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Canopy interception on tree architecture models of aubreville, stone and leeuwenberg in Lore Lindu National Park Area, Indonesia

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Abstract

An important component in the hydrological cycle is vegetation, especially its role in intercept rainfall. This study aims to determine the effect of rainfall on the throughfall, stem flow and canopy interception on Aubreville architectural models, Leeuwenberg and Stone tree stands. This research conducted at the forest garden land of Gumbasa sub watershed, in Palu watershed. Administratively the region is in districtof Gumbasa, Sigi Regency, Central Sulawesi Province, which is included in the Lore Lindu National Park Area. Determination of the sample conducted representatively, using the survey method by way of the path along the river at Gumbasa Sub watershed. Data were analyzed using statistical analysis through a simple linear regression equation. The results showed that the relationship between rainfall to stem flow, throughfall, and canopy interception is linear and highly significant at the level of 99%. The best architectural trees model to increase the amount of water up to the ground surface is the Leeuwenberg model of species *Calophyllum soulattri* (Clusiaceae).

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Introduction

Branching pattern of the plant will establish a tree architecture model. Branching architecture is a picture of morphology in a particular phase of a tree growth series circuit, real and can be observed at any time. The architectural concept shows the dynamic nature of models for plant continues to grow according to time and space. The architectural model looks at when plants are young and growing well (Hidayat, 1992). The architectural model is applied to plant a tree stature as a picture of one phase in a series of growth. Each type of tree has distinctive features in a series of growth process that genetically inherited to its heredity. Because of its consistent features so the architectural model in every type of tree can be used as additional data in distinguish it from other tree species (Arrijani, 2006).The influence of the type of vegetation on the water system at an area partly because each plant species has architectural models are different. Knowledge of architecture model tree is very important to know their role in intercept rainfall.

Interception of rainwater is one of the important components in the hydrological cycle (Saberi and Rosnani, 1999). Portions of rainfall that reaches the forest floor or tree stands known as net precipitation which can be divided into two components, namely throughfall and stem flow (Klassen *et al.*, 1996). Canopy interception process is influenced by many factors, including the density of stems, leaves of the plant, the type of rainfall, rainfall intensity and duration of rainfall events (Chanpaga and Watchirajutipong, 2000). Naturally, the forest vegetation plays an important role in controlling soil erosion. Through the mechanism of rain interception, forest canopy decrease the kinetic energy and the speed of rainwater particle to reach the ground surface (Singh, 1987).

When rainfall falls has exceeded the capacity of the tree canopy, the overage will pass or flow through the stem is potential to become a surface runoff (Bruijnzeel, 1990).

Compared with the water that flows down through the tree stem, throughfall is known as the largest contributor as a water replacement in the watershed and the water system in the forest (Arcova *et al.*, 2003; Oliveira and Dias, 2005). The amount of rainwater that is intercepted by plant varies depending on the type of plant leaves, canopy shape, wind speed, solar radiation, temperature as well as humidity. The different types of plants will affect differences in the structure and architecture of the canopy, and will influence the behavior of plants against rainwater interception (Hutchion *et al.*, 1986; Herwitz and Slye, 1992).

As one evapotranspiration component, the amount of interception loss not only changes the partitioning of rainfall into throughtfall and stem flow but influences the nutrient flux dynamics in a forest ecosystem. The dynamics of I are mainly dependent on the rainfall features, canopy structure characteristics, micrometeorological conditions, and interactions between these factors (Link *et al*, 2004; Muzylo *et al*, 2009; Chen and Ming, 2016).

Interception as one component in the hydrological cycle that although its value is small and sometimes often overlooked, but it has a huge impact for the condition of the water system in the watershed. Interception intree stands can reduce surface runoff, erosion or flooding early and simultaneously generate clean air and cool the surrounding environment.

In Taiwan, interception loss has been found to account for nearly 10% of the annual rainfall for mixed hardwood forests (Lu and Tang, 1995; Lin *et al.*, 1996).Several studies have been done with regards to canopy interception by Sadeghi *et al.* (2014) in timber in Tehran, Iran; Chairani and Jayanti (2013) on pine tree by stating that the age of the plant greatly affect the interception, the more dense canopy of trees, the greater of interception; Gasparoto *et al.* (2014) on *Eucalytus cloeziana* forest, *Pinus* sp, and seasonal semideciduous forest (FES) in Ipero, Sao Paulo); Supangat (2012) onEucalyptus forests;

Kaimuddin (1994) on stands of pine, Agathis and Schima; Ruslan (1983) on Sungkai pine stands and natural forests; Aththorick (2000) in educational forest of Gunung Walat, Sukabumi that the canopy interception on the model *Agathis dammara* Massarttypesas much as 478.19 mm of total rainfall of 548.2 mm (87.23%).

To reveal the effect of tree architectural model of some hydrological aspects that integrate components of rainfall as independent variables, which is one part of the hydrologic cycle then researchperformed with the aim to determine the effect of rainfall on the throughfall, stem flow and canopy interception onthe stands of architectural model of Aubreville, Leeuwenberg and Stone.

Materials and methods

Location and time

Research conducted in the forest garden land at Gumbasa Sub watershed, in Palu Watershed at the coordinates of 01°17' Nort latitude and 119°58' East longitude. Administratively the region is in Gumbasa District, Sigi Regency, Central Sulawesi Province, which is included in the Lore Lindu National Park area. The study carried out for nine months from August 2015 until April 2016.

Research procedure

Preparation:Preparation of the research is to perform the field orientation using the instructions contained in the land use map, map of forest land and slope map. Preparation conducted by looking at the overall study site with a view to get an overview of the general condition of Gumbasa Sub Watershed which is the upstream of Palu Watershed. The results of field orientation as basis in determining the location of the plot to study the throughfall, stem flow and interception of any tree architectural model.

Research implementation

Data of tree architecture model:The tree architectural model chosen for the research plots parameters of hydrology (throughfall, stem flow, canopy interception)done purposively on three trees architectural model repeated in 3 times i. e. the Aubreville model species *Macaranga mappa* (Euphorbiaceae), Leeuwenberg model species *Calophyllum soulattri* (Clusiaceae) and Stone model species*Castanopsis acuminatissima* (Fagaceae).

