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# The Effect of Tree Architecture Models on Rainfall Partitioning At the Upstream of Tondano Watershed, Minahasa Regency, North Sulawesi Province

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## ABSTRACT

This study intended to measure the rainfall partitioning on 5 types selected trees at upstream of Tondano Watershed. This watershed was located in Minahasa Regency, North Sulawesi Province. of Indonesia. Selected trees were included: *E.celebica, E.aromaticum, T.cocao, G.Mangostan,* and *A.pinnata*. This selection was due to maximum of important value index among the whole trees at location of study. Measuring on rainfall partitioning was conducted by field research during October 2010 to May 2011. There was built drum storage for measuring surface run off. The dimension of trial block was 5 x 22.5 m and restricted by soil. This research needed 15 plot tests for measuring run off. Result showed that tree architecture was correlated with the partitioning components value of rainfall. The rainfall partitioning were included though fall, stem flow, interception, run off, and infiltration.
**Keywords**: tree architecture model, run off, through fall, stem flow, interception

## INTRODUCTION

Presentation of vegetation at one area would give great positive impact for ecosystem balance in larger scale. Different impact of vegetation type due to the system of water management was caused by different architecture model belonged to each kind of tree habitus which presented the morphology as a series phase of tree growing [1]. Architecture model of certain tree would influence translocation of rainfall into stem flow, through fall, infiltration, and surface run off. It was related with the function of vegetation in decreasing erosion rate.

Function change from forest to coffee plantation would decrease the input of litter and it would change of micro climate condition because of this opened area [2]. Data of study showed that vegetation had important function in regulating hydrological cycle of a ecosystem. On the ecosystem of tropical rainfall forest, if there was high intensity of rainfall, rainfall would be transformed through some steps. It was intended to reduce kinetic energy of rainfall which would ruin the soil. Part of rainfall would be endured at the leaf and would re-vapour to atmosphere, and the rest was flowed into soil surface as stem flow and through fall so that damaged power would minimize by the vegetation. Then surface run off would enter into the soil by infiltration process so that would decrease surface run off.

Variability in stem flow volume, which was produced from a variety of factors, had been investigated in many forested environments. Precipitation intensity, crown morphology, and stem morphology had all been shown to influence the variability in stem flow. Morphologic differences between trees had been quantified to explain stem flow variability. During precipitation, the morphology and distribution of the trees the forest controlled the fate of the water. The morphology of the vegetation could influence the quantity and distribution of water descending from the canopy to the ground surface [3]. The tree stem had also been documented to control stem flow variability [4][5]. Trees with smooth bark would conduct water to the ground more efficiently with less loss occurring in the form of stem drip. Johnson [6], Cape *et al*. [7], Kellman and Roulet [8], and Herwitz [9] all found that branching habit was a controlling factor in the generation of stem flow. Stem drip was water that fell directly from the stem to the ground due to a localized drip point, typically on a rough textured bark surface. Wind might also play a role in the timing of stem flow during rainfall. Under the influence of wind, water falling to the ground as drip from the canopy could be deflected and deposited directly on the stem [10].

The process of rainfall interception and its successive evaporation was not always considered as a significant process in the hydrological cycle. Rutter *et al.* [11] found canopy interception values of 12% of the precipitation for a defoliated oak and 48% for a Norway spruce forest in the United Kingdom. Bryant *et al.* [12] also found comparable results for a different kind of forest in the southeast of the United States. For a pine, mixed, lowland hardwood, pine plantation and upland hardwood forest, Bryant *et al.* [12] measured that respectively 22%, 19%, 18%, 18% and 17% of the rainfall was intercepted by canopy and successively

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evaporated. And Schellekens *et al*. [13] found that about 50% of the gross precipitation evaporated from the canopy of a Tabonuco type forest in northeastern Puerto Rico. All these studies merely considered canopy interception.

## MATERIALS AND METHODS

Measuring partitioning component of rainfall was carried out by field research during October 2010 to May 2011. Plot test was selected based on the variation of tree architecture model of vegetation type which had the highest important value index (INP) at Tondano Sub Watershed. Selected vegetations were *Elmerellia celebica* (ATTIMS), *Eugenia aromaticum* (PETIT), *Theobroma cocao* (STONE), *Garcinia mangostana* (FAGERLIND), *Arenga pinnata* (CORNER) [1] and the architecture model was presented as in Figure 1 below.

