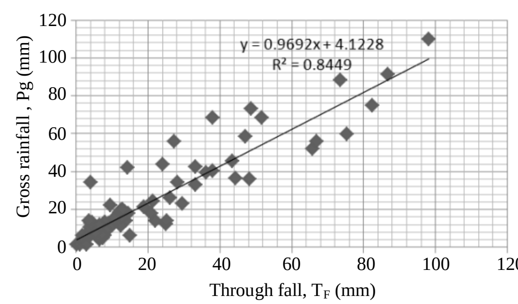

Fig. 5: Linear regression of gross rainfall against throughfall to predict the throughfall coefficient for Plot 12

shows the value of canopy storage capacity, S. In this study, the canopy storage capacity for Plot 11 was 0.4981 and 0.2720 for Plot 12.

The canopy storage capacity can be presented by Eq. 4 and 5:

$$T_f = 0.083P_g - 0.498 \text{ for plot11} \left(r^2 = 0.876\right) \quad (4)$$

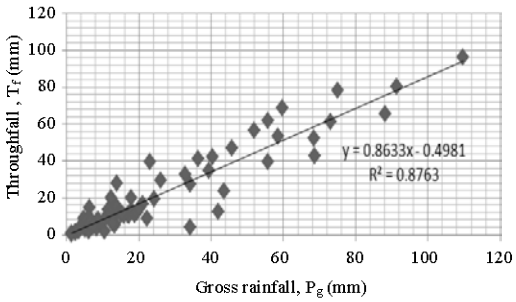

Fig. 6: Linear regression of throughfall against gross rainfall to predict the canopy storage coefficient for Plot 1

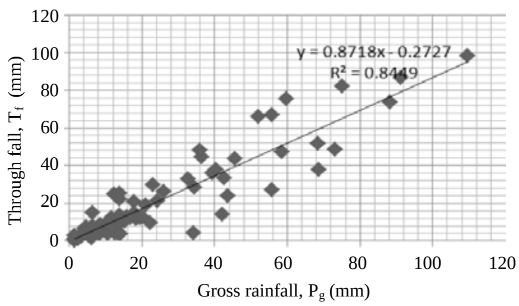

Fig. 7: Linear regression of throughfall against gross rainfall to predict the canopy storage coefficient for Plot 12

$$T_f = 0.8718P_2 \text{ for plot12} \left(r^2\, 0.845\right) \quad (5)$$

Stemflow: The total stemflow recorded for both plots was 0.255 (0.013%) for Plot 11 and 0.695 (0.032%) of the total gross rainfall within the study period. Based on the monthly stemflow as shown in Fig. 8, highest stemflow recorded was 0.059 for Plot 11 and 0.133 for Plot 12, respectively.

In this study, the value of canopy storage capacity coefficient and trunk storage c apacity coefficient for Plot 11 were 0.0014 for S_t and 0.002 for P_t as the negative intercept on stemflow axis and the gradient of the linear regression between stemflow against gross rainfall with r^2 value is 0.746 whereas in Plot 12 the value of canopy storage capacity coefficient, s_t and trunk storage capacity coefficient, P_t were 0.003 and 0.0025, respectively and r^2 value is -0.0012 (Fig. 9).

Interception Loss, I: Interception losses values are determined in two different ways. Figure 10 and 11 determined from the measured data and calculated by applying Gash Model. The measured interception loss

