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RELATIONSHIP OF TREE ARCHITECTURE ON CANOPY THROUGHFALL AND STEM FLOW IN THE UPSTREAM OF BATANG MAHAT RIVER BASIN LIMA PULUH KOTA REGENCY INDONESIA

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Abstract. *A study about the effect of tree architecture on canopy throughfall and stem flow was conducted upstream of Batang Mahat River Basin, Lima Puluh Kota Regency, West Sumatra, Indonesia. Four dominant tree species in the location, Voacanga foetida, Guioa sp, Schima wallichii and Rhodoleia champonii, were selected and represented in architecture by Scarrone, Schoute, Rauh and Leeuwenberg, respectively. Furthermore, the sample was three trees of each species. The throughfall canopy was measured using a 1 x 1 m plastic plot placed at the edge, while the stem flow was calculated by two meters plastic tube with a five-litre tank at the bottom. These data were collected eight times over one month. The study aimed to the analyzed relationship between tree architecture and canopy throughfall and stem flow upstream of the Batang Mahat River Basin. The result showed that Schima wallichii differed significantly in throughfall canopy relative to the other three species. Additionally, V. foetida significantly differed in stem flow compared to the other tree species. There was no correlation between throughfall canopy, stem flow and precipitation, but the two parameters were affected by three architectures. These findings are useful for soil and water conservation in the upper Mahat River Basin*
Keywords: tree architecture; throughfall canopy; stem flow; Batang Mahat River Basin

1. Introduction

Batang Mahat is one of important river basin in Lima Puluh Kota Regency. It often floods during the rainy season. Vegetation is an important component of river basin conservation because it reduces water loss during the hydrology process (Yang *et al*., 2019). The tree canopy retains the rainwater and directly falls to the ground (Ginebra-solanellas *et al*., 2020). A thick tree canopy holds and saves more water than its thin counterpart (Baptista *et al*., 2018; Herwitz & Slye, 1995; Li *et al*., 2017; Xiao *et al*., 2000) through the process called interception. It is affected by various factors such as species, density (Soedjoko *et al*., 2016), canopy types, tree height, and branches (Gonzalez-Ollauri *et al*., 2019); Herwitz, 1987). Furthermore, interception is also affected by the types of leaves (Ginebra-solanellas *et al*., 2020; Návar, 2019).

Tree architecture is the morphology that can distinguish species (Halle *et al*., 1978). It is used for the aesthetic design of urban forests, soil and water conservation (Arrijani & Lombok,

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2006). Various studies reported that different morphology strongly influences canopy throughfall, stem flow, and infiltration (Arrijani, 2006; Aththorick, 2000; Faye, 2011; Naharuddin *et al*., 2016; Nuraeni *et al*., 2014; Umam, 2011). However, the water flow models differ among trees with similar architecture (Nuraeni *et al*., 2014). There are 24 tree architecture models (Halle *et al*., 1978), but only a few are known for their interception and water flow model through the canopy, stem and infiltration.

This study aimed to show the effect of four tree architectures on the throughfall canopy and stem flow upstream of the Batang Mahat River Basin. The models, including Leewenberg, Scarrone, Rauh, and Schoute, were represented by *Rhodoleia champonii* tree, *Voacanga foetida*, *Schima wallichii*, and *Guioa* sp, respectively. The area's four tree species were highly dominant (Ekawaty *et al*., 2022). It was hypothesized that tree architectures affect throughfall canopy and stem flow differently. This research is expected to be useful for soil and water conservation, preventing erosion and maintaining water availability.

2. Methods

2.1. Study Site

This study was conducted in June 2021 (one month) upstream of Batang Mahat River Basin Lima Puluh Kota Regency, West Sumatra, Indonesia (Figure 1). The site is hilly, ranging from 800-1000 masl. Furthermore, the temperature, humidity, and precipitation ranged from 21.9 – 25.9 ^{0}C, 48-77% and 51-362.3 mm yearly (Climatology station of Politeknik Pertanian Negeri Payakumbuh, 2020). There were eight rainy days during the study.

