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Annual canopy interception at artificial lowland tropical forest

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Abstract

The objective of this paper is to present the application of interception model developed in artificial lowland tropical forest. This model estimates annual canopy interception loss with temporal resolution effects. A 12-month data from 2 plots in study area were collected and the measured interception loss was compared with results calculated using original Gash, modified Gash and the interception model developed. The results show that the model can be applied to estimate annual interception loss.

1 Introduction

Canopy interception is the rainwater that is stored on the leaves and branches of a tree which is subsequently evaporated. Canopy interception can be calculated by measuring rainfall above the trees or measured in an open area nearby (gross rainfall, P) and subtract the throughfall (T_f) and stemflow (T_s) (Gerrits and Savenije, 2011). There are several methods to measure canopy interception. The most commonly used interception models are the conceptual model of Rutter et al. (1971) and the analytical model of Gash (1979) or revisions of these models, the modified Gash et al. (1995).

The most commonly used method is to measure rainfall above the canopy and subtract throughfall and stemflow (Helvey and Patric, 1965). However, the problem with this method is that the canopy is not homogeneous, which causes it to be difficult to obtain representative throughfall data. Using multiple rain gauges under the canopy (Helvey and Patric, 1965; Keim et al., 2005; Gerrits et al., 2009) minimises this problem. Sometimes the collectors are moved around to achieve a better representation of throughfall (Lloyd and Marques, 1988; Tobón-Marin et al., 2000; Manfroi et al., 2006; Ziegler et al., 2009). Another method to overcome the problem with the spatial distribution of the canopy was introduced by Calder and Rosier (1976) and applied by Shuttleworth et al. (1984), Calder et al. (1986), and Calder (1990). They covered the forest floor with plastic sheets and collected the throughfall. The disadvantage of this

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method is that if the study is conducted over long period of time, irrigation is required. Otherwise, at the end of the study, the trees will dry out and may even die due to water shortage. This overview was mentioned by Gerrits and Savenije (2011).

Several models have been developed to simulate forest interception. Almost all of these models concentrate on canopy interception, sometimes including stem interception (Rutter et al., 1971; Gash, 1979; Calder et al., 1986; Keim et al., 2005). In principle these models can be expanded to include forest floor or any surface interception as well. A more detailed overview and comparison can be found in Muzylo et al. (2009). As Muzylo et al. (2009) pointed out; the few comparative studies, failures to validate models and lack of consideration given to uncertainties in parameters and measurements are the most outstanding drawbacks. Furthermore, the uncertainties in model input data are hardly taken into account in rainfall interception modelling. For example, Rutter model needs hourly or rather shorter resolution data set for the model to be applied. Unfortunately, high-resolution data are not always available especially in developing countries because data collections are costly. Moreover, lack of canopy characteristics and meteorological data may also affect the estimation of interception values (Azinoor et al., 2012a).

In this study, an annual interception loss using minimum inputs interception model was applied. The model already takes into account the temporal resolution effects of the precipitation data available. For validation, the model was applied to artificial lowland tropical forest and were compared with calculated values obtained from original Gash model and revised Gash model.

2 Methodology

2.1 Study area

This study was conducted at Bukit Lagong Forest Reserve, Kepong, Selangor located at 3°15′ N latitude and 101°37′ E longitude. This 485 ha forest reserve is governed by

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Forest Research Institute of Malaysia (FRIM) and it is covered with primary lowland mixed *dipterocarp* forest which 78 % of this forest reserve is planted forest (Azinoor et al., 2012b). Figure 1 shows the boundary of Bukit Lagong forest governed by FRIM and the shaded area indicated the locations of study area.

In this study, two plots, namely Plot11 and Plot12 were selected as the plots for study areas. Each plot has an area of 400 m^2 (20 m × 20 m) and all trees above 10 cm dbh (diameter at breast height) within the plots were identified, tagged and numbered. For Plot11, 21 trees with dbh more than 10 cm have been identified and another 20 trees for Plot12. Plot11 is dominated by *Kulim* species while Plot12 is mainly occupied by *Kledan, Keruing, Simpoh and Mempisang* species. The highest canopy height may rise up to 17 and 29.5 m for Plot11 and Plot12, respectively. Stand Visualization System (SVS) has been used to visualize the forest standing study area in 3-D view based on the selected trees over the area of interest.

