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Monitoring Spatial Variability of Lowland Depterocarp Forest in Lake Chini Catchment, Malaysia

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Abstract: In the hydrologic cycle, raindrops that fall on the forest canopies do not necessarily reach the soil surface. Part of the rainfall is captured by the crowns and other surfaces of trees, which then evaporates back to the atmosphere. The amount of water that is subtracted from the total rainfall in this manner is known as interception. Water drips down the forest canopy via two processes: stemflow and throughfall. Stemflow refers to the amount of rainwater that drips down tree stems and branches to the ground. Throughfall, on the other hand, refers to the penetration of rainfall through forest canopy via spaces between leaves or dripping from the leaves, twigs and stems. Both these components were measured in a 100 metre x 100 metre interception plot located in a secondary lowland Dipterocarp forest at Lake Chini. Thirty tree samples were used and each tree was identified as regards species, family, diameter breast height (DBH), size of canopy and canopy density. In this study, interception data were collected during every rainfall event in November and December 2007. This interception study provided essential information on how the function of the forest could affect the crucial hydrological cycle within this forest ecosystem and also the wetland water balance. Indirectly, the interception process that took place in this study area could reduce and control land erosion effectively by controlling the total amount of rainfall generating surface run-off. Apart from that, the interception process could also supply and replenish water to the soil and ensure that the water balance in the forest area was maintained.

Key words: Interception · Lowland dipterocarp forest · Water balance · Ecosystem · Stemflow

INTRODUCTION

The study of interception refers to the study of loss of rainfall before it can reach the earth's surface. Interception is part of the hydrologic cycle that is so important to the water balance of this earth. The amount of rainfall which an area receives depends on whether there are objects covering the area, such as a forest, hill and building. The trees in a forest act as cover and affect how much rainfall the area receives. Trees act as a filter too. In either role, trees will intercept part of the rainfall, reducing directly the flow of water to the earth's surface. Interception by trees is done through their leaves, canopies, branches, stems and twigs. Trees have various methods of intercepting rainfall. It was for the purpose of understanding these methods that this study was carried out in the secondary forest area of Lake Chini in Pekan, Pahang.

In general, trees affect the distribution of rainfall because they will intercept some of the rain that falls on their canopies before it can reach the ground. This process contributes towards maintaining the forest temperature, slowing down the surface run-off and balancing the water cycle in the atmosphere. The amount of water intercepted by a tree depends on the structure of its branches, forks and the density of its foliage. Therefore, different species of trees will intercept different amounts of rainfall. Some of the intercepted rainfall will not fall to the ground but will evaporate directly off the various tree surfaces back to the atmosphere. The amount of rainfall that is lost through this process is called net interception loss [1]. Some of the intercepted rainfall will flow from the leaves to the branches, down the trunk and to the ground. This process is called stemflow. Some of the rain that falls onto the canopies of trees finds its way through the leaves and twigs of canopies and the spaces

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between canopies before falling to the ground. Rainfall that falls without being intercepted by plants is named throughfall [2]. Both these processes determine the amount of rainfall that reaches the ground, which in turn contributes towards the moisture content of the soil.

Precipitation begins at high ground. The forests in the highland areas will capture the rainfall and this water will flow slowly down to the plains. Natural interception processes will occur in these forest areas. Some of the rain will be intercepted by the leaves and other parts of the tree and evaporate back to the atmosphere. The rest will either flow from the leaves of the canopies to the branches, down the branches to the trunk and then to the ground, or drip down the leaves and twigs of the canopy and then to the ground. Rain falls to the ground via the canopies, therefore, in either of two methods, by stemflow or by throughfall [3].

The amount of water that reaches the surface of the earth from the atmosphere can be measured either by net precipitation or net rainfall collected. The percentage of interception can be calculated from the amount of collected rainfall. According to Andy *et al.* [4], the intercepted amount of rainfall is equal to the total gross rainfall less total stemflow and less total throughfall. The components of this equation are influenced by the gross amount of rain that falls at a certain time.

An increase of green areas will increase the processes of evapotranspiration and interception by the canopies of trees [5]. Forest studies made in tropical and temperate areas showed the relevance of interception and evapotranspiration processes in the control of amount of surface water, by reducing and slowing the time taken by the water to be absorbed into the soil [6-8].

