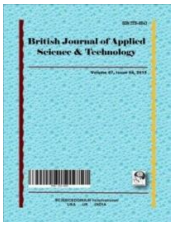

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The Role of Litter in Rainwater Interception

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Authors' contributions

This work was carried out in collaboration between both authors. Author SP designed the study, wrote the protocol, suvervised the study, performed the statistical analysis and wrote the first draft of the manuscript and managed literature searches. Author SY collected samples from the field and performed the laboratory test, managed the analyses of the study and literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: The function of plants litter on the soil surface in the hydrologic cycle, which is decreasing evaporation, protect of rain interception and surface runoff control. The research aim to know function of plant litter in the rain interception.
Place and Duration of Study: The research was done in Tawangsari village, Pujon district, Malang regency, Indonesia in lands cover disturbed forest, productions forest, agro forestry and coffee monoculture.
Methodology: Experiment done in Randomize Blocks Design with 3 replications. For litter observations done on the plot size 40 x 5 m and the interception of rain was measured by using the Rainfall Simulator at high, medium and low intensity. The amount of interception measured by soil water balance approach and gradient of litter moisture.
Results: Disturbed forest land (HT) produce the thickest litter and the highest interception value (both by water balance approach and gradient of litter moisture) than the other plot. The thickness of litter have a positive correlation with interception value (R^2=0.70). Interception value have a negative correlation with runoff (R^2=-0.99), while it have a positive correlation with soil moisture (R^2=0.79).
Conclusion: Land cover is influence the production of litter and soil moisture by increasing the

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rainwater interception. The thickness of litter can intercept more rainwater but reduce surface runoff so it could be increase the soil moisture.

Keywords: Litter; land cover; interception; soil moisture.

1. INTRODUCTION

Litter is the dead organic matter [1] that is part of a dead plant leaves, branches, twigs, flowers and fruits that fall and stay on the ground either still intact or partially decaying. Litter can maintain soil friability [2], provide energy for soil organisms [2,1], reduce the bulk density, increase soil water holding capacity and CEC [1], plays an important role in the recycle of plant nutrients [3,1,4,5], increasing the soil moisture, improve soil infiltration, reduce evaporation and act as a mulch to prevent weed growth [6,7,4]. The presence of litter on the soil surface is also able to block the blows raining so granular soil aggregates are not easily damaged, reduce surface runoff and soil erosion that maintained soil porosity [8,2,7,1,9] and improve soil structure [10]. Dynamics of litter production depends on climatic factors, season, substrate quality character of vegetation [1], age of vegetation, plant morphology [11,12] and material of parent soil [7]. Meanwhile the litter quality is influenced by the plant character, structure and microbial activity in the soil [1]. Changes in land use have impacted on the changes of land cover vegetation, that affects the production and quality of biomass litter at the surface of land [13].

Interception is part of the rainwater retained on vegetation [14] or litter [14,15] which will evaporate into the air in a few hours or days during or after rain [16]. In the hydrology aspect, interception is very important because it will block the rainwater that will be up to the soil surface and then be infiltrated into the soil profile [17]. Rainwater interception is the main variable in the profile water balance and region water balance [14]. Character vegetation [18] and the age of the vegetation [19] play an important role in determining the level of rainfall interception. The volume of rainwater which can reach soil surface will decrease with increasing of land cover [14]. According Yulianur et al. [20] the volume of rainwater that had intercept varies according to species of plant.

Several studies carried out to determine rainwater interception by the canopy and trunk. Rainwater will also intercept by litter layer on the soil surface and even the amount of rainwater which intercept by litter layer can reach twice as many [21]. Interception by litter is a function of the mass of litter per unit area; layer thickness and litter composition; water-holding capacity by litter; wetting frequency and drying rate of litter [18]. Patterns of land cover and cropping patterns (monoculture and intercropping) are very influential on the hydrological cycle and water balance [22]. The value of rainwater interception on coffee plantations at Aceh was 76% of the total rainfall [20]. Interception by the litter is still less attention, it is necessary to study, mainly in relations to its quality. The study have two objective were to know the rainwater interception value by litter of several land cover and to study the relationship of litter interception and runoff.

2. METHODOLOGY

The study was conducted in the village of Tawangsari, Pujon, Malang, East Java. Research and field sampling was conducted in January-February 2009, while the laboratory analyzes performed on soil physical and chemical laboratory, Department of Soil Science, Faculty of Agriculture, Brawijaya University, Malang, East Java.

Fieldwork carried out in four different land cover systems, namely: Disturbed forest, production forest, agroforestry and coffee monoculture. The composition of vegetation in each treatment plot is presented in Table 1. The experimental design used was a randomized block design (RBD) with 3 replications of each plot at the top, middle and bottom plot (Fig. 1). Measurement and litter collection is done in a plot [5] size of 40 x 5 m using 50 x 50 cm wooden frame. Measurements of litter thickness at field conditions were done before analyzed them at laboratory.