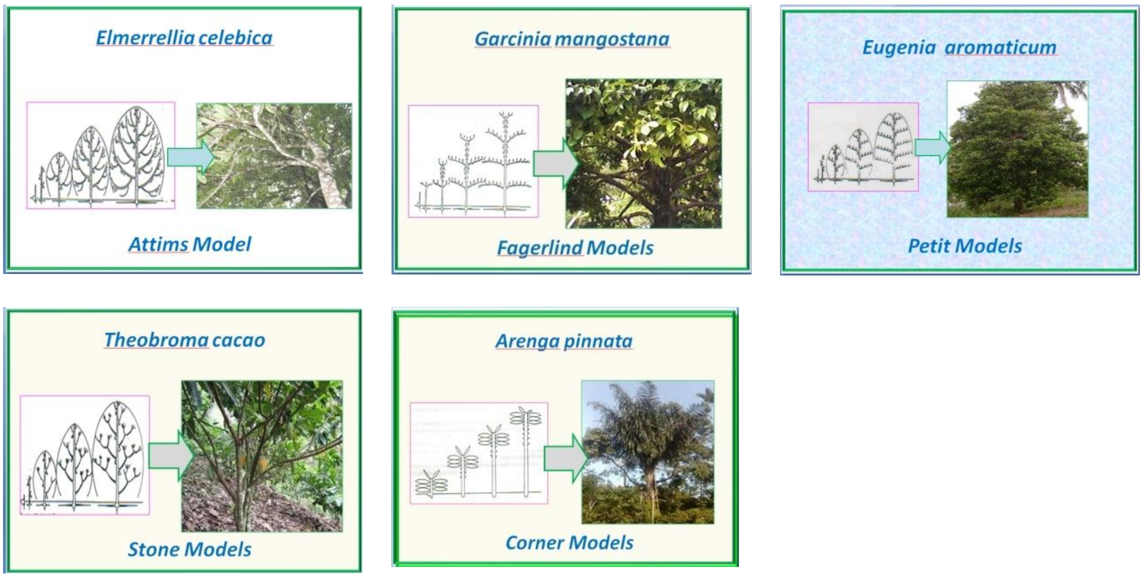


Figure 1 Selected vegetation type and tree architectue

Number of surface run off under the observed block was measured by using drum storage. Dimension of trial block was 5 x 22.5 m. For holding inflow and outflow of water, it was built restriction block of soil. Run off which flowed after through apron was stored in 3 storage drums. Surface run off which stored in drum II and III was only 1/5 part, but the rest of 14/15 part was let outside drained.

The diameter of storage drum was 56 cm with 70 cm of height from the base to divided hole. Drum I and II was holed into 15 holes with each diameter was 3 cm and inter drums were connected by pipe. It was mean that if drum I was full of run off, the water would flow to drum II and III. The drums were covered so that rainfall could not be entered. Apron was made of zinc with 30 cm of length, 30 cm of width, and 20 cm of depth. Surface run off was recorded every rainfall date.

1. Measuring run off
   Measuring the number of run off was carried out every rainfall date at the same time and it was minimal measuring of 30 times. Storage of run off was as in Figure 2 Volume of surface run off was calculated with the equation as follow:

$$V_{ap} = V_1 + 15\,V_2$$

Note: $V_{ap}$ = Total volume of surface run off ($cm^3$); $V_1$ = Volume of run off at drum I ($cm^3$); $V_2$ = Volume of run off at drum II ($cm^3$)

Figure 2 Storage of run off

2. Measuring through fall
   Measuring of perforated water of leaf canopy was carried out by storing though fall for each selected tree. Storage was made of plastic with dimension of 1 x 1 $m^2$ with wood structure (Figure 3). Measuring of through fall was carried out at 5 samples and 3 times for each of them. Volume of stored through fall was calculated by the equation as follow:

   $$Tfi = Vi / Li \text{ cm} = Vi / Li \times 10 \text{ mm}$$

   Note: Tfi = Height of i through fall (mm),Vi = Volume of i through fall ($cm^3$), Li = number area of i storage ($cm^2$)

Figure 3 Storage of through fall

3. Measuring of stem flow
   Measuring of stem flow was carried out by making plastic spiral circle at the stem and it was empty into storage can (Figure 4). Volume of stem flow was calculated by the equation as folow:

   $$Sfi = Vi / Li \text{ cm} = Vi / Li \times 10 \text{ mm}$$

   Note: Sfi = height of i stem flow (mm),Vi = volume of i stem flow ($cm^3$), Li = number area of i stem flow ($cm^2$)

Figure 4 Storage of stem flow

4. Measuring of interception
   The formula of interception at leaf canopy or through fall interception was as follow:

$$C = P - (T + S)$$

   Note: C= through fall interception (mm), P= rainfall (mm), T= through fall (mm), S= stem flow (mm)

## RESULTS AND DISCUSSION

### Rainfall Partitioning

Measuring result of the whole components of rainfall partitioning and water balance analysis at 5 type of vegetations which presented tree architecture model of selected tree was described as in Table 1.