Observations of tree architectural models is done by examining the morphological features of the canopy and branches in general, the pattern of tree development, development of main stem, branches and twigs development in accordance with the termsof Halle and Oldeman (1975); Nedi (1997) and refers to the identification key that has been developed by Setiadi (1998).

Rainfall measurement:Rainfall measurement is done by manually installing measuring devices (ombrometer) in forest plantation area on an open space with a height of 1 m from the ground surface (Fig. 1). Measurement of the volume of rainwater in mm done every day as much as 30 times rain events.

Data collection of throughtfall and stem flow: Measurement of throughtfall is collected using a plastic sheet associated with reservoir bucket then given a wooden frame with an area of 1 x 1 m, then placed under the tree canopy (Fig. 2).

Measurements were made 30 times every morning after the rain on each tree architecture models. The amount of throughtfall that measured as many as 3 trees (as replication) on three tree architecture models.Stem flow measurement is done by looping half plastic hose on the surface of stem that had been cleared in advance with the height hose between 1 m above the ground (Fig. 3). This is to prevent splashing rainwater from the forest floor during the rains. Hoses are attached by glue so that its position remains in place, lower end of the hose is placed jerry can lead to the shelter.

Measurements were made 30 times every morning after the rain on each respective tree architectural model. Volume of the stem flow measured as much as 3 trees (as replication) on three tree architecture models.

Data analysis

Tree architectural model:Then the architecture of tree species to be identified were set represent or resemble to the most suitable model of 23 models that have been described. Having regard to and measure the parameters *viz.* forms of stem growth, shape and composition of branches on the stem, shape and composition of branches on a lateral branch, position of sexual organs (flowering) and high stem free of branch.

Throughfall and stem flow:To analyze the volume of throughfall at each daily rain events performed by the following equation (Thomaz, 2005):

TF = V/A

Where: TF = throughfall (mm), V = volume of rainwater stored in each gauge (L), A = funnel collection area of each gauge (m^2).

To analyze the flow of stem on each daily rainfall events carried out by the following equation (Kaimuddin, 1994; Yusop *et al*., 2003):

SF = X/πr2

where: SF =stemflow(mm), X = volume of rainwater stored in each gauge (cm^3), π = constants, r = radius of the tree canopy projection.

Canopy interception:From the results of measurements of rainfall, througfall and stem flow, then calculated amount of canopy interception by volume balance approach as follows (Waterloo, 1994):

I = R - (TF + SF).

where: I = rainfall interception loss (mm),R= rainfall (mm),Tf= throughfall (mm),Sf= steamflow (mm).

The relationship of rainfall to the throughfall, stem flow and canopy interception: To determine the relationship of rainfall to the throughfall, stem flow and canopy interception used simple linear regression analysis, with precipitation as an independent variables.Simple linear regression analysis model appropriate formula according to Gomez, Gomez (1984) and Supranto (1986) as follows:

Y = a + bx

where:Y= dependent variable, a= constants, b= regression coefficient, x =independent variable.

The selected model is a model with a coefficient of determination (R^2), the largest and logic in estimating the throughfall, stem flow and canopy interception.

From the scattering of the measured data can be seen form the appearance of the spread of the data, either to follow the pattern of linear or non-linear, in order to help the selection of the model and perform the Analysis of Variance (ANOVA). To facilitate the regression analysis, then used the Statistical Product and Service Solutions (SPSS) program, the results are presented in the table regression coefficient.Presence or absence of the relationship between variables is an influential regression relationship then do regression with F test.

Testing is done by comparing the value of F arithmetic with F table value on a particular real level, with the testing criteria:

Ho: ß = 0, none of the independent variables that influence Y (F arithmetic <F table).

H1: ß = 0, at least one or more independent variables are mutually effect on Y (F arithmetic > F table).

Results and discussion

Characteristic of tree architectural model

Tree stands characteristic of Tree Architectural Model of Aubreville, of Leeuwenberg, and of Stone was identifiable tree height, high stem free of branch, canopy depth, canopy diameter, canopy area, leaf width, and trunk diameter (Fig. 4).

In general of fig. 4, characteristic value of Leeuwenberg's model is lower than that of Stone's model.The three models (Leeuwenberg, Stone, and Aubreville) had orthotropic branching characteristic – branches are leaning upwards affecting stem flow value and canopy area of each tree architectural model. Besides, growth of lateral meristem on orthotropic branching was assumed to trigger stem diameter and tree height. Big orthotropic branches which are large in number need big stem, too, to support the tree.

Fig. 1. Rainfall Measuring devices (Ambrometer) at Study Sites.

Although the nature branching of Aubreville's model was orthotropic, its branch tended to be flat.Bark characteristic of the three models was different but bark furrows of Aubreville's and Stone's model was similar- shallow, rather roughly, while Leeuwenberg's was shallow and rather smooth. Such bark characteristic highly influenced stem flow value.

Fig.2. Measurement throughtfall at study site.

Based on the hydrological parameter, tree architectural model influences the value of runoff and throughfall, and then the throughfall and rainfall determine the amount of interception value in fig 4, a justification could be that the canopy structure characteristics such as vegetation type, tree density, crown height, cover fraction and leaf shape can affect the canopy water storage capacity, which is also important for the estimation of interception loss (Deguch *et al*, 2006).

Fig.3. Measurement of stem flow at study sites.

Different architectural model owned by typesof tree will result in different growth as well. The types of pioneer tree generally prioritize stem elongation followed by new branches. Nonetheless, formation of new branches sometimes co-occurred with stem elongation.Types of slow-growing tree are generally characterized by gradual branch growth followed by slow stem elongation. These kinds of trees are characterized by rhythmic growth pattern. This means there are certain growing phases which slow down or stop, and then continue when environmental factors support.

Throughfall

The result of analysis on throughfall taking place for 30 days of precipitation for each architectural model was presented in Fig. 5.