Measurement of rainfall interception by litter were performed using an artificial rainfall simulator [23] for each land cover which contained three replicates with high, medium and low intensity. Deuteronomy observations were done on 40 m x 5 m or 200 m^2 plots.

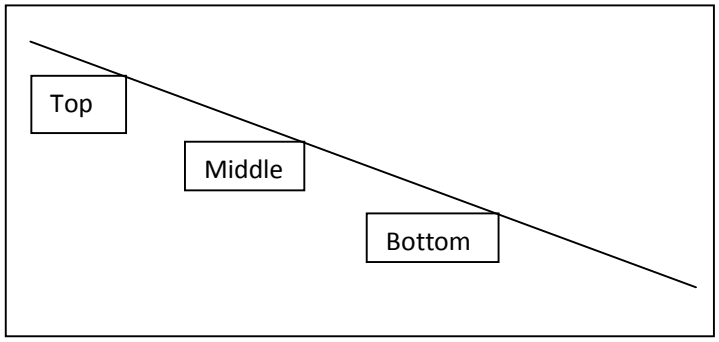

Fig. 1. Location of observation squares in the plot

Table 1. Vegetation composition in the experimental plots

Experiment plot	Vegetation composition
Disturbed forest (HT)	Perennial crop (mahagony, pine, "dadap", rain tree, bamboo) and shrubs
Production forest (HP)	Eucalyptus, maize, coffee, banana, teak, pine, elephant grasses.
Agroforestry (KC)	Pine, banana, "suren", "dammar", leucaena, jack fruit, avocado, maize, carrot.
Coffee monoculture (KM)	Coffee

2.1 Interception Measurements

Interception value was calculated by two approaches:

2.1.1 Water balance approach

Water balance approach [24]. The equation used is:

$$I = P - (\Delta S + R)_{[25]},$$

Where I is rain interception (mm); P is precipitation (mm); ΔS is gradient of moisture storage (mm) and R is surface runoff (mm)

2.1.2 Litter moisture approach

Measurement of rainwater interception by litter using litter moisture approach [26] was count by the different between water content of litter after and before treatment.

$$I = BBs - BKs,$$

Where I is rain interception (mm); BBs in fresh weight of litter after treatment (mm); BKs is dry weight of litter without treatment (mm).

Analysis of variance (ANOVA) was done to determine effects of treatment on the parameters under study. Then it would be followed by least significant difference test (LSD) at the 5% level. The correlation test was conducted to know the relationship between the parameters. Meanwhile, to know the effect of independent variables on the dependent variable was done by regression test with the help of computer software SPSS version 11.5 and MS. Excel [9].

3. RESULTS AND DISCUSSION

The results suggest that litter layer thickness is significantly different among the land cover types (Table 2).

Table 2. Litter layer thickness (cm) at different land cover

Land cover	Thickness of litter (cm)
Disturbed forest (HT)	5.4 d
Production forest (HP)	4.5 c
Agroforestry (KC)	4.2 b
Coffee monoculture(KM)	0.8 a

Notes: Number in a coulomb followed by same letters are not significant different (LSD 5%)

Based on Table 2, the highest litter thickness values significantly different from other treatment plots found in disturbed forest land cover (HT) followed by production forest, agroforestry and coffee monoculture. The thickness of litter layer was illustrated the litter production rate at different land cover.

Land use changes from forests to plantation are could reduce the level of income litter [27]. The high of litter thickness in the disturbed forest (HT) in this study thought to be influenced by the complexity of vegetation in it. Litter production varies depending on the vegetation composition [1,28,5], which more diverse vegetation will provide litter inputs with varying quality, so that the supply of organic matter from litter decay is continuously. *Cryptomeria japonica* litter layer turned out to be thicker than the litter of *Lithocarpus edulis* in Japan [29]. Mass of litter on protected areas was higher than unprotected areas in India [1]. The mean of litter production in a mixed vegetation of *C. lanceolata* and *M. Macclurei* higher than single vegetation of *C. lanceolata* in China [4]. The results of other studies that support this result of this study are the highest production of litter found in secondary forest and plantation which consisting of 4 species of plants in Costa Rica [30].

3.1 Rainwater Interception by Litter use Water Balance Approach

The results suggest that rain interceptions by the litter use water balance approach are significantly different among the land cover (Table 3).