2.2 Rainfall, P

Gross rainfall, P_g is defined as the precipitation that drops into a catchment and measured above the forest canopy or in an open area. Gross rainfall is collected by placing a gauge in the elevated place so that no water from other process will get in the gauge that provides erroneous data. In this study area, there is an existing rainfall station owned by Malaysia Meteorological Department (MMD). The gauge is located at open area about 30 m from the plots. The data was collected on daily (24 h) basis.

2.3 Throughfall, T_f

Throughfall, T_f describes the process of precipitation passing through the plant canopy during the rainfall event. Throughfall may be the water that drips after intercepted by the tree leaves and branches or the falling rainfall that reach the ground surface directly through the canopy gap without intercepting the canopy. In this study, throughfall was measured using 25 collectors with 225 mm diameter and 200 mm deep. The collector

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was placed at each plot grid with 5 m intervals. Throughfall is measured by several throughfall collectors randomly located below the canopy cover. Since the canopy area of the forest is dense; the volume of throughfall was divided with the receiving area of the collector to obtain throughfall value in depth (mm) (Yusop et al., 2003). The throughfall collector is shown in Fig. 2.

2.4 Stemflow, S_f

Stemflow, S_f is defined as the process that directs precipitation down plant branches and stems. 15 trees for each plot were selected depends on the accessibility in setting up the stemflow collar, as shown in Fig. 4. The collar method is adopted in measuring stemflow where in this process the selected trees were spirally fitted with the spiral rubber collar and draining into a collecting tank. The rubber collar is made of PVC hose and was fitted around the tree stem using nails. It was sealed with silicone glue to seal the space between the stem and the edge of the collar. The 5.5 L capacities of collecting tanks were emptied daily and measured using measuring cylinder. However, 4 of the 5.5 L tanks have been changed to 10 L tanks on 14 April 2012, and later replaced by 25 L tanks on 22 May 2012 due to overflow of stemflow from the tanks.

Volume of stemflow is converted in to depth (mm) by Eq. (1) (Bo et al., 1989):

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

where D_1 is the total number of trees in plot, D_2 the number of uncollared trees, B_1 is the total basal area of all trees ($m^2\,plot^{-1}$), B_2 as the basal area of the uncollared trees ($m^2\,plot^{-1}$), V_c is the total volume of stemflow ($L\,plot^{-1}$) and A is the plot size (m^2).

Figure 3 shows the location of trees, throughfall collectors and stemflow collectors placed at Plot11 and Plot12, respectively.

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2.5 Canopy cover, c

Canopy cover, c that is defined as the tall canopy fraction divided by forest fraction is essentially important for the purpose of estimation of interception loss by Gash model. In this study, the canopy cover values were obtained by using WinSCanopy 2009a and RGBFisheye.exe application software that automatically calculate the diffuse transmittance (% PPFD) from digital hemispherical photographs taken with exposure setting based on the luminance of the zenith of the sky (Ishida, 2005). PPFD means the photosynthesis photon flux density of the canopy cover of the forest. In this study, 25 locations were chosen at every grid points. The photographs were taken on a cloudy day. The canopy cover was analysed using WinSCANOPY 2009a software program to measure the percentage of canopy cover using hemispherical photography images for the plot. For the subsequent year, analysis was made using the RGBFisheye.exe application software that automatically calculates the diffuse transmittance (% PPFD) from digital hemispherical photographs taken with exposure setting based on the luminance of the zenith of the sky. Both programs evaluate the percentage of openness of the canopy.

2.6 Interception model

2.6.1 Original Gash model analysis

Original Gash model is also known as the separates interception loss model which separates the calculation of rainfall event that is not enough to saturate the canopy cover structure, but is enough to saturate the canopy cover as well as saturate the trunk storage. The original Gash model analysis is carried out when all the parameters needed are obtained. The parameters needed are $\overline{E}/\overline{R}$, p, p_{t}, S and S_{t}. Then interception loss of the canopy structure for this study area can also be determined using formula derived in Table 1.

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2.6.2 Revised Gash model analysis

Revised Gash model is reformulated from original Gash model to make it suitable in the estimation of interception loss for sparse forests. The phase of rainfall events used in this model is the same as in the original Gash model that are not enough to saturate the canopy cover structure, but are to enough saturate the canopy cover as well as saturate the trunk storage. The other parameters which will be used are the canopy cover (c) whereas the S_c and $\overline{E}_c$ can be derived. The formula in determining the interception loss using revised Gash model is shown in Table 1.