Throughfall measured in thirty days of precipitation of Stone's architectural model was generally lower with a total of 68.96 mm (13.26%) compared to those of Aubreville's, which was 107.53 (20.67%), and of Leeuwenberg's, which was 98.52 mm (18.94%) from the total rainfall of 520 mm (Fig. 5), Comparatively, Gasparato *et al*, (2014) found a lower value (3,9 mm) seasonal semideciduous forest (FES) in Ipero, Sao Paulo. Arcova *et al.* (2003) and also Oliveira and Dias (2005) reported lower mean values of total precipitation capable of promoting throughfall, respectively 0.62 and 1.28 mm. As for *Pinus* sp., a result close to that in this study (2.04 mm) was found by Calux and Thomaz (2012) in a study with *Pinus elliottii* forest.

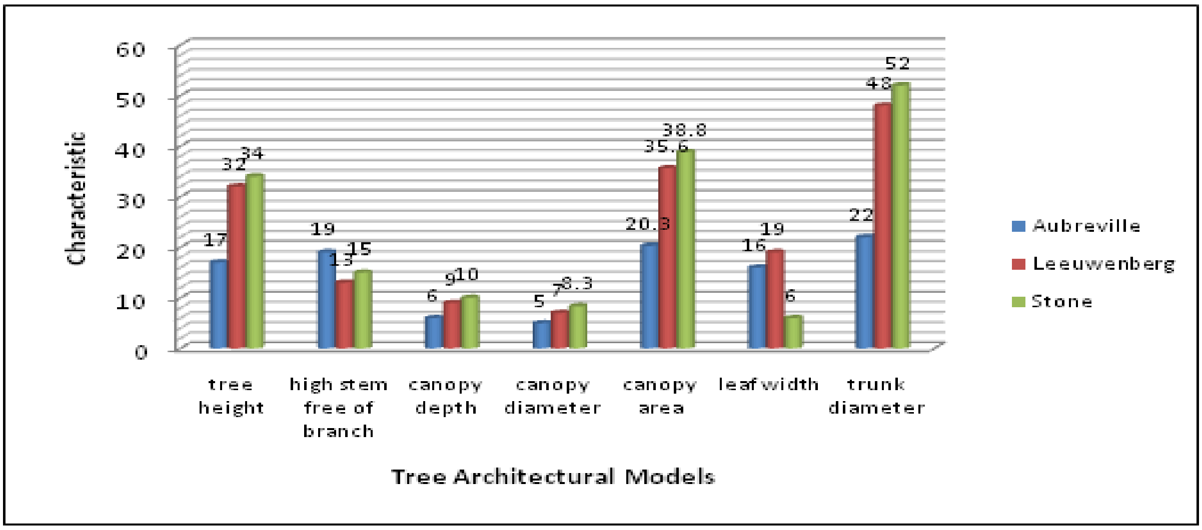

Fig. 4. Characteristic of Each Tree Architectural Models.

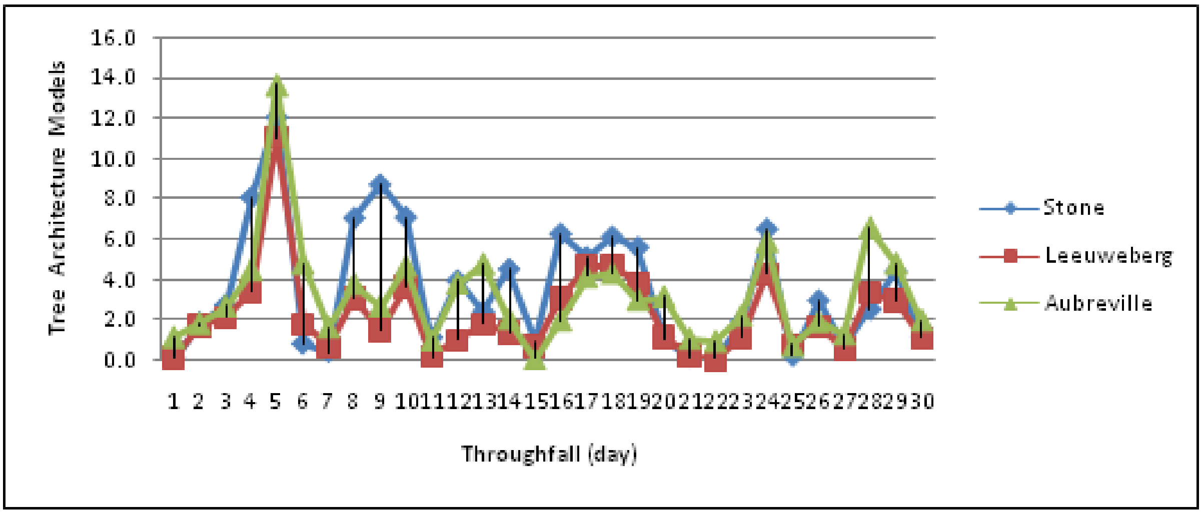

Fig. 5. Throughfall.

This indicated that branch position of Stone's and Leeuwenberg's tended to gravitate to the top so that rainwater hitting the branches would partly become stem flow, and only a small part would become throughfall. Observation in the field showed that layout of Aubreville's model branch was symmetrical and evenly spread along the stem from first branching to the top. This made canopy pores larger enabling a great deal of rainfall to penetrate to the canopy through forest floor. Besides, leaf width was greater so that more water was captured, which mostly flowed through the throughfall. The observation also showed that canopy density of Aubreville's model was thinner than those of Leeuwenberg's and of Stone's. Rainfall affected the size of the throughfall.

The result of the observation during research period showed that in view of simple linear regression analysis, it was found that there was a different correlation among the tree architectural models (Fig. 6).

Regression equation showed that rainfall and throughfall had a linear correlation. This means that rainfall value linearly influenced throughfall value. Therefore, each additional rainfall would improve the throughfall value. The proportion of throughfall value of each tree architectural model explained through rainfall was stated in cooficient of determination(r^2). Based on the R^2 throughfall value, it is indicated that 74 percent of the rainfall value could described the value of throughfall occurred on Aubreville's with R = 0.86 (very strong), 82 percent of Leeuwenberg's with R = 0.91 (very strong) and 72 percent of Stone's with R = 0.84 (very strong).