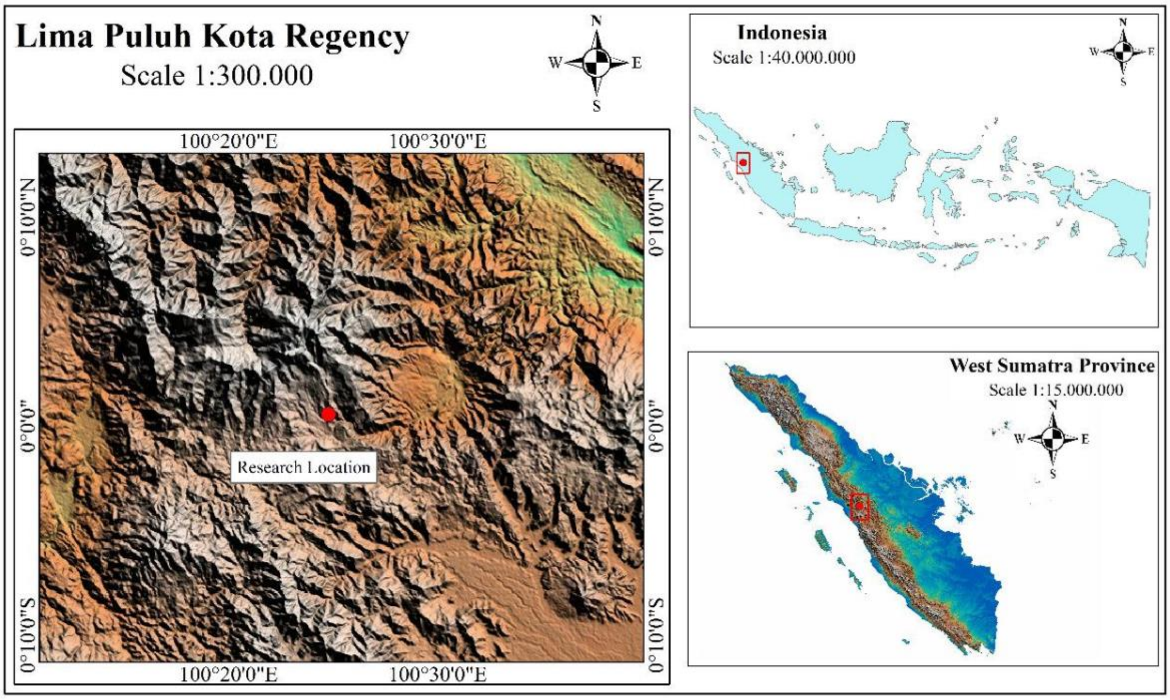

Figure 1. Study site

2.2. Data Collection

Three trees with a diameter of> 10 cm were selected for each species. Throughfall canopy data was collected using a 1 x 1 m plot made from plastic, positioned below and at 1 m from the ground. A thick silicon plastic was attached around the stem of each tree at a one-meter height from the ground and carefully positioned to block water flows from the stem to the ground. Subsequently, a small hole was established at a point to allow water flows to a five litres container through a 1-inch plastic tube. The amount of water collected in the container was calculated as stem flow. The throughfall canopy and stem flow were assessed eight times in one month (the data collection dates were: 3, 4, 12, 14, 15, 23, 27 and 29). Meanwhile, precipitation was measured in an open area without canopy cover by using an outdoor ombrometer.

2.3. Data Analysis

2.3.1. Throughfall Canopy

The following equation (1) was used to calculate the throughfall canopy (Naharuddin *et al*., 2016; Nuraeni *et al*., 2014).

$$Tfi = Vi/Li \quad (1)$$

Where:

Tfi = height of throughfall canopy (mm)
Vi = volume of throughfall canopy (mm^3)
Li = area of container (mm^2)

2.3.2. Stem Flow

The following equation (2) calculates stem flow (Nuraeni *et al*., 2014).

$$Sfi = Vi/Li \quad (2)$$

Where:

Sfi = height of stem flow (mm)
Vi = volume of stem flow (mm^3)
Li = area of tree canopy (mm^2)

Analysis of Variance (ANOVA) was applied to determine the effect of tree architectures on throughfall canopy and stem flow. This was analyzed using the model (3).

$$Y \sim \beta_0 + \beta_1 ta + \varepsilon \quad (3)$$

Y is the dependent variable (e.g. throughfall canopy), and *ta* is tree architecture. TukeyHSD was used when ANOVA detected a significant effect.