2.6.3 Interception model with temporal resolution analysis

A simple interception model simplified from the Rutter canopy model is also applied in this study. Its governing equation is shown as Eq. (2):

$$\begin{cases} \frac{dS_c}{dt} = p - e - p_t \\ p_t = \begin{cases} p - e_p & S_c = C_c \\ 0 & S_c < C_c \end{cases} \\ e = e_p \frac{S_c}{C_c} \end{cases} \quad (2)$$

where S_c is canopy storage (mm); C_c is storage capacity (mm); t is time (h); p is rainfall intensity (mm h^{-1}); e_p is potential evaporation rate (mm h^{-1}); e is canopy evaporation rate (mm h^{-1}); and p_t is throughfall rate (mm h^{-1}). This model has exactly the same structure as the Rutter stemflow model, and it is also equivalent to the Rutter canopy model with parameter $b = \infty$ which controls the drainage rate from canopy, $D = D_0 C_c \exp(b(S_c - C_c))$, where D_0 is another positive parameter controlling the drainage rate (Azinoor et al., 2012a).

To obtain data with temporal resolution, hourly precipitation data was calculated as an average value for each resolution. In this process, the total precipitation during divisions is preserved for all temporal resolutions (Azinoor et al., 2012c). This is to avoid

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the computational error during calculation. The relationship between interception and temporal resolution was derived from various depths of storage capacity (from 0.1 to 10.0 mm) and temporal resolution (from 1 to 24 h).

The function of the interception can be expressed by Eq. (3):

$$E_c = E_{c,0} + f(d) \cdot TR, \tag{3}$$

where $g(d) = 0.109d^{0.58}$, $E_{c,0}$ is the annual physical interception value (mm), P is the annual precipitation (mm), and d is the depth of storage capacity (mm).

$E_{c,0}$, annual physical of interception (mm) = $P(1-e^{-g(d)})$, where $g(d) = 0.109d^{0.58}$. The relationship of each depth with the temporal resolution is expressed by Eq. (4):

$$f(d) = A \cdot d^m \cdot \exp(-d^n) \tag{4}$$

where $A = 9.2$, $m = 0.08$, $n = 0.45$ and d is the depth of storage capacity.

Details description of the site and data preparation was described in Azinoor and Lu (2010).

3 Results and discussion

3.1 Rainfall, throughfall and stemflow

The difference between gross rainfall and net rainfall (throughfall and stemflow) is measured as interception loss. The data was collected from 11 April 2012 until 24 April 2013, which is twelve months of data collection excluding data for August 2012 data due to some technical problem. 94 rainfall events were recorded during the 12 month period from April 2012 until April 2013 which contributes total rainfall of 2095.84 mm. The minimum gross rainfall recorded is 1.4 mm on 28 September and 12 October 2012 whereas the extreme rainfall events recorded was 109.7 mm on 18 April 2012.

Figures 5 and 6 show that interception loss for Plot11 is 21.31 % of gross rainfall while for Plot12, interception loss values of 18.89 % was obtained. For throughfall volume, the percentage over gross rainfall for Plot11 is 78.71 % and for Plot12 is 80.96 %. The throughfall volume consumes big composition of gross rainfall since the precipitation drips from the canopy cover when it is over the storage for the canopy. Stemflow values are 0.013 and 0.034 % of gross rainfall for Plot11 and Plot12, respectively.

3.2 Throughfall coefficient, *p*

Throughfall coefficient, p is determined by using linear regression of gross rainfall against throughfall, where the slope indicates the value of p. In the regression analysis, the threshold value taken is gross rainfall greater than 3 mm which was assumed to be sufficient enough to saturate the canopy (Carlyle-Moses and Price, 1999). The threshold value for this study is higher than other studies because tropical forest consists of large canopy structure and it contributes to high interception loss (Asdak et al., 1998).

Based on the regression, the R^2 value of 0.863 and 0.8256 for Plot11 and Plot12 respectively show that good correlations exist between gross rainfall and throughfall values. The correlations between the two parameters for the present site can be comfortably predicted by using Eqs. (5) and (6) for Plot 11 and Plot12 respectively.

$$P_g = 1.0112T_f + 3.0545 \quad (5)$$

$$P_g = 0.9642T_f + 3.3687 \quad (6)$$

In this study, the value of throughfall coefficient, p, is 1.0112 for the Plot11 and 0.9642 for the Plot12.