According to [9], the amount of rainfall measured in a certain area depends on the existence of surface cover such as a forest, hill, building, road or other man-made covers. These covers, be they natural or man-made, will intercept part of the rainfall in a certain area. In a forest area, the canopies of the trees will intercept the rain before it can reach the ground. Therefore, interception refers to loss of rainfall before it reaches the ground.

Other study reported by Herwitz [10], stemflow depends greatly on the species of the tree. A tree with smooth branches and trunk will allow rainwater to flow down them in greater amounts and in a shorter time than a tree with rough bark. The angle of the twigs make with the branches and the angle of the branches make with the trunk too will determine the amount of stemflow. An angle of 60 degrees will result in a stemflow of 80 percent of rain that falls on the tree. It depends also on whether the branches are wet or dry. This means that insufficient rainfall will cause insufficient wetness to allow rainwater to penetrate the canopy for a flow to happen [11].

According to Asdak *et al.* [12], throughfall is rain that falls straight to the ground through spaces within a canopy, or rain that drips from leaves or branches straight to the ground. The rain falls on the tree or canopy, collects on the leaves before falling to the ground as throughfall. Water collected on the leaves falls to the ground in a number of ways, for example when the tree is shaken by the wind.

Forests must be protected for they are an important factor in determining how much rainfall an area receives. They are necessary to ensure the processes of interception, throughfall and stemflow take place in the hydrologic cycle of a forest ecosystem and are kept in equilibrium. The measure of intercepted, throughfall and stemflow amounts are therefore important for the understanding of a forest's functions in the hydrologic cycle. Studies have shown the adverse effects on the equilibrium of water as a result of failure in the process, for example an increase in surface water run-off, soil erosion and the frequency of floods. This interception study was carried out in the secondary forest of Lake Chini to show the importance of this process in controlling the problems mentioned.

Aston [13] indicated that the amount of rain that falls in a certain area depends on the existence of covers such as a forest, hill, building, road and other man-made covers in the area. Covers, whether natural or man-made, will intercept part of the total rainfall in the area. Rain that falls in a forest area will first be intercepted by the canopies of the trees before it can reach the ground. In this context, interception refers to the loss of rainfall before it can reach the ground.

An increase of green areas will increase the processes of evapotranspiration and interception by canopies of plants [14]. Forest studies in tropical and temperate areas have shown the relevance of interception and evapotranspiration processes in the control of the amount of surface water, by reducing and slowing the time taken by the water to be absorbed into the soil [15,16]. This study conducted in the secondary forest of Lake Chini is important because the area of study is a reserve area under the protection of the Pahang State Government. Any change in the form of land-use in the area will affect the rate of entry of surface water run-off into the lake, with the danger of affecting the water equilibrium of the lake. Interception is also important in controlling the effect of sedimentation in the lake, where sedimentation is a problem.

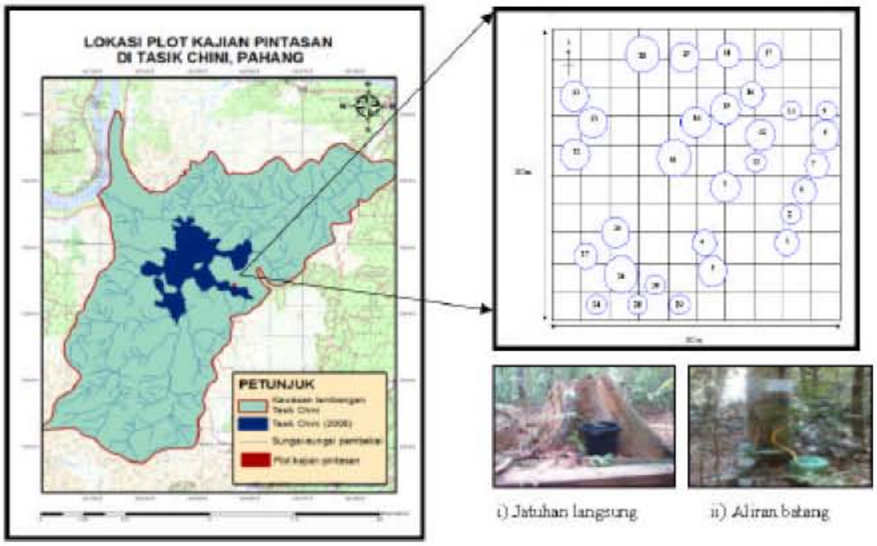


Fig. 1: Map of Lake Chini and area plot of interception study in the Lake Chini Pekan, Pahang