The mean of throughfall canopy and stem flow was analyzed for correlation with precipitation during data collection.

3. Results and Discussion

3.1. Throughfall Canopy

The following Table 1 shows the average throughfall canopy of the species.

Table 1. Average of Throughfall canopy of species.

Date of rainfall	Precipitation (mm)	Average of throughfall canopy (mm)			
		V	G	S	R
3	2	0.873333	0.540000	0.446667	0.843333
4	2	3.326667	4.933333	4.173333	4.173333
12	6	8.540000	1.596667	1.083333	1.440000
14	4	5.483333	0.763333	0.616667	0.963333
15	8	6.746667	7.030000	4.913333	4.200000
23	36	7.636667	6.463333	5.046667	4.870000
27	4	1.563333	0.160000	0.160667	0.173333
29	5	0.820000	1.286667	1.100000	0.773333

V = *Voacanga foetida*, G = *Guioa* sp, S = *Schima wallichii*, R = *Rhodoleia championii*

The highest and lowest throughfall canopy was observed in *Voacanga foetida* and *Rhodoleia champonii*. This can be seen in the architecture of *V. foetida*, categorized as Scarrone, where the number of branches is rarer than the Leewenberg tree, represented by *R. champonii*, such that a substantial amount of rainwater fell to the ground. Also, the throughfall canopy is affected by the thick tree canopy (Halle *et al.*, 1978).

Table 2. TukeyHSD test on throughfall canopy. V = *Voacanga foetida*, G = *Guioa* sp, S = *Schima wallichii*, R = *Rhosdoleia championii*.

Between	Diff	lwr	upr	P adj
R-G	-0.5120833	-264.498.704	1.620.820	0.922 ns
S-G	-0.6540833	-278.698.704	1.478.820	0.852 ns
V-G	15.270.833	-0.60582038	3.659.987	0.246 ns
S-R	-0.1420000	-227.490.371	1.990.904	0.998 ns
V-R	20.391.667	-0.09373704	4.172.070	0.066 ns
V-S	21.811.667	0.04826296	4.314.070	0.043 s

* $P < 0.05$, ns = non-significant
s = significant

Throughfall canopy differed significantly between tree architectures (F = 3,01, df = 3, *p-value* = 0.035). However, the TukeyHSD test showed that a significant differentiation was only discovered between Scarrone (*Voacanga foetida*) and Rauh (*Schima wallichii*) (Table 2). This suggested that the differentiation of the throughfall canopy does not always accompany different tree architecture. The species can differ in the shape of the branches, allowing different amounts of rainwater to fall through the canopy (Faye, 2011). The branches of *Voacanga foetida* are wider than those of *Schima wallichii*, allowing twice as much precipitation to reach the ground as branches with narrower diameters, as shown in Figure 2.

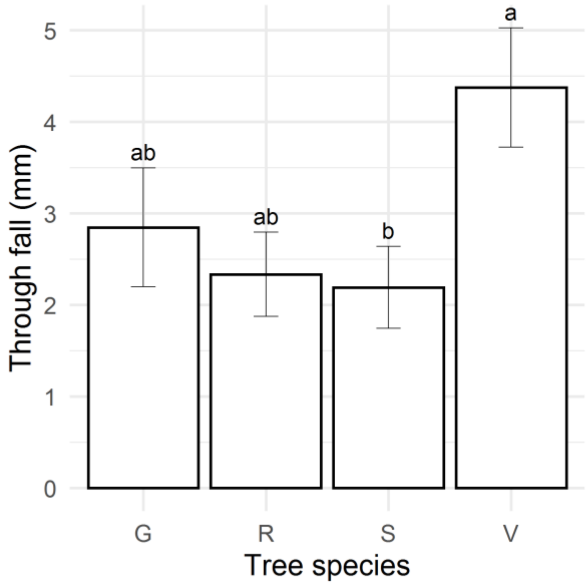

Figure 2. The differentiation of species on the throughfall canopy

3.2. Stem Flow

Table 3 shows the average stem flow of each species.