3.3 Canopy storage capacity, *S*

Canopy storage capacity is defined as the amount of water left on the canopy in zero evaporation conditions when rainfall and throughfall have ceased (Gash and Morton,

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1978). Asdak et al. (1998) stated Leyton et al. (1967) method that is usually used in determining the value of S seems to be subjective both in recognition of the inflection relating with the point of canopy saturation, and in fitting the upper envelope to the scattered points. Thus, this study adopted the method of using separate linear regressions of gross rainfall vs. throughfall for individual small storms (Lloyd et al., 1988) which is more appropriate for determining S in tropical forest. The value of S is given by the slope of the linear regression for zero throughfall.

There were 94 rainfall events recorded during the study period but only 49 gross rainfalls are considered small storms; rainfall events which are ranging from 1.5 to 15 mm. Linear regressions of throughfall against gross rainfall were computed for each plot. The values of S used in the model were 0.8091 for Plot11 and 0.7378 for Plot12.

3.4 Trunk storage capacity, S_t and proportion of the rainfall to stemflow, p_t

The trunk storage capacity, S_t was calculated in a similar way to the canopy capacity with the regressions of stemflow against gross rainfall for each trunk in the plot. The mean slope of the regressions gave the value of p_t, the portion of the gross rainfall which is diverted onto the trunks. For the estimation of S_t and p_t, gross rainfall and stemflow data were extracted for all rainfall events larger than 3 mm, the threshold value which represents canopy saturation (Carlyle-Moses and Price, 1999). These values of stemflow were regressed against gross rainfall.

For Plot11, the mean relationship between stemflow, S_f and gross rainfall, P_g is given as Eq. (7) with R^2 is 0.7391, and Eq. (8) for Plot12 with R^2 is 0.5773.

$$S_f = 0.0002P_g - 0.0014 \quad (7)$$

$$S_f = 0.0003P_g + 0.0014 \quad (8)$$

From the regression analysis, the S_t values are 0.0002 for Plot11 and 0.0003 for Plot12 while the p_t value are 0.0014 for both Plot11 and Plot12.

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3.5 Ratio of mean evaporation rate over mean rainfall rate, $\overline{E}/\overline{R}$

Another method was used to determine the mean evaporation rate over mean rainfall rate due to the lack of information on the evaporation rate per unit ground area on the study area. Determine the ratio of mean evaporation rate per unit ground area during rainfall over the mean rainfall rate, $\overline{E}/\overline{R}$ obtained by the linear regressions of interception loss, I observed in the forest against gross rainfall, P_g. The mean slope of the regressions gave the value of $\overline{E}/\overline{R}$.

From Plot11, the relationship between interception loss and gross rainfall is shown in Eqs. (9) and (10):

$$I = 0.1463P_g - 0.1842 \quad (9)$$

$$I = 0.1434P_g - 0.7888 \quad (10)$$

The R^2 values, 0.1562 for Plot11 and 0.1172 for Plot12, showed poor relationship between the parameters as it is affected by the negative values of interception loss from field measurement. Crockford and Richardson (2000) stated that the negative interception value may occur due to the value of throughfall higher than the gross rainfall. It also may occurred due to the overestimation of throughfall or underestimation of gross rainfall. Some other factors that may also contribute to these problems as the throughfall collector placed under the tree with relatively have a large leaves (Yusop, 1996). Consequently, the value of $\overline{E}/\overline{R}$ is 0.1463 and 0.1434 for Plot11 and Plot12, respectively.

3.6 Percentage of canopy cover, c

Canopy cover, c is defined as the tall canopy fraction divided by forest fraction. In this study, the value of canopy cover is obtained by using WinSCanopy 2009a and RGB-Fisheye.exe application software that automatically calculate the diffuse transmittance

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(% PPFD) from digital hemispherical photographs taken with exposure setting based on the luminance of the zenith of the sky (Ishida, 2005). The image of canopy cover as in Fig. 7 was captured at the 25 locations at every corner of grid point for both plots, and each image is analysed by the software to give the percentage of canopy cover. The sample of image after being analysed is shown in Fig. 8.

Stand Visualization System (SVS) has been used to visualize the forest standing study area in 3-D view based on the selected trees over the interest area. Figure 9 is the result from SVS software analysis where it illustrated the forest stand of Plot11 and Plot12 and Fig. 10 shows the details of the forest stand in both plot.

