Analysis of the role of plant canopy on hydrological systems

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Abstract. High rainfall intensity causing high erosion rates in Indonesia. Land cover conditions greatly determine water degradation in the hydrological cycle. The shape and type of plants canopy have significant effect on soil structure and water absorption. This study aimed to examine the role of plant canopy on the value of rainwater canopy escape as a supporter of hydrological cycle. Tree species were determined based on the level of dominance at study site using transect method. The dominant trees are Sea Sengon Tree (Paraserianthes falcataria), Teak Tree (Tectona grandis), Suren Tree (Toona sinensis) and Durian Tree (Durio zibethinus). The results showed that high rainfall intensity with a long rain period affected the amount of canopy escape. Durian Tree has highest canopy density with value of 0.301, and Sengon Laut is the lowest with value of 0.240. The value of passing the canopy of the Suren Tree is lower than the other tree species. The shape of canopy of Suren tree, which is round and oval, also affects the lower pass value of canopy compared to other tree species. The higher the value of canopy density can reduce the value of canopy escape to support the hydrological cycle.

1. Introduction
The intensity of rain in Indonesia is high and is one of the main parameters that affect the climate [1]. The intensity of rain that has a significant effect requires good utilization to be utilized for the needs of living things and reduce the potential for natural disasters. The presence of rainwater that falls on the surface is closely related to the hydrological cycle in the region. The increase in rainfall intensity in Indonesia is directly proportional to the increase in flood disasters caused by high rainfall intensity and poor hydrological processes.

There has been an increase in flood disasters in the Samin sub-watershed, part of the Bengawan Solo watershed, which is included in the 108 critical watersheds, which has occurred every year and requires mitigation measures. The high intensity of rain and the slope of the slopes found at the study site also increase the occurrence of erosion, mainly due to inappropriate land use factors [2]. The use and selection of vegetation plants as ground cover is very influential in the process of holding the amount of kinetic energy from rainwater, reducing the amount of percolation water, preventing run-off, and the ability of roots to infiltrate [3].

The less-than-optimal hydrological process, especially in the absorption of rainwater into the soil, can occur along with land degradation and changes in land use so that it interferes with the absorption of rainwater in the soil. Changes in land use that continue to occur are the dominant driving factor in the hydrological cycle in the watershed system [4]. The existence of land cover that covers the soil surface,
types of plants and tree vegetation affect the hydrological cycle and water degradation [5]. The selection of the right vegetation plants has an influential impact in helping the process of absorption of rainwater into the soil. The shape and type of plant canopy have a significant influence on soil structure and water absorption into the soil [6]. The novelty of this study is to analyze the impact of the tree canopy based on the level of dominance in the Samin sub-watershed location as a hydrological function with a 4-way approach method (North, East, South and West). This study aims to determine the value of the rainwater escape canopy of several tree samples and the shape of the canopy.

2. Materials and methods

The research was carried out in February – May 2021 in Sepanjang Village, Tawangmangu District, Karanganyar Regency, Central Java Province. The research location is at the coordinates of 7.68° South Latitude 111.11° East Latitude and 814 masl. The research location has a slope of 25° and is planted with horticultural crops on the bottom and annual plants on the top cover. The tools used in the study were a meter, a meter, an ombrometer, a rainwater collection device that was made to adjust to the sample. The materials used in this study were Sengon Sea Tree (*Paraserianthes falcataria*), Teak Tree (*Tectona grandis*), Suren Tree (*Toona sinesis*) and Durian Tree (*Durio zibethinus*).

This research is qualitative research that describes the appropriate conditions and occur in the field. Data were taken directly in the area by observing the canopy escape in each tree sample using a rainwater collection device. Determination of the location using the purposive sampling method based on the characteristics of the critical land of the Samin sub-watershed, which is part of the Bengawan Solo watershed. The land has a slope of 25°, which is categorized as steep land, requiring good management.

Samples were taken based on the level of tree dominance at the study site using the transect method. There are four transects taken with each having 4 points and each point having four quadrants. There were 20 plant samples selected to be observed, with each tree consisting of 5 samples. Observation of canopy escape using the approach method with 4 cardinal directions (North, West, South and East) with each tree having 4 containers to accommodate the canopy escape according to the shape of the tree canopy. Observational data taken were then analyzed using regression and correlation analysis to determine the effect of rainwater on canopy escape and how significant the effect was. The data were also analyzed using the canopy density index to get the value of the canopy density for each type of plant.

3. Results and discussion

The results showed that there was an influence between the intensity of rainfall and the canopy pass value of several tree samples obtained in the field. Overall, each observed tree sample has a positive value that is close to 1. The larger the R value obtained is close to 1, it indicates that there is a close and positive relationship between the influencing and the affected factors. [7]. The intensity of rainfall that occurs is a factor that affects the value of the canopy escape. The size of the influence value obtained by each tree on the intensity of rain is caused by the difference in the shape and structure of the tree canopy [8].