Table 1: Tree sample physiological characteristics

Tree No.	Species name	Height (m)	DBH (cm)	Canopy size
1	*Teijsmanniodendron Simplicifolium*	22	43.4	Moderately dense
2	*Terminalia calamansanai*	23	35.7	Moderately dense
3	*Shorea sp*	47	72.0	Dense
4	*Cryptocarya rugulosa*	25	47.7	Moderately dense
5	*Horsefieldia superba*	21	51.1	Moderately dense
6	*Pentaspadon motleyi*	22	39.8	Moderately dense
7	*Pentaspadon motleyi*	26	37.7	Moderately dense
8	*Gymnacranthera forbesii*	24	48.9	Sparse
9	*Xanthophyllum amoenum*	27	30.7	Moderately dense
10	*Koompassia malacceasis*	43	82.9	Dense
11	*Canarium megalanthum*	26	33.5	Moderately dense
12	*Dialium laurinum*	40	67.2	Moderately dense
13	*Ochanostachys amentera*	24	33.7	Moderately dense
14	*Shorea* sp	35	65.6	Moderately dense
15	*Dialium wallichii*	35	56.0	Moderately dense
16	*Daryodes rugosa*	27	37.5	Sparse
17	*Syzgium cumingiana*	30	38.5	Moderately dense
18	*Cyathocalyx pruniferus*	26	31.7	Sparse
19	*Shorea balanocarpoides*	40	69.0	Moderately dense
20	*Shorea lepidota*	41	73.0	Moderately dense
21	*Pentaspadon motleyi*	44	61.5	Moderately dense
22	*Scorodocarpus borneensis*	31	62.7	Sparse
23	*Ochanostachys amentera*	34	56.0	Sparse
24	*Shorea macroptera*	22	27.5	Sparse
25	*Canarium megalanthum*	25	56.2	Moderately dense
26	*Pentaspadon motleyi*	46	80.1	Moderately dense
27	*Shorea maxwelliana*	32	43.7	Moderately dense
28	*Shorea maxwelliana*	21	36.1	Moderately dense
29	*Syzgium clariflora*	24	35.8	Moderately dense
30	*Shorea maxwelliana*	28	34.8	Moderately dense

Study Area and Methodology: The Lake Chini secondary forest, located in the Lake Chini basin, is a dynamic natural forest ecosystem encompassing an area of 5,105.23 hectares. The basin is located at latitude 3° 15' 40" N and longitude 102° 45' 40" E. There are two dominant lowland dipterocarp forests in this valley, one where logging had been carried out and the other which had been cleared by inhabitants of the area who wanted to improve their lot by growing crops on the cleared area. This farmland was subsequently abandoned and a secondary forest grew in its place [17]. FELDA is active in the basin with its rubber and oil palm plantations. However, in the south-western part of this lake, a primary forest exists. This forest is a protected area and has been gazetted by the state government as a national park, the Lake Chini State Park.

Having a tropical climate, the area is hot and humid year-long. Rain falls regularly. Humidity is high, being more than 80 percent. Average yearly temperature is also high at 28°C. This results in a high rate of water evaporation back to the atmosphere. This in turn results in frequent rain. Wind velocity in the area is low at 0.5 m/s [18]. In this interception study, a total of 30 trees identified as samples were used. Each tree of a minimum 20 cm diameter was attached a stemflow measurement set. Each sample tree in this plot of 100 m x 100 m (Figure 1), located in the Lake Chini secondary forest, is a native species. Black bin throughfall measurement sets were placed under the thinnest canopies in the plot. The physiological characteristics of each tree sample (Table 1) in the plot were determined through observations made with botanical faculty members of UKM.

RESULTS AND DISCUSSIONS

The total stemflow is greatly influenced by such factors as rainfall period, total rainfall, how long it lasted, its intensity and presence of wind. In general, the total throughfall obtained can be seen in the absolute amount through increase in wind speed. The total throughfall is low if the wind velocity is low and *vice versa*. If wind velocity is increased, the total throughfall will also increase [19]. During the period the study was made, the wind velocity was low. As a result, the total throughfall obtained too was low as wind velocity did not play a part during this period. Figure 2 a and b compares total gross rainfall, throughfall rate and stemflow rate on the days observed of the respective month.