Based on the analysis, the values of canopy cover were ranging from 88.50 to 97.55 % for Plot11 and 89.53 to 97.65 % for Plot12 in years 2012 and 2013. This shows that the percentage at every point is not constant even though they are located at the same plot. This is due to the type of trees that are dominant at the point. Consequently, for the year 2012, the values of canopy cover are 94.11 % for Plot11 and 95.25 % for Plot12 while for the year 2013, the values of canopy cover are 93.42 and 94.76 % for Plot11 and Plot12, respectively. As the calculation of interception loss will be using modified Gash model, these values are averaged out to suit the formula. The values obtained are 93.77 and 95.01 % for Plot11 and Plot12, respectively. The range of canopy cover from 89 to 98 % shows that Bukit Lagong Forest Reserve is classified under dense forest, which consistent with the study reported by Ibrahim et al. (2008).

3.7 Interception loss from original Gash model and revised Gash model

From the parameters obtained previously, the interception losses for study area were calculated using revised Gash model. The model requires that $\overline{E}$ and $\overline{R}$ to be calculated from the hours that the canopy is saturated. To maintain the simplicity of the model it is therefore necessary to approximate this condition by selecting a rainfall rate, above which it is considered the canopy will always be saturated (Gash, 1979). The threshold rate of 3 mm was chosen to represent saturated conditions. The following procedure is adopted:

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1. Values of $\overline{E}/\overline{R}$ obtained were used to calculate P'_g for the study period using the value of $S = 0.8091$ for Plot11 and $S = 0.7378$ for Plot12 obtained in the regression of gross rainfall against throughfall.

2. Further assumptions that there is only one storm per rainday were made. Then, the raindays were divided into those with $P_g \geq P'_g$ and those with $P_g < P'_g$. These two rainfall sets of daily rainfall amounts were then summed up to give $\sum_{j=1}^{n} P_{G_j}$ and $\sum_{j=1}^{m} P_{G_j}$.

3. The numbers of raindays, n with $P_g \geq P'_g$ was noted.

4. The numbers of raindays, q with $P_g \geq S_t/p_t$ was noted, and the rainfalls of raindays with $P_g \geq S_t/p_t$ were summed up.

For Plot11, the measured interception loss obtained is 284.02 mm (13.6 %), calculated from original Gash model is 308.47 mm (14.7 %) and from revised Gash model is 284.02 mm (15.9 %). Meanwhile, for Plot12, the measured interception loss, calculated interception loss from original Gash model and revised Gash model obtained are 226.77 mm (10.82 %), 285.33 mm (13.61 %) and 329.93 mm (15.74 %), respectively.

The range of interception loss for this study is from 10 to 16 % and is consistent with the interception loss study conducted by Asdak et al. (1998) but 25–43 % underestimated from the study conducted by Carlyle-Moses and Price (1999). The interception loss obtained from Asdak et al. (1998) is 6–14 % and the study was implemented at the Wanariset Sangai on the upper reaches of the Mentaya river, Central Kalimantan. The interception loss obtained from Carlyle-Moses and Price (1999) is 19.3–21.4 % and the observation was made in a temperate hardwood forest plot within the Erindale Ecological Research area, University of Toronto at Mississauga, Ontario, Canada.

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3.8 Interception loss from interception model with temporal resolution

The interception loss model estimates canopy interception loss annually with temporal resolution effects. The inputs for the model are the annual precipitation, depth of storage capacity and temporal resolution of the data. The function of the interception can be expressed by the Eq. (11):

$$E_c = E_{c,0} + f(d) \cdot TR, \tag{11}$$

where $E_{c,}$ is the annual physical interception value or annual "true value" of interception (mm) = $P(1 - e^{-g(d)})$, $g(d) = 0.109d^{0.58}$, P is the annual precipitation (mm), and d is the depth of storage capacity (mm).The relationship of each depth with the temporal resolution is expressed by Eq. (12):

$$f(d) = A \cdot d^m \cdot \exp(-d^n) \tag{12}$$

where $A = 9.2$, $m = 0.08$, $n = 0.45$ and d is the depth of storage capacity.

From the model calculation, the interception losses are 280.2 mm (13.37 %) and 273.2 mm (13.03 %) for Plot11 and Plot12, respectively. The results is summarised as shown in Table 2.

4 Conclusions

An interception model with temporal resolution effects had been designed to estimate interception loss annually. The results calculated from the model were validate with interception loss values measured at the artificial reserved lowland tropical forest and the results calculated using original Gash and revised Gash model. The range of the interception loss obtained from this study is from 226.77 mm (10.82 %) to 329.93 mm (15.93 %). On the other hand, the results show that the model can estimate interception loss with 1.3–16.9 % differences compared to the measured values. It can be con-

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cluded that the interception loss model with temporal resolution effects can be apply to lowland tropical forest.