Table 1 Water balance at 5 observed tree architectur model

| Plan/Model of tree architecture | Rainfall | Through fall | Stem flow | Interception* | Runoff | Infiltration** |
|---|---|---|---|---|---|---|
| | (mm) | (mm) | (mm) | (mm) | (mm) | (mm) |
| **E. celebica (ATTIMS)** | 1020 | 541.96 | 1.27 | 476.77 | 7.15 | 536.08 |
| **G. mangostana (FAGERLIND)** | 1020 | 766.45 | 0.62 | 252.93 | 6.24 | 760.83 |
| **E. aromaticum (PETIT)** | 1020 | 979.27 | 0.45 | 40.28 | 4.84 | 974.88 |
| **T. cocao (STONE)** | 1020 | 811.43 | 0.50 | 208.07 | 6.65 | 805.27 |
| **A. pinnata (CORNER)** | 1020 | 698.88 | 0.08 | 321.04 | 5.60 | 693.36 |

**) Interception = Rainfall – (Through fall + Stem flow)*
***) Infiltration = Rainfall – Runoff*

Total value of highest through fall was at type of *E. aromaticum*, it was 979.27 mm and the lowest was also at *E. celebica* with total through fall of 541,96 mm. Generally, rate of through fall was occurred at high intensity of rainfall if compared with through fall at low intensity of rainfall.

Mean value of highest stem flow for all samples was found at *E. celebica*, the value was 1.27 mm and the lowest was the type of *A. pinnata*, the value was 0.08. The difference was caused by the diameter of *E. celebica* and *G. mangostana* were bigger than the others type. Circumference of 5 observed trees was in the range of 25 cm to 205.7 cm. The increasing of circumference would increase stem flow at almost the whole rainfall occurrence.

The highest interception value was found at the type of *E.celebica*. The value was 476.77 mm and the lowest was at species of *E. aromaticum* with interception value of 40.28 mm. Generally, interception value on dry month was higher than on wet month. The difference of interception value was caused by stem condition of *A. pinnata* had dense hair so that stored much rainfall. Water saturated of stem and leaf was higher than the other type of vegetation.

The highest infiltration value was found at the type of *T. cocao*, the value was 974.88 mm and the lowest was at the type of *E. celebica* with infiltration value of 536,08 mm. This condition was caused by seresah production of *T.cocao* was high enough and decomposition process under canopy of this tree was good so that soil pores were better.

The highest run off value was found at the type of *E. aromaticum*, the value was 7,16 mm and the lowest was at the type of *E. celebica* with run off of 4.84 mm. the surface run off was very important for conservation effort because surface run off would take particle of erosioned soil which would accelerate process of sedimentation or shallowing Tondano Lake. Therefore, planting of *E. aromaticum* (clove) at Tondano sub watershed had to make attention to the pattern and the distance of plant.

Result of this study showed that type of *E. celebica* was as the best tree for being planted between the types of *E. aromaticum* so that the danger of surface run off could be decreased.

### The correlation between tree architecture model and measuring rainfall partitioning

Architecture model of ATTIMS and CORNERS had significant correlation with FAGERLIND compared with the others architecture model. If it was due to the aspect of stemflow parameter, seresah/litter, infiltration, and interception, the correlation among these three architecture models was higher than the other two models. Because of these 4 parameters had positive value in conservation of soil and water, the three architecture models had positive perspective in the effort of soil and water conservation. Therefore, combination of vegetation in agroforestry at Tondano sub watershed was suggested using mix of the three architecture models.