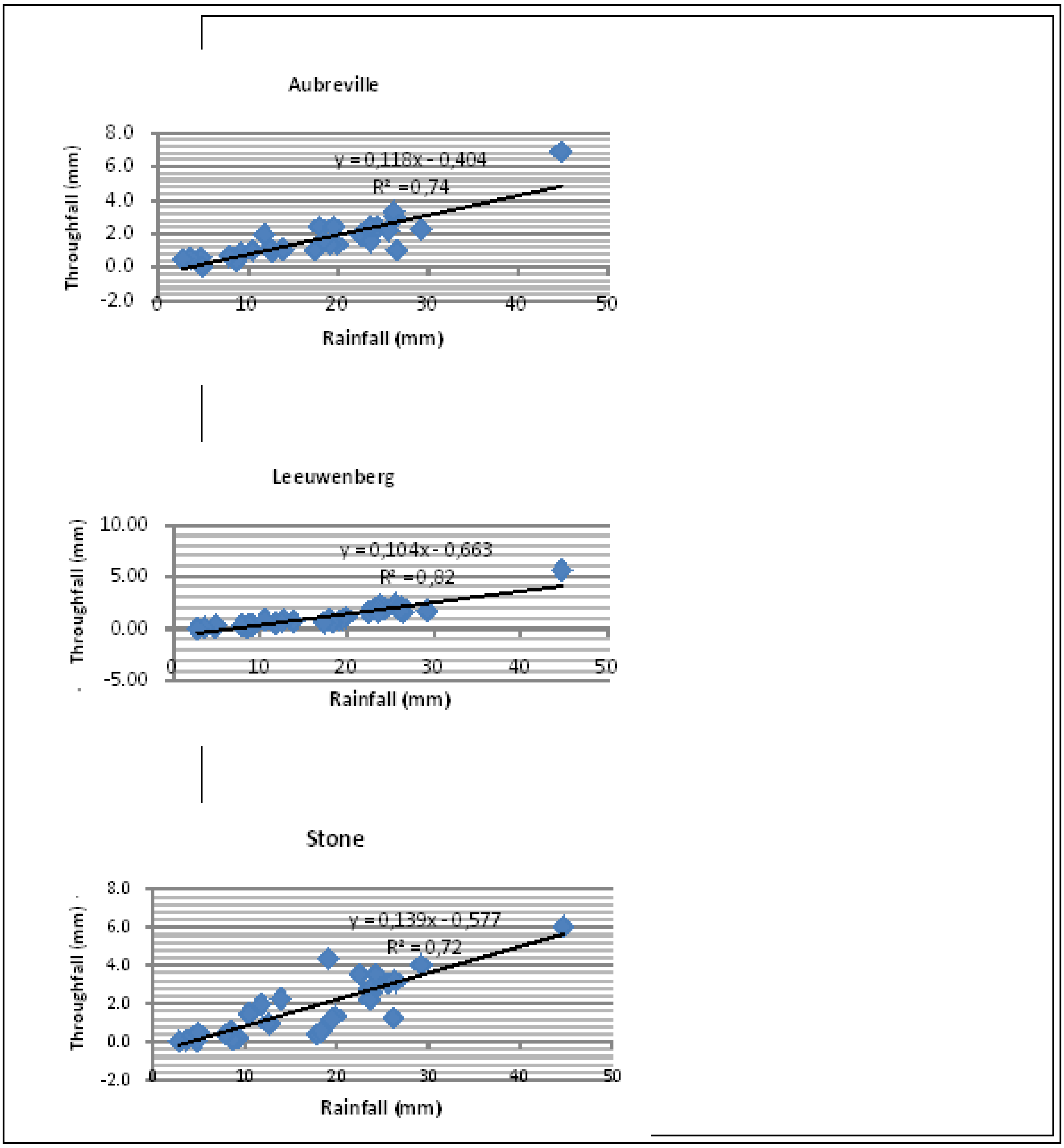

Fig. 6. Linear Regression between Rainfall and Throughfall on Architectural Models of Aubreville's, of Leeuwenberg's and of Stone's

The result of ANOVA test or F test of the three architectural models indicated that the $F_{counted}$ of Aubreville's model was 78.34, of Leeuwenberg's was 133.70 and of Stone's was 67.15 and the F_{table} was 7.64 with significance level of 99% and the F_{table} was 4.20 with significance level of 95%. This means that there was a significant correlation between rainfall and throughfall variables.

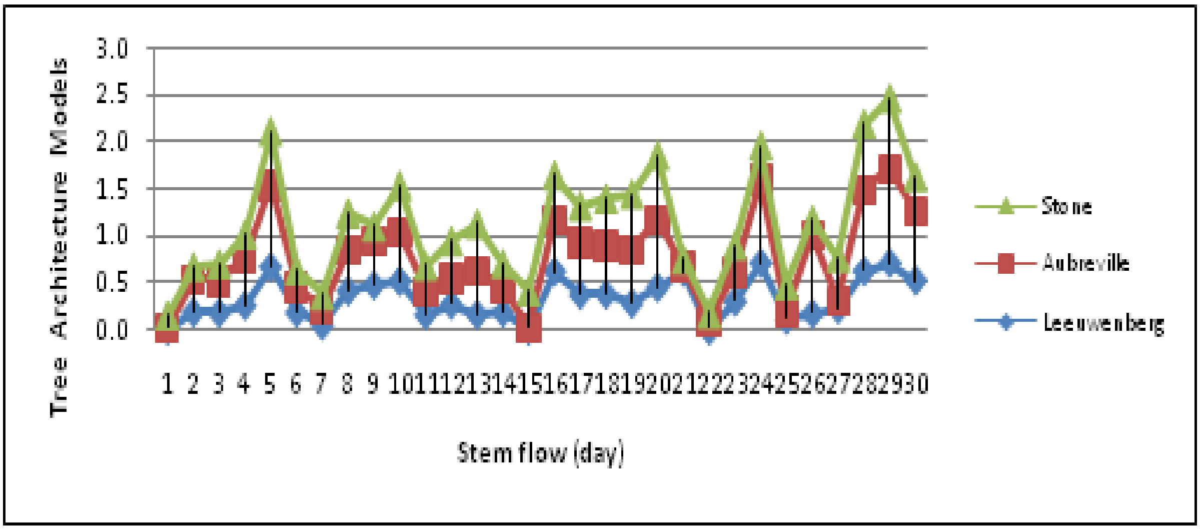

Fig.7. Stem flow.