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Table 1. Components of interception loss for original Gash model and modified Gash model.

Component of interception loss	Original Gash model	Revised Gash model
For m storms insufficient to saturate the canopy ($P_g \le P'_g$)	$(1-p-p_t)\sum_{j=1}^{m} P_{g_j}$	$c\sum_{j=1}^{m} P_{g_j}$
For n storms sufficient to saturate the canopy ($P_g > P'_g$)		
Wetting up canopy	$n\left\{(1-p-p_t)P'_g - S\right\}$	$n\left\{cP'_g - S\right\}$
Wet canopy evaporation during storm	$\frac{\overline{E}}{\overline{R}}\sum_{j=1}^{n}(P_{g_j} - P'_g)$	$\frac{c\overline{E}_c}{\overline{R}}\sum_{j=1}^{n}(P_{g_j} - P'_g)$
Evaporation after rainfall ceases	nS	nS
Evaporation from stems for q storms $> S_t/p_t$ which saturate the stem	$qS_t + p_t\sum_{j=1}^{m+n-q} P_{g_j}$	$qS_t + p_t\sum_{j=1}^{n-q} P_{g_j}$
Parameters		
Rainfall necessary to saturate the canopy	$P'_g = -\frac{\overline{R}S}{\overline{E}}\ln\left[1 - \frac{\overline{E}}{(1-p-p_t)\overline{R}}\right]$	$P'_g = -\frac{\overline{R}S_c}{\overline{E}_c}\ln\left[1 - \frac{\overline{E}_c}{\overline{R}}\right]$
Mean wet canopy evaporation rate	$\overline{E} = \overline{E}_w$	$\overline{E} = c\overline{E}_c$
Canopy capacity	S	$S = cS_c$
Canopy cover fraction	$1-p$	c

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Table 2. Summary of interception loss obtain from site measurement, original Gash model, revised Gash model and interception loss model.

Interception loss	Plot11 (mm)	Plot11 (%)	Plot12 (mm)	Plot12 (%)
Measured	284.02	13.55	226.77	10.82
Original Gash model	308.47	14.72	285.33	13.61
Revised Gash model	333.91	15.93	329.93	15.74
Interception model	280.25	13.37	273.16	13.03

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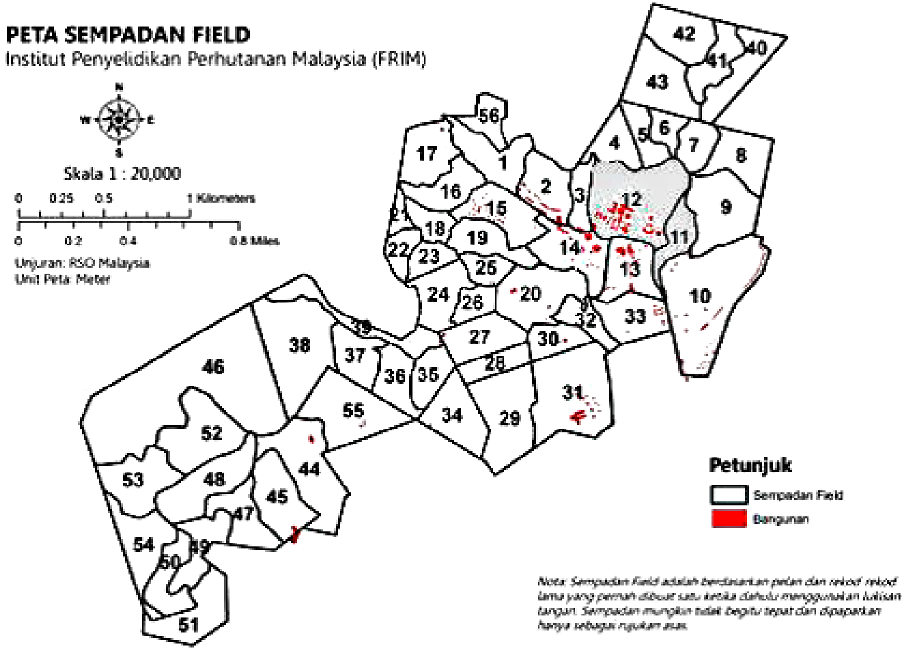

Figure 1. Study area (Plot11 and Plot12).

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Figure 2. Throughfall collector.