Based on the results of the regression analysis between the intensity of rain and the escape of the Sengon tree canopy, it was found a positive relationship value and a fairly high value with R² 0.7759 (Figure 1). The greater the intensity of the rainfall, the higher the canopy escape value for the Sengon tree. The Sengon tree has a canopy shape that can provide shade with a canopy structure such as an umbrella so as to provide protection for plants or soil in the canopy area [9]. The canopy of the Sengon tree is in the form of an umbrella and has a high canopy position and has an average thickness of 17.5 m and an average canopy width of 7 m.
Based on the results of the regression analysis between rainfall intensity and passing the Suren tree canopy, it was found that the value of a positive relationship and a high value was close to 1 with $R^2 = 0.8141$ (Figure 2). The greater the intensity of the rainfall, the higher the canopy escape value for the Suren tree. The canopy structure of the Suren tree, which has branches and twigs that are supported by compound leaves, makes Suren trees highly recommended as top cover plants on sloping land areas [10]. The canopy of the Suren tree is oval in shape and has a high canopy and an average canopy thickness of 16 m and an average canopy width of 5 m.

Based on the results of the regression analysis between the intensity of rain and the escape of the teak tree canopy, it was found that the value of a positive relationship and the highest value compared to other samples was close to 1 with $R^2 = 0.8533$ (Figure 3). The greater the intensity of the rainfall, the higher the canopy escape value for teak trees. Teak tree stands have wide and large leaves making mature teak trees have the ability to protect from rainwater and light intensity well. The canopy of teak trees is in the form of an umbrella and has a canopy and branches that are not very high and has an average canopy thickness of 13 m and an average canopy width of 5 m.

Based on the results of the regression analysis between the intensity of rain and the escape of the durian tree canopy, it was found that the value of a positive relationship and a high value was close to 1 with $R^2 = 0.7878$ (Figure 4). The greater the intensity of the rainfall that occurs resulted in the high value of the canopy escape on the Durian tree. The shape of the Durian tree canopy that can soar high makes the durian tree able to become a productive tree and an antidote in various environmental roles because of the dense and even branching of the canopy [11]. The Durian tree canopy is umbrella-shaped and has a low canopy and branching but has a high thickness with an average canopy thickness of 19 m and a canopy width of 5 m.
Table 1. Regression results and correlation between rainfall intensity and sample trees

|                  | Rainwater discharge | Sea Sengon Tree | Suren Tree | Teak Tree | Durian Tree |
|------------------|---------------------|-----------------|------------|-----------|-------------|
| Rainwater discharge | 1                   | 0.883**         | 0.903**    | 0.925**   | 0.889**     |
| Sea Sengon Tree   | 0.883**             | 1               | 0.970**    | 0.958**   | 0.989**     |
| Suren Tree        | 0.903**             | 0.970**         | 1          | 0.960**   | 0.962**     |
| Teak Tree         | 0.925**             | 0.958**         | 0.960**    | 1         | 0.959**     |
| Durian Tree       | 0.889**             | 0.989**         | 0.962**    | 0.959**   | 1           |

Note: ** Correlation is significant at the 0.01 level (2-tailed).

The results of the analysis on each observed sample tree have a high and significant positive correlation value close to 1 (Table 1). The correlation between Sengon (lowest), Suren, Teak (highest), Durian trees and rainwater discharge were significant. The higher the correlation value, which is close to 1 and has a significant result, it indicates a close relationship between the rainwater discharge and the escape of the sample tree canopy [12].

Figure 5. Canopy density index

The calculation of the canopy density index is carried out to find out how much the calculation of the density of a tree sample has on its canopy structure [13]. To find out the canopy density index was influenced by several factors including trunk diameter, canopy height or thickness, canopy width, number of branches, branching angle, and tree canopy escape values. To get IKT the data was analyzed using the formula $IKT = \frac{K(3\sum\text{branch})}{22/7\text{(header height)}^2\text{(header width)}^2}$ [14]. Based on the results of the analysis, it was found that the density index of the Sengon tree was 0.24, the Suren tree was 0.294, the teak tree was 0.205 and the durian tree was 0.301 (Figure 5). The durian tree canopy density index was the highest and the teak tree the lowest among the other tree samples. Based on the observations and the results of the analysis, it was found that the best canopy role in the hydrological cycle is the Durian tree which has the shape of an umbrella canopy and the highest canopy density index among the other samples and based on correlation regression analysis has a relationship and closeness between rainfall intensity and canopy escape which is not large compared to other samples.

4. Conclusion
The response of tree canopy escape to rain intensity varies and is influenced by canopy shape and canopy density factors. The Durian tree showed the best results among other samples seen from the relationship and its closeness to the intensity of rain and the index of canopy density. Durian trees can be a good choice as an effort to increase the role of the tree canopy in the hydrologic cycle.
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