The type of leaves of Aubreville's architectural model was larger than those of Leeuwenberg's and of Stone's. This affected the value of throughfall of single and relatively large type of leaves, which was strong enough to withstand rain water exposure. Another factor affecting the value of throughfall was the thickness of the canopy.

The thicker the canopy of a tree is, the less the rain water infiltrates through the leaf's cracks (Asdak, 2004; Herwitz, 1985). A justification could be that the under Brandt, (1987) canopies strongly affect throughfall drop size and terminal velocity.

Stem flow

The result of stem flow measurement in thirty days of precipitation was displayed in Fig. 7.

Fig.e 7 showed that the highest everyday stem flow was found in Stone's architectural model with a total of 13.06 mm (2.51%) followed by that of Aubreville's with a total of 10.74 mm (2.06%) and that of Leeuwenberg's, which was the lowest, with a total of 9.56 mm (1.84%) of the total rainfall of 520 mm.

Compared with the Leeuwenberg's and Aubreville's models, the stem flow height of Stone's architectural model related to trunk diameter, spreading (patens)growth of branches, branchlets and twigs and clear length bole height. Stone's and Leeuwenberg's models had higher tree stands character value as seen in each tree stand characteristic.

A justification could be that the according to Supangat *et al*, (2012) reported that the amount of water becoming the stem flow was influenced by trunk diameter, clear length bole height and shape/plant architectural branching. The result of simple linear regression analysis on correlation between rainfall and stem flow showed that the correlation among each of the tree architectural models varied (Fig. 8).

There was a linear correlation between rainfall and stem flow on each of the architectural models (Fig. 8). It means, the value of rainfall linearly affected the value of stem flow. Thus, every increase of rainfall would improve the throughfall value.

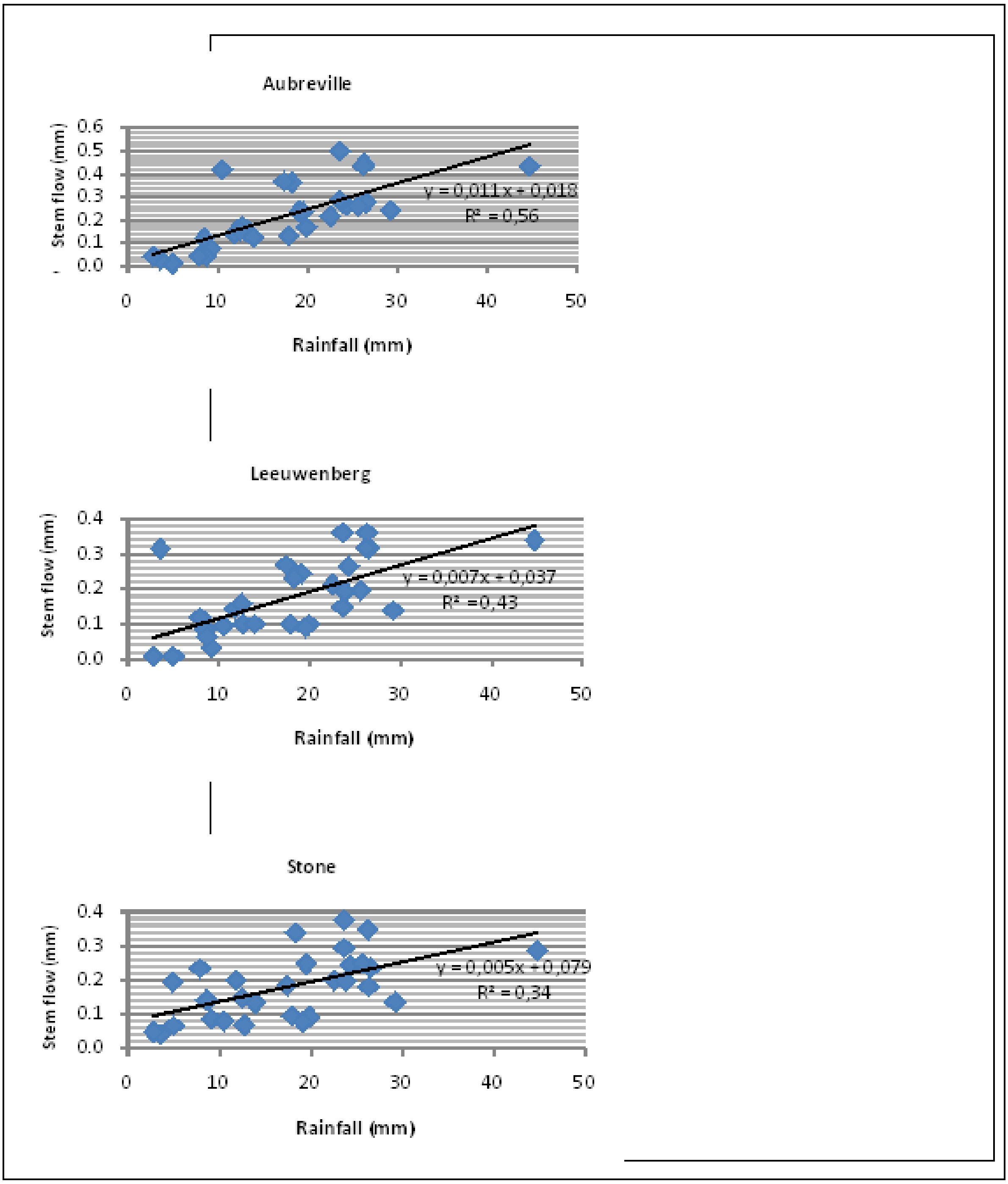

Fig.8. Linear Regression between Rainfall and Stem Flow of Aubreville's, of Leeuwenberg's and of Stone's Architectural Models.