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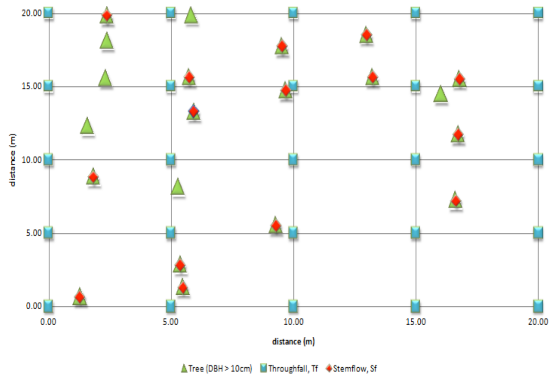

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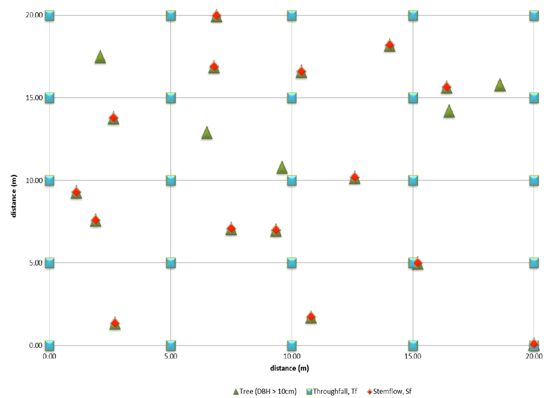

(b)

Figure 3. Location of tress, throughfall and stemflow collectors **(a)** Plot11 and **(b)** Plot12.

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Figure 4. Stemflow collector.

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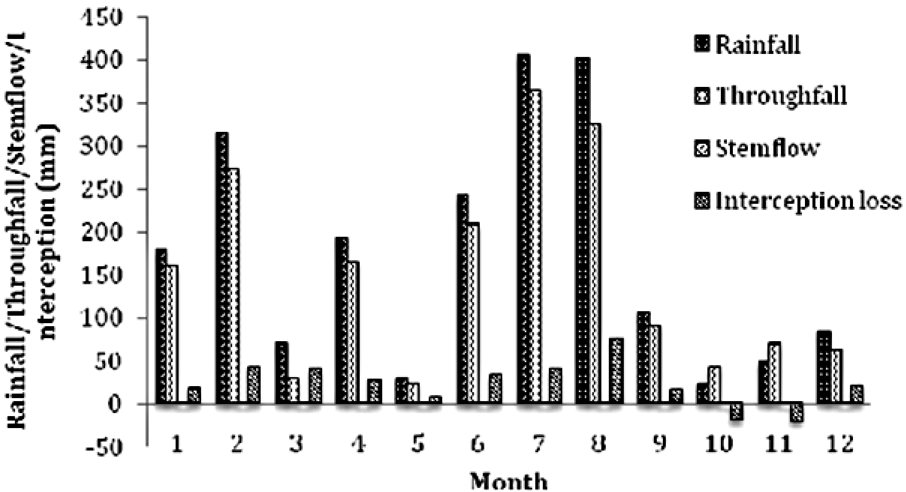

Figure 5. Rainfall, throughfall, stemflow and interception loss for 12 months of Plot11.

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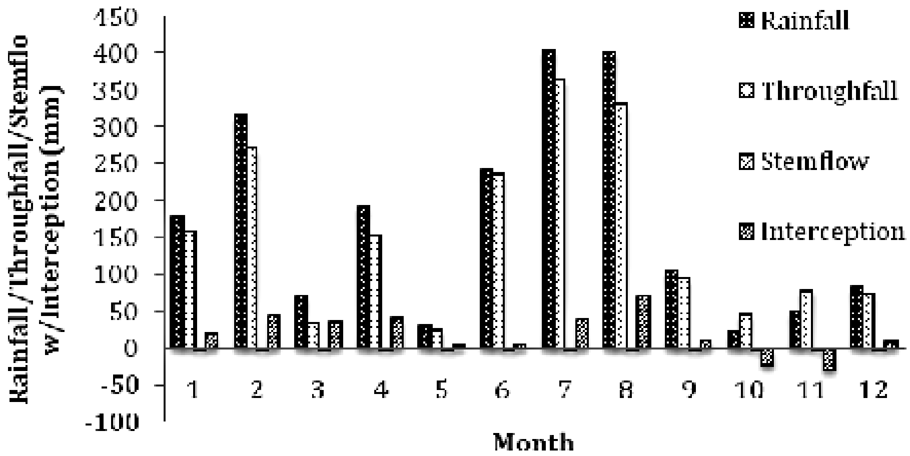

Figure 6. Rainfall, throughfall, stemflow and interception loss for 12 months of Plot12.