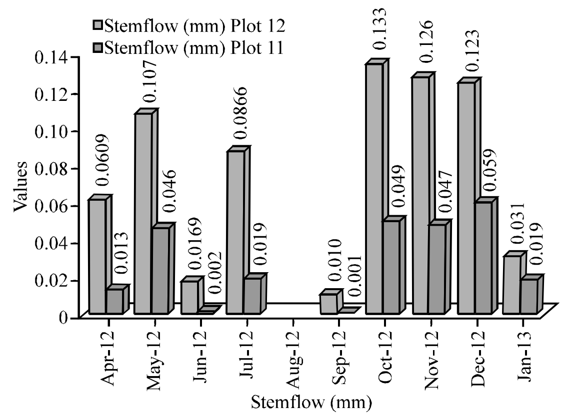

Fig. 8: Monthly stemflow bar chart of Plot 11 and 12

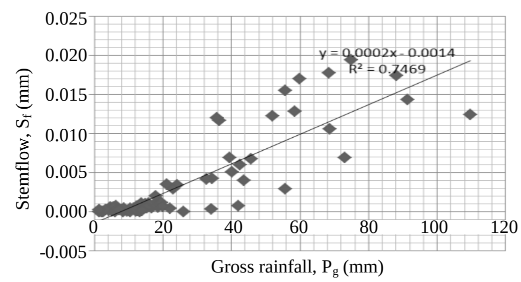

Fig. 9: Linear regression of stemflow against gross rainfall to predict the canopy storage coefficient, s_t and trunk storage coefficient for p_t Plot11

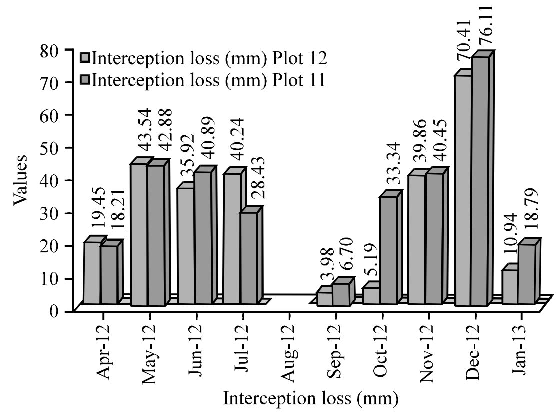

Fig. 10: Monthly interception losses within the study periods for Plot 11 and 12

obtained from the direct measurement for both Plot 11 and 12 were 305.8 or 15.8 and 269.11 mm or 13.5% of the total gross rainfall.

The value of interception loss ranging from -16.27 to 30.59 mm for both plots. The negative interception value due to the value of throughfall was higher than the gross

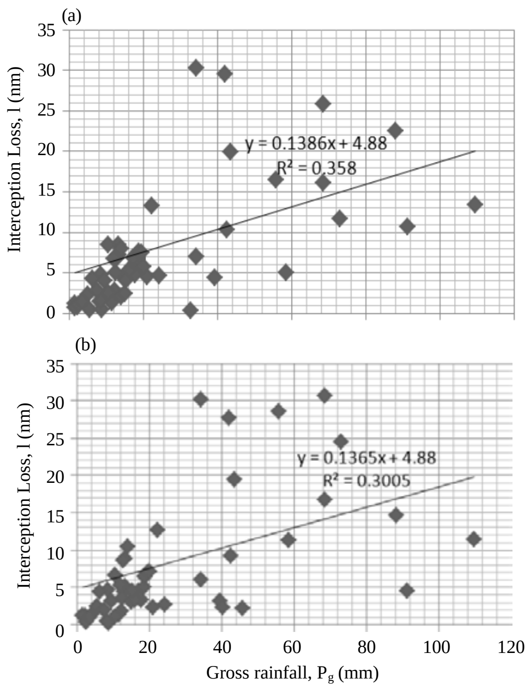

Fig. 11: Regression of interception loss against gross rainfall to predict the ratio of evaporation rate and mean rainfall for: a) Plot 11 and b) Plot 12

rainfall. It may occur due to overestimation of throughfall or underestimation of gross rainfall. Throughfall collector that was placed under the trees with large leaves could contribute to this problem.

The finding of this study was compared with another study. The study that has been done at Air Hitam Forest Reserved, Selangor showed that the interception loss determine was 26.9% (Nik *et al*., 1979). Meanwhile, an estimation of 18% interception loss of rainforest near the Kuala Belalong Field Studies Centre in Brunei was found in the other study. This proved that the interception lose in this study was quite close to the other study which they both were conducted in tropical rainforest.