The proportion of throughfall value of each tree architectural model explainable through rainfall was stated in coeficient of determination(r^2). Based on the R throughfall value, it is indicated that 56 percent of the rainfall value indicated the value of throughfall occurred on Aubreville's with R value = 0.74 (strong), 43 percent of that on Leeuwenberg's with R value = 0.66 (strong) and 34 percent of that on Stone's with R value = 0.58 (fair).

The result of ANOVA test or F test of the three tree architectural models showed that the $F_{counted}$ of Aubreville's model was 35.21, that of Leeuwenberg's was 16.73, and that of Stone's was 14.56 and the F table was 7.64 with significance level of 99 percent and the F table was 4.20 with significance level of 95 percent. This means that there was a very significant correlation between rainfall and stem flow variables. Generally, the value of each tree architectural model, Aubreville's, Leeuwenberg's and Stone's, was affected by branching pattern, trunk diameter and bark characteristic.

Aubreville's and Stone's bark characteristics were shallow and relatively rough furrows, while those of Leeuwenberg's, which affected the value of stem flow of each tree, were shallow and relatively smooth furrows. The results were in line with Herwitz (1985); Crockford and Richardson (2000) rough bark may store more water, and therefore generatestem flow less than smooth bark.

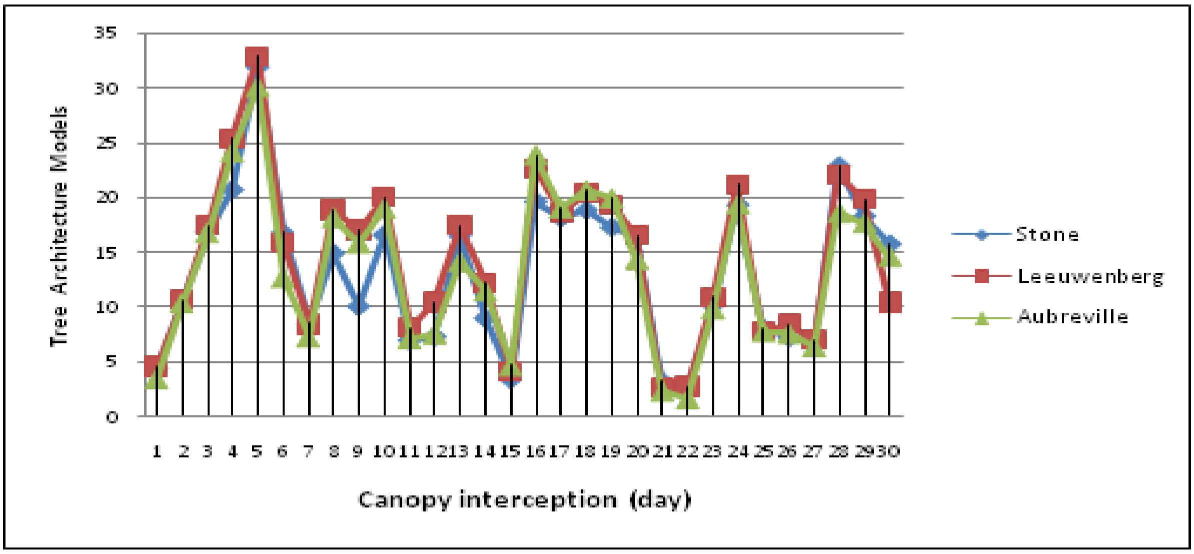

Fig. 9. Canopy interception.

The three tree architectural models constituted orthopedic branching (vertical) feature. The branching of such architectural models formed an angle of smaller than 90 degrees, which ultimately affected the value of stem flow on tree. Also, stem diameter of this architecture was big enough to increase speed of stem flow.

Canopy interception

During 30 days of precipitation of canopy interception for each tree architectural model was presented in Fig. 9 as follows.

Canopy interception of each tree architectural model showed that the highest canopy interception each day occurred in Leeuwenberg's with a total of 217.90 mm (54.21%), followed by that in Aubreville's which was 204.31 mm (46.89%) and that in Stone's, which was the smallest, with 200.97 mm (38.27%) of the total rainfall of 520 mm.

The data above showed that the total rainfall intercepted was directly proportional to the existing rain water. However, the percentage of intercepted rain water became smaller when rainfall increased as Bruijnzeel (1990) states that the percentage of interception will be bigger if rain is not heavy. The least rainfall will almost entirely be intercepted by plant canopy.

The volume of rain water intercepted related to leaf Area Index, which affected canopy storage capacity. If this storage capacity was bigger than the rainfall, the rain water would be intercepted entirely. Nonetheless, if the rainfall was bigger than the storage capacity, the canopy would be saturated to hold rain water. As a result, the rain water partly flowed through stem flow and became throughfall, which made interception smaller.

Canopy storage capacity was noted through size and density of the canopy. Age of tree highly influenced canopy density; the denser the tree canopy is, the bigger the interception will be (Asdak, 1998). This is due to the amount of the rain water captured by canopy which would be intercepted.