The study made in the Lake Chini secondary forest showed conclusively that the stemflow readings were greatly influenced by gross rainfall because they were high. Figure 3(a) correlates the relationship existing between these two. The correlated coefficient value obtained is 0.9781 and 0.9808 (r^2) for November and December 2007 respectively. The significance level for this variable is 95% with a relationship value of 0.9013 (r^2). This indicates that the interception rate is influenced by rainfall in the study area. Should the rainfall amount increase, the interception amount too will increase, in line with the increase in total rainfall. The relationship value is 0.9672 (r^2) and the significance level for this variable is 98% (Figure 3b).

The nature of the bark of a tree, whether it is smooth or rough, affected the amount of stemflow collected. The amount collected from a smooth-barked tree was more than that from a rough-barked tree. This is because the rough bark contains holes that have a tendency to absorb more water and thereby reduce the stemflow. According to Van Dijk and Bruijnzeel [20], a tree with smooth bark has a low absorption rate and has the ability to allow water to flow faster because the water is not hindered by holes in the trunk. In the study conducted in the Lake Chini secondary forest, it was found that sample trees 27, 28 and 30 (*Shorea maxwelliana*) had the most collection of stemflow because their trunks were smooth and their twigs thin. These twigs were capable of catching rainfall with the result that more rainwater was collected. The fourth tree (*Lauraceae*) had a large trunk diameter (72 cm) but the stemflow was small, compared to another sample tree (*Gymnacranthera forbesii*) with a trunk diameter of 48.9 cm which collected more stemflow. Sample tree 20 was a tree of great height with a smooth trunk. A large amount of stemflow was collected from this tree.

Twigs and branches are important factors in determining the amount of stemflow collected. Branches and twigs attached at an angle make it easier for more rainwater to flow to the trunk faster when compared with the case of branches or twigs that are attached horizontally. The density of a canopy too plays a role in determining the amount of stemflow. A dense canopy will capture more rainwater than a sparse one. In the study, sample tree 6, a *Pentaspadon motleyi* species, had a large stemflow amount even though the tree stood at an angle. This condition in fact made it easier for rainwater to flow faster down the tree.

Total interception is measured using the following equation:

$$I = R - (Sf + Tf) \tag{1}$$

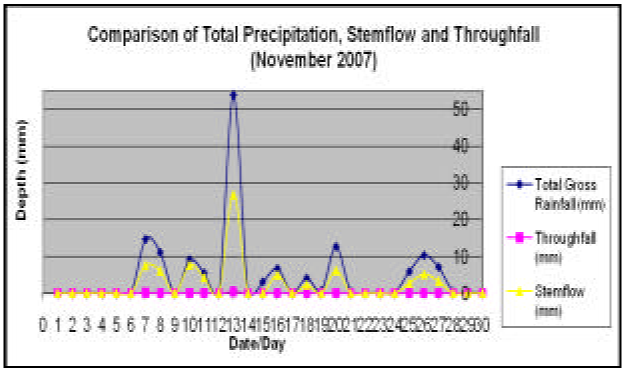
Where,
I = interception
R = direct rainfall
Sf = stemflow
Tf = throughfall

From the study carried out in the secondary forest of Lake Chini, it was found that interception was determined more by stemflow than throughfall. This was proved by the fact that stemflow collections were much more than throughfall amounts. The study showed the highest total interception of 76.21 mm was obtained from total gross rainfall of 187 mm on 10.12.07. On 29.11.07, 21.12.07 and 22.12.07, the lowest total interception of 0.02 mm was shown from gross rainfall of 0.2 mm. The total throughfall was 9.41 mm while stemflow contributed 17,112.78 mm. This showed that stemflow was the major contributor in the interception process in the study area. The thickness of the canopies that covered almost the entire study plot was the reason. The results of study are summarised in Table 2.