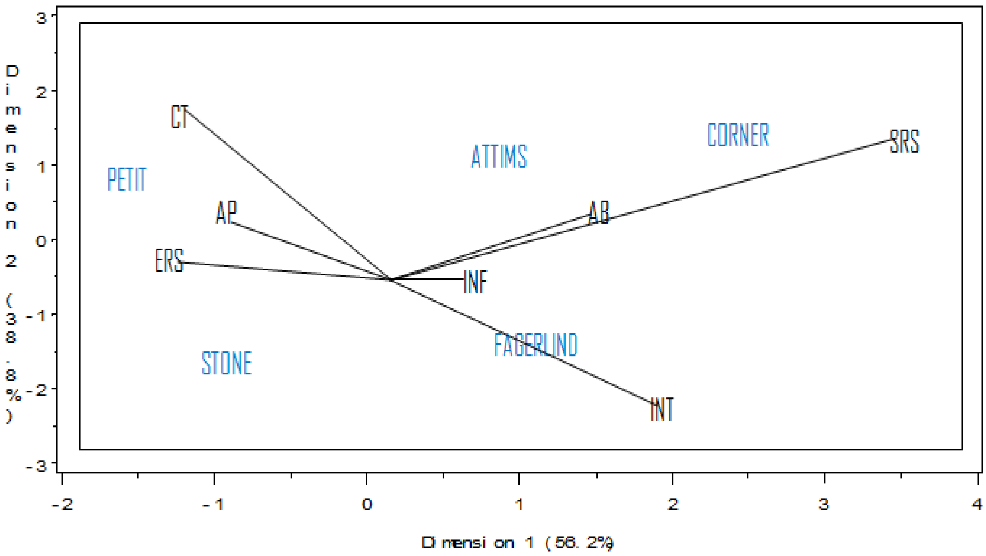


Figure 5 Biplot diagram: variability respons of tree architecture models due to hydrological components (CT= throughfall, AB= stemflow, INT= interception, AP= run off, INF= infiltration, SRS= seresah, and ERS= erosion)

Architecture model of PETIT and STONE showed the stronger correlation compared with the other architecture model mainly due to throughfall and surface run off. Ecologically and in the effort of soil and water conservation, these two parameters could cause erosion. Therefore, these two architecture models were recommended not to use as developed vegetation at Tondano sub watershed. Rainfall partitioning at each observed tree architecture model was presented as shown in Figure 6.

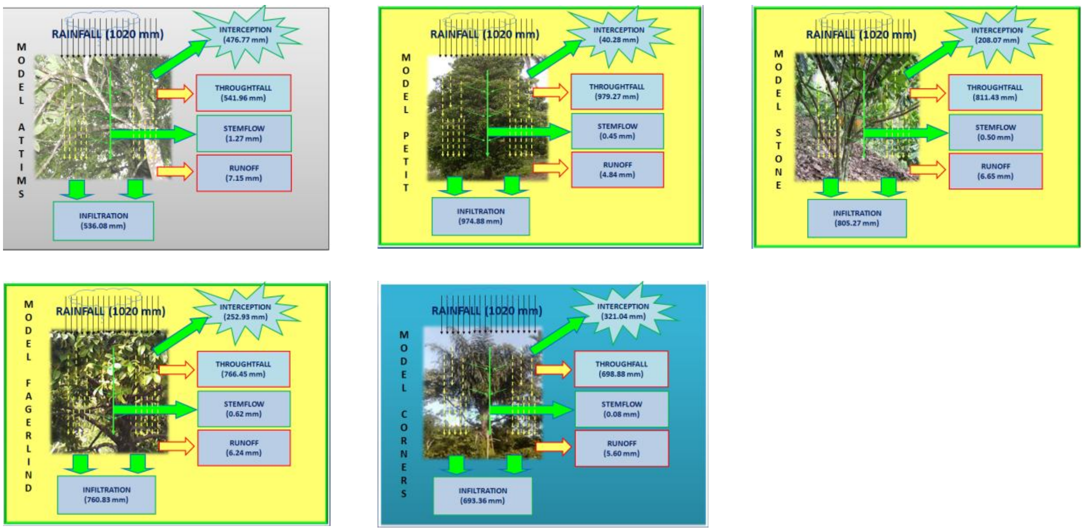


Figure 6 Rainfall partitioning at each tree architecture model

## CONCLUSION

The difference of tree architecture model gave great impact to the number of measuring distribution component of rainfall. Interception: Attims > Corner > Fagerlind > Stone > Petit. Surface run off: Attims > Stone > Fagerlind > Corner > Petit. Infiltration: Petit > Stone > Fagerlind > Corner > Attims.

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