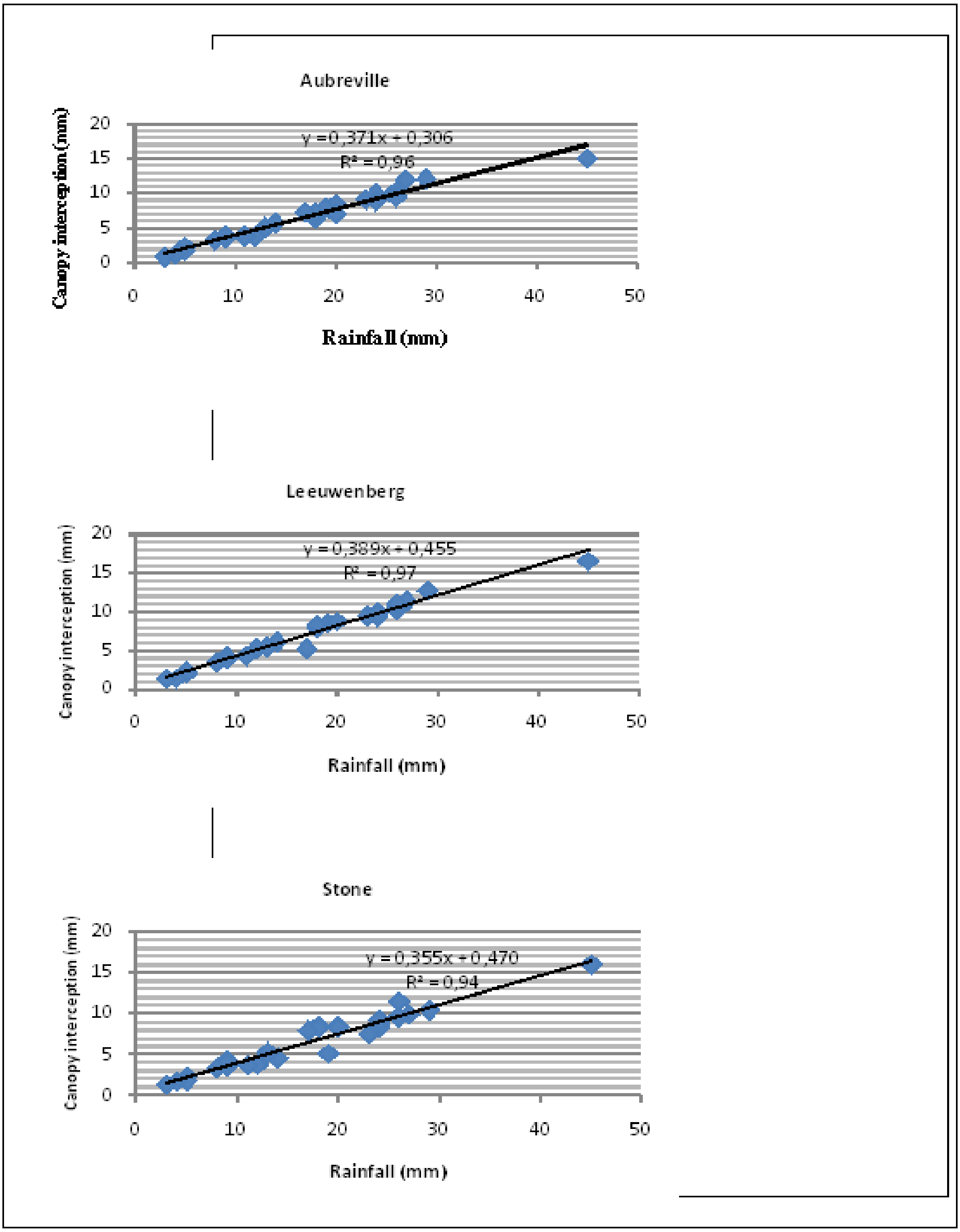

Fig. 10. Linear Regression between rainfall and canopy interception of architectural models of Aubreville's, Leeuwenberg's and Stone's.

Based on simple linear regression test, it was indicated that there was a correlation between rainfall and canopy interception. Graphic showing linear regression correlation between rainfall and interception of each tree architectural model was presented in Fig. 10.

Coeficient value of the correlation between rainfall and canopy interception was 0.96. It means that 96 percent of canopy interception ocurred in Aubreville's was influenced by rainfall with R value = 0.98 (very strong). The result of regression analysis on the correlation between rainfall and canopy interception indicated that the coeficient of determination (r^2) was 0.97, meaning that 97 percent of canopy interception ocurred in Leeuwenberg's was influenced by rainfall with R value = 0.98 (very strong). The result of regression analysis on the correlation between rainfall and canopy interception showed that the coeficient of determination (r^2) was 0.94, meaning that 94 percent of canopy interception ocurred in Stone's was affected by rainfall with R value = 0.97 (very strong).

The result of ANOVA test or F test of the three tree architectural models indicated that $F_{counted}$ of Aubreville's was 442.50, that of Leeuwenberg's was 778.69 and that of Stone's was 1832.51 and the F table was 7.64 with significance level of 99 percent and the F table was 4.20 with significance level of 95 percent. It means, there was a significant influence between rainfall and canopy interception variables.

In this research, the amount of interception was influenced by both vegetation and weather factors. In terms of vegetation factor, width and density of canopy of each model were highly influencial. Weather factor contributing to interception on each architectural model was rainfall and sun radiation. The rainfall highly influenced the value of interception. The higher the rainfall was, the bigger the volume of water intercepted would become. For the architectural models of Aubreville's, Leeuwenberg's and Stone's, the value of interception produced was highly influenced by rainfall.

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References

Arcova FCS, V de Cicco, PAB Rocha. 2003. Precipitação efetiva e interceptação das chuvas por floresta de mata atlântica em uma microbacia experimental em Cunha, São Paulo. Revista Árvore **27(2),** 257-262

Arijani. 2006. Korelasi Model Arsitektur Pohon Dengan Laju Aliran Batang,Curahan Tajuk, Infiltrasi, Aliran Permukaan dan Erosi (Suatu studi tentang peranan vegetasi dalam konservasi tanah dan air pada sub-DAS Cianjur Cisokan Citarum Tengah). Disertasi (unpublished). Program Pasca Sarjana, Institut Pertanian Bogor.

Asdak C. 2004. Hidrologi dan Pengelolaan Daerah Aliran Sungai. Gadjah Mada University Press. Yogyakarta.

Asdak C, Jarvis PG, Van Gardingen P, Fraser A.1998. Rainfall interception loss in unlogged and logged forest areas of Central Kalimantan, Indonesia. Journal of Hydrology **206,** 237-244.

Aththorick TA. 2000. Pengaruh Model Arsitektur Pohon Massart dan Rauh terhadap Aliran Batang, Curahan Tajuk, Aliran Permukaan dan Erosi di Hutan Pendidikan Gunung Walat Sukabumi. Tesis (unpublished). Program Pascasarjana Institut Pertanian Bogor.

Brandt J. 1987. The effect of different types of forest management on the transformation of rainfall energy by the canopy in relation to soil erosion. In: Proceedings of the Forest Hydrology Watershed Management Conference. Vancouver, BC IAHS Publication **167**, 213–222

Bruijnzeel LA. 1990. Hydrology of moist tropical forest and effects of conversion:A stage of knowledge review. UNESCO International Hydrological Programme & Free University, Amsterdam.