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Figure 7. Image captured using camera model Fisheye lens.

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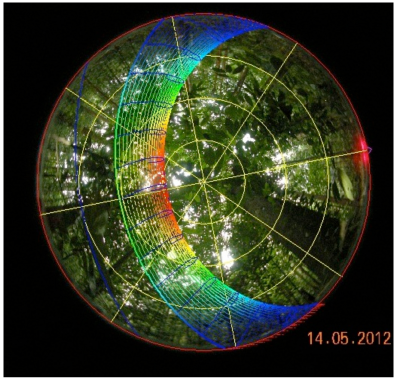

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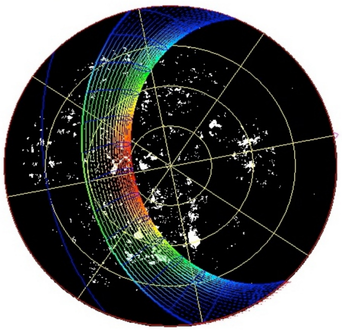

(b)

Figure 8. Image of canopy cover after analysis **(a)** in normal view and **(b)** in black and white version.

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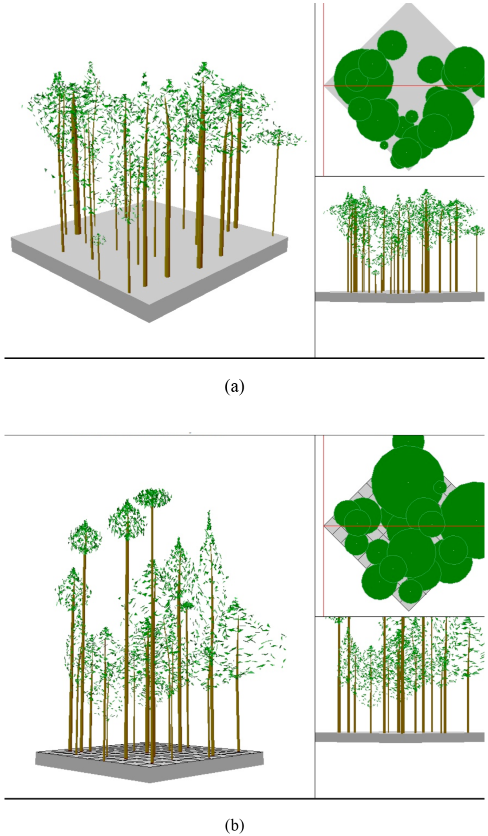

Figure 9. Perspective view, overhead view and profile view projected using SVS software for **(a)** Plot11 **(b)** Plot12.

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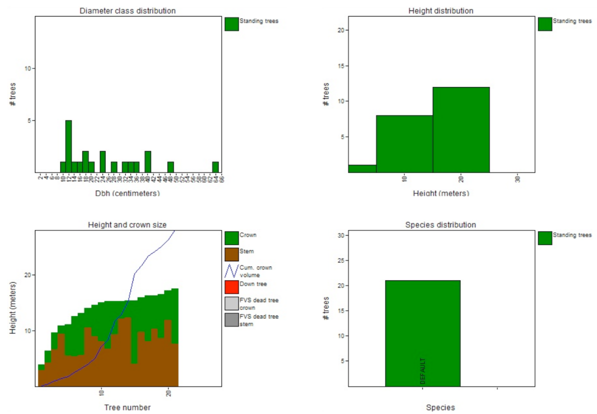

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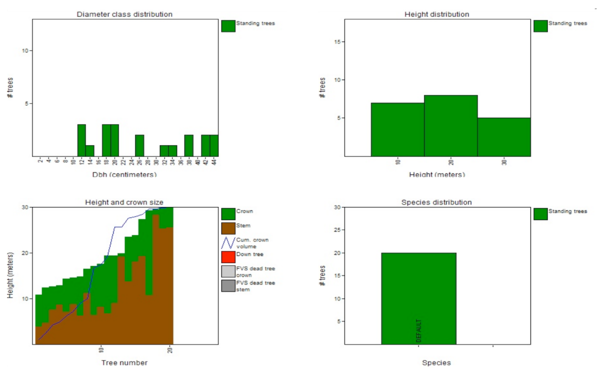

(b)

Figure 10. All stand graph for **(a)** Plot11 and **(b)** Plot12.

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