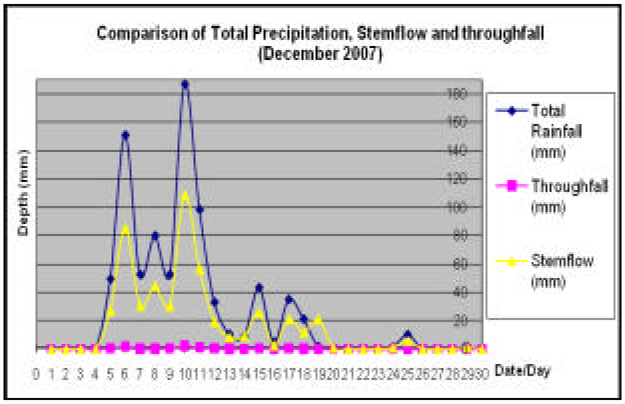
Studies showed that the total interception obtained in tropical forest areas was greater than those obtained in temperate forest areas. The highest total interception was obtained in tropical areas is justified because the trees there tend to grow closer to one another, are of differing heights and sizes resulting in many layers of dense canopies and undergrowth. This statement was confirmed by the study conducted in the secondary forest of Lake

Table 2: Percentages of throughfall and stemflow in the interception process in the secondary forest of Lake Chini

Date	Gross Rainfall (mm)	Throughfall (mm)	(%)	Stemflow (mm)	(%)
Nov-07	144.6	0.81	44.509	80.24	55.491
Dec-07	844.4	8.6	39.654	509.56	60.346



(a)



(b)

Fig. 2: Comparison of interception rates in study plot- Nov and Dec 2007

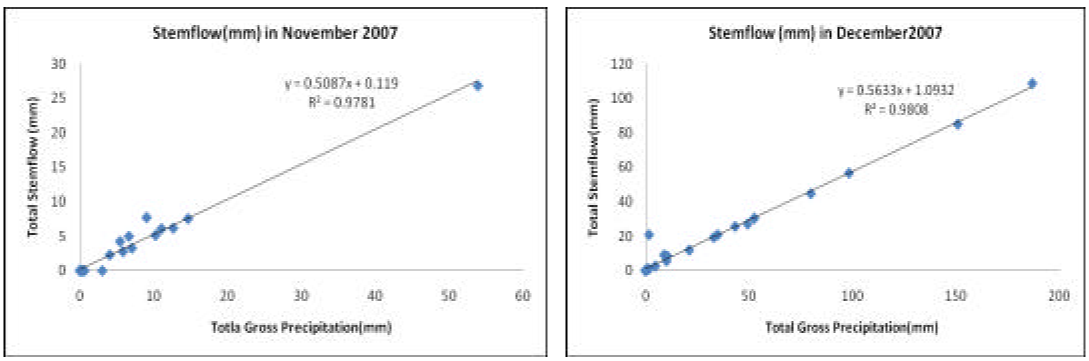


Fig 3a: Relationship between total rainfall and stemflow

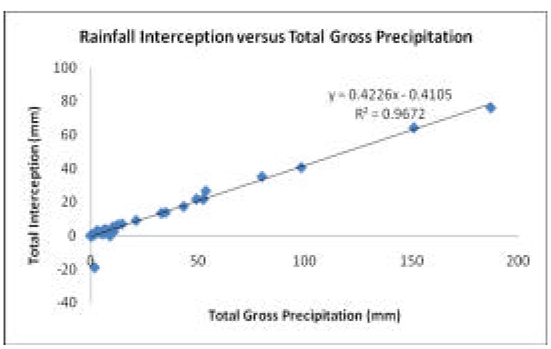


Fig. 3b: Relationship between total rainfall and stemflow

Chini which possessed characteristics similar to those described by Lai and Osman [21]. These forest characteristics resulted in the interception components, throughfall and stemflow, registering high amounts. The forest under study was a tropical forest where the canopies of the trees were dense, which greatly influenced interception.

Other factors such as season, rainfall intensity, period of rainfall and wind velocity have an effect on interception. According to Singh [22], certain factors have immediate effect on evaporation, for example atmospheric pressure, humidity, wind velocity, a moderate climate and the amount of sunshine. In the study, it was found that the seasons greatly influenced interception. November and December are rainy months. The intensity of the sun during the rainy months is naturally less than that during the hotter season, resulting in less evaporation.

CONCLUSION

The results of the study showed that the roles played by throughfall and stemflow in the hydrology system influenced the interception rate in the study area. This demonstrated that the role played by stemflow influenced interception rate to a greater extent than throughfall. This study also demonstrated the importance of the forest area of the lake basin and that any minor change in land-use could influence the function of the forest as a water catchment area, apart from causing a more damaging impact should the process of interception by the forest fail. The incidence of surface water run-off and the transport of sediment into the lake are influenced by this forest function.

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