Table 3. Average stem flow of species. V = *Voacanga foetida*, G = *Guioa* sp, S = *Schima wallichii*, R = *Rhodoleia championii*

Date of data collection	Precipitation (mm)	Average of stem flow (mm)			
		V	G	S	R
3	2	0.000559	0.000057	0.000135	0.000127
4	2	0.008277	0.000859	0.001438	0.000758
12	6	0.053995	0.001113	0.002258	0.004528
14	4	0.008099	0.000158	0.001157	0.003143
15	8	0.094618	0.003623	0.013368	0.003453
23	36	0.039960	0.002234	0.013522	0.000129
27	4	0.000510	0.000038	0.000133	0.006002
29	5	0.000805	0.000083	0.000078	0.000114

The highest and lowest stem flow was discovered in *V. foetida and Guoia* sp, respectively. ANOVA test indicates that this parameter differed significantly between species (F = 6.82, df = 3, *p-value* = 0.000361), but only for comparison with *V. foetida*, as presented by TukeyHSD in Table 4.

The stem flow of *V.foetida* was approximately eight folds higher than *S. wallichii*, *Guioa* sp and *R. champonii*, and the last three species did not differ from each other (Figure 3). This species' highest stem flow is caused by the characteristic of the bark, which is mostly smooth with very few rough textures, allowing water to fall faster to the bottom.

Table 4. TukeyHSD test for comparison analysis between species

Between	Diff	lwr	upr	P adj
R-G	0.001011933	-0.012121490	0.01414536	0.997 ns
S-G	0.002433979	-0.010699444	0.01556740	0.962 ns
V-G	0.019545296	0.006411872	0.03267872	0.001 ss
S-R	0.001422046	-0.011711378	0.01455547	0.992 ns
V-R	0.018533362	0.005399939	0.03166679	0.002 ss
V-S	0.017111317	0.003977893	0.03024474	0.005 ss

* P < 0.05, ns = non-significant
ss = very significant

The differences are thought to be caused by the morphology of stems. *S. wallichii* had extremely rough bark with depth ridges along the bark, similar to *R. champonii* but a little milder than *S. wallichii* (Faye, 2011). Australian Native Plants Fact Sheet (2014) reported that *V. foetida* is a tree with smooth bark and swallow ridges, which allows the waterfall faster to the ground.

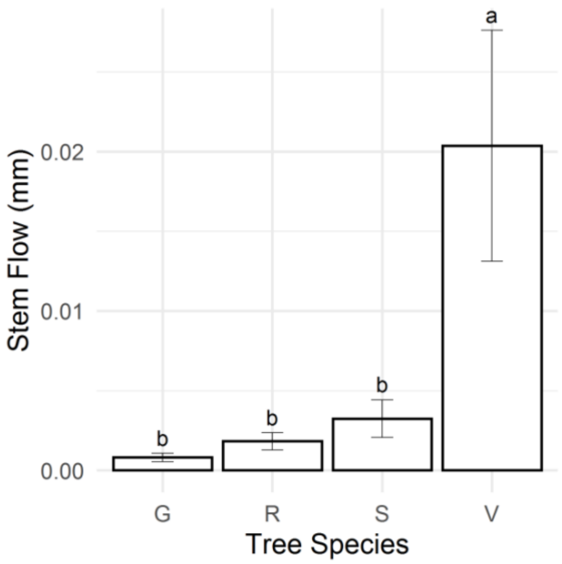

Figure 3. The differences in stem flow among species

4. Conclusion

Schima wallichii differed significantly from *Voacanga foetida* on throughfall canopy. *V. foetida* had the highest stem flow compared to *S. wallichi*, *R. champonii* and *Guioa* sp., while the last three species did not differ. It is assumed that the shape of the surface of the stem influences stem flow. Throughfall canopy and stem flow were significantly affected by tree architectures.

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