CONCLUSION

Based on the results obtained from the study, the following conclusions have been made. Artificial tropical forest in Bukit Langong poses high density of canopy cover structure that produces high interception loss and influences the natural hydrological cycle in the forest.The calculated study of interception loss of Bukit Lagong Reserved Forest is 364.27 mm for Plot 11 and 318.07 mm for Plot 12, meanwhile, the measured interception loss of Plot 11 and 12 is 305.8 and 269.11 mm, respectively. The result of calculated Gash Model and measured interception loss were compared as to meet the objective of this study. The results indicated that the Gash Model produces higher value than the measured value. The results were then compared in percentage form in which Plot 11 poses 19.1% and Plot 12, 18.2%, compared to the measured value.

RECOMMENDATIONS

There are some recommendations made for this study: for an improved data analysis and a better result of Gash Model parameter analysis, the period of data collection must be extended. On the other hand, 5 years was spent by the other study to obtain their result in this related field.

To improve this study on the determination of Gash Model parameters, the study of Leaf Area Index (LAI) must be considered in order to obtain the details result on the stemflow and throughfall analysis. The Leaf Area Index may be different based on the trees species thus it may contribute to different values of data collection. It also has a significant correlation between the canopy cover structures. As the Leaf Area Index increased, the canopy cover structure also increased and would give a significant results on the interception loss.

Seasonal changes should also be considered in this study. This is due to the fact that they will be a month in which the rainfall distribution in tropical rainforest is higher. Basically, wet season will be from October until January whereas dry season is from July until September. These situations too will influence the rainfall that later affects the data collection.

ACKNOWLEDGEMENTS

The first researcher acknowledges financial support from the Ministry of Higher Education Malaysia through a Fundamental Research Grant Scheme (FRGS) (Grant 600-RMI/FRGS 5/3 (18/2015). The researchers would like to thank FKA UiTM, RMI UiTM, JPS and FRIM for their support to this project.

REFERENCES

Asdak, C., P.G. Jarvis and P.V. Gardingen, 1998. Modelling rainfall interception in unlogged and logged forest areas of Central Kalimantan, Indonesia. Hydrol. Earth Syst. Sci. Discuss., 2: 211-220.

Carlyle-Moses, D.E. and A.G. Price, 1999. An evaluation of the gash interception model in a northern hardwood stand. J. Hydrol., 214: 103-110.

Deguchi, A., S. Hattori and H.T. Park, 2006. The influence of seasonal changes in canopy structure on interception loss: Application of the revised Gash Model. J. Hydrol., 318: 80-102.

Dijk, V.A.I.J.M. and L.A. Bruijnzeel, 2001. Modelling rainfall interception by vegetation of variable density using an adapted analytical model: Part 1, model description. J. Hydrol., 247: 230-238.

Gash, J.H., C.R. Lloyd and G. Lachaud, 1995. Estimating sparse forest rainfall interception with an analytical model. J. Hydrol., 170: 79-86.

Gash, J.H.C. and A.J. Morton, 1978. An application of the Rutter Model to the estimation of the interception loss from Thetford Forest. J. Hydrol., 38: 49-58.

Gash, J.H.C., 1979. An analytical model of rainfall interception by forests. Q. J. Royal Meteorol. Soc., 105: 43-55.

Nik, M.M., M.B. Hamzah and S. Ahmad, 1979. Rainfall interception, throughfall and stemflow in a secondary forest. Pertanika, 2: 152-154.

Pypker, T.G., B.J. Bond, T.E. Link, D. Marks and M.H. Unsworth, 2005. The importance of canopy structure in controlling the interception loss of rainfall: Examples from a young and an old-growth Douglas-fir forest. Agric. For. Meteorol., 130: 113-129.