Calux J, Thomaz El. 2012. Interceptação e Precipitação Interna: Comparação Entre Floresta Ombrófila Mista e *Pinus elliotttii* var. *elliotti*. Revista Eletrônica do Curso de Geografia, Jataí **19**, 24-39.

Chen YY, Ming HL. 2016. Quantifying Rainfall Interception Loss of a Subtropical Broadleaved Forest in Central Taiwan. Journal Water **8(1)**, 1-19.

Chairani S,Dan Jayanti DS. 2013. Intersepsi Curah Hujan Pada Tegakan Pohon Pinus (*Casuarina cunninghamia*). Jurnal Rona Teknik Pertanian **6(1)**, 405-412

Chanpaga U,Dan Watchirajutipong T. 2000. Interception, throughfall and stem flow of mixed deciduous with teak forest.

Crockford RH, Richardson DP. 2000. Partitioning of rainfall into throughfall, stemflow and interception: effect of forest type, ground cover and climate. Hydrology Process **14**, 2903–2920.

Deguchi A, Hattori S, Park HT. 2006. The influence of seasonal changes in canopy structure on interception loss: Application of the revised Gash model. Journal hydrology, **318**, 80–102.

Gasparoto EAG, Kelly CT, Emily TS, Roberta OAV. 2014. Throughfall in Different Forest Stands of Iperó, São Paulo. Journal of Cerne,**20(2),** 303-310.http://dx.doi.org/10.1590/01047760.201420021260

Gomez KA, Gomez AA. 1984. Statistical Procedures for Agricultural Research (2nd ed.).John Wiley & Sons Inc., New York. USA.

Herwitz RS, Slye. 1992. Climate Needs and Problems in Widland Hidrology and Watersheds Research. Dept. of Forest, Canada.

Herwitz RS. 1985. Interception storage capacities of tropical rainforest canopy trees. Journal of Hydrology **77**, 237-252.

Hidayat EB. 1992. Morfologi Tumbuhan Bandung , Jurusan Biologi ITB , Bandung.

Hutchion BA, Matt DR, McMillen RT, Gross LJ, Tajchman SJ, Norman JM. 1986. The architecture of a deciduous forest canopy in Eastern Tennessee, USA. Journal of Ecology **74**, 635-646.

Kaimuddin. 1994. Kajian Pendugaan Intersepsi Hujan pada Tegakan Pinus merkusii, Agtahis loranthifolia dan Schima wallichii di Hutan Pendidikan Gunung Walat Sukabumi. Tesis.(unpublished). Magister Program Pascasarjana Institut Pertanian Bogor, Bogor.

Klassen W, Lankreijer HJM, Veen AWL. 1996. Rainfall interception near a forest edge. Journal of Hydrology**185(1),** 349-361.

Lu S, Tang K. 1995. Study on Rainfall Interception Characteristics of Natural Hardwood Forest in Central Taiwan; Bulletin of Taiwan Forestry Research Institute **10**, 447–457.

Lin TC, Hsia YJ, King H. 1996. A Study on Rainfall Interception of a Natural Hardwood Forest in Northeastern Taiwan. Journal Forestry **11**, 393–400.

Link TE, Unsworth M, Marks D. 2004. The Dynamics of Rainfall Interception by a Seasonal Temperate Rainforest. Journal of Agricultural Meteorology**124,** 171–191.

Muzylo A, Llorens P, Valente F, Keizer J, Domingo F, Gash J. 2009. A Review of Rainfall Interception Modelling. Journal Hydrology **370**, 191–206.

Nedi S. 1997. Kajian Kualitas Air Sungai Siak di Kotamadya Pekanbaru. Tesis(unpublished). Sekolah Pascasarjana Institut Pertanian Bogor, Bogor.

Oliveira JJC, Dias HCT. 2005. Precipitação efetiva em fragmento secundário da Mata Atlântica. Revista Árvore, Journal of Viçosa **29**, 6-15.

Ruslan M.1983. Intersepsi Curah Hujan pada Tegakan Tusam (Pinus merkusii, Sungkai (Pinus canescens), dan Hutan Alam di DAS Riam Kanan, Kalsel. Tesis(unpublished). Fakultas Pascasarjana Universitas Pertanian Bogor.

Saberi O, dan Rosnani HM. 1999. Rainfall interception by lowland tropical rainforest in Air Hitam, Selangor, Malaysia. Dalam: Rahim, N.A. Water: Forestry and Land Use Perspectives. Technical Documents in Hydrology **70**, 67-68.

Sadeghi SMM, Attarod P, Pypker TG, Dunkkerley D. 2014. Is Canopy Interception Increased In Semiarid Tree Plantation? Evidence From a Field Investigation In Tehran, Iran. Turkish Journal of Agriculture and Forestry **38,** 792-806. http://dx.doi.org/10.3906/tar-1312-53.

Setiadi D.1998. Keterkaitan Profil Vegetasi sistim Agroforestry Kebun Campur dengan Lingkungannya. Disertasi(unpublished). Program Pasca Sarjana, Institut Pertanian Bogor.

Singh RP. 1987. Rainfall interception by Pinus wallichiana plantation in temperate region of Himachal Pradesh, India. Journal of Indian Forester **104,** 559-566.

Supangat BS, Sudira P, Supriyono dan H,Poedjirahajoe E.2012. Studi Intersepsi Hujan pada Hutan Tanaman *Eucalyptus pellita* di Riau. Jurnal
Agritech **32,** 318-324.

Supranto J. 1986. Statistik Teori dan Aplikasi. Penerbit Erlangga, Jakarta.

Thomaz EL. 2005. Avaliação de Interceptação e Precipitação Interna em Capoeira e Floresta Secundária em Guarapuava, PR. Geografia, São Paulo **14**, 47-60.

Waterloo MJ. 1994. Water and nutrient dynamics of Pinus caribaea plantation forests on former grassland soils in Viti levu, Fiji. PhD dissertation (unpublished). Vrije Universiteit van Amsterdam, Amsterdam, the Netherlands.

Yusop Z, Yen CS, Hui CJ. 2003. Throughfall, Stemflow and Interception Loss of Old Rubber Trees. Jurnal Kejuruteraan Awam **15,** 24-33.