Based on Table 3, values of rain interception by the litter-layer assessed with water balance approach in disturbed forest (HT) is higher and significantly different from other types of land cover on rainfall intensity high and low, but not significantly different from production forest (HP) on moderate intensity of the rain. While the value of rainfall interception by litter with water balance approach in the coffee monoculture (KM) is the lowest and significantly different from other types of land cover in all rainfall intensity. Litter layer on the disturbed forest (HT) is thicker than the other land cover which is caused a higher interception than the other plots. Basically the forest disturbance could be influence of the rainwater interception. According to Sato et al. [29], disturbance to forest could reduce protection values on the surface soil and increase the potential for surface runoff. Deforestation leads to reduced transpiration, rainfall interception by the canopy, increasing rainfall interception by litter if without burning the forest, but did not increase rainfall interception by litter if accompanied by the burning of forests [31]. The high value of litter interception of rainfall by water balance approach to this research is influenced by the level of litter thickness in which a layer of litter in disturbed forest (HT) is higher than the other plots. This result is supported by the notion that rainfall interception by litter varies depending on the mass of the litter layer (place and time; composition of plants; presence of wind, water, fire, fauna and decomposition processes) in soil and litter drying rate [21]. Furthermore, according to Bulcock and Jewitt [18], litter thickness and the litter composition varies with season, location, and litter decomposition process.

3.2 Rainwater Interception by Litter use Litter Moisture Approach

The results suggest that rain interceptions by the biomass litter use litter moisture approach are significant different among the land cover (Table 4).

Table 3. Rainwater interception by litter: Water balance approach at different landuse

Land cover	Rainwater Interception by litter (mm)		
	High rain intensity	Moderate intensity	Low intensity
Disturbed Forest (HT)	57.65 d	15.19 c	5.95 c
Production Forest (HP)	42.73 c	13.04 c	4.84 b
Agroforestry (KC)	33.15 b	10.1 b	4.05 b
Coffee monoculture (KM)	18.9 a	7.56 a	2.46 a

Notes: Number in a coulomb followed by same letters are not significant different (LSD 5%)

Table 4. Rainwater interception by litter: Litter moisture approach at different landuse

Land cover	Rainwater Interception by litter (mm)		
	High rain intensity	Moderate intensity	Low intensity
Degraded Forest (HT)	58.17d	18.46 d	5.45 b
Production Forest (HP)	40.4 c	14.43 c	4.47 b
Agroforestry (KC)	31.27 b	10.75 b	4.34 b
Coffee monoculture (KM)	18.04 a	6.68 a	2.08 a

Notes: Number in a coulomb followed by same letters are not significant different (LSD 5%)

Based on Table 4 values of rain interception by litter with litter moisture approaches on disturbed forest (HT) is higher and significantly different from other types of land cover in the treatment of high rainfall intensity and moderate, but not significantly different from the production forest plot (HP) and agroforestry (KC) in the treatment of low rainfall intensity. While the value of rainfall interception by litter with litter moisture approaches the coffee monoculture (KM) is lower and significantly different from other types of land cover in all treatments rainfall intensity. This indicates that the value of rain interception by litter is affected by the thickness of the litter layer associated with the type of land cover/vegetation character. Based on Table 2, 3 and 4 disturbed forest (HT) produce the highest litter thickness for about 5.4 cm which it cause the higher rainwater interception value both by water balance and litter moisture approaches. The composition of vegetation and land use change affect the balance of the through fall, interception and evaporation [10]. Eucalyptus litter which is most found at disturbed forest (HT) also determines the level of interception by litter in this study. This is consistent with the results of Bulcock and Jewitt [18] where the value of rainfall interception by litter differ between types of plants, which is 160.4 mm in *Eucalyptus grandis* litter; 124.7 mm in the litter of *Acacia mearnsii* and 231.2 mm in the litter of *Pinus patula* in South Africa. Interception values are influenced by rainfall intensity and the character of the litter in which interception of rainwater by *Lithocarpus edulis* litter higher than the *Cryptomeria japonica* litter in Japan despite *Cryptomeria japonica* litter layer is thicker than the *Lithocarpus edulis* litter [29]. Rainwater interception by litter in savannah ecosystems was 12% [16], while the interception of rainwater by litter in Beech forest was 22% [6]. Rainwater interception by litter was 19.1% of the total rainwater interception with interception rate by litter <7.7% in China and obviously rainwater interception by litter decreased with increasing of vegetation age [19]. The value of rainwater interception by litter of deciduous forests only 2-5% in North America [31].

3.3 Effects of Litter Thickness on the Rainwater Interception

From results of the correlation and regression between litter thickness and rainwater interception (Fig. 2) suggests a close relationship and significant (R^2= 0.70 **) with standard deviation 15%. Every increasing of 1 cm litter thickness followed by increase of 17.084 mm rainwater interception. The relationship between the litter thickness and rainwater interception is closely associated with the character plant and litter produced. The results are consistent with several previous studies that rainwater interception by litter have a straight relationship with the litter thickness [32,33].

3.4 Effects of Rainwater Interception by Litter on the Surface Runoff

Rainwater interception by litter and surface runoff (Fig. 3) have a close relationship (R^2 = 0.99) with standard deviation 17%. This means that the rainwater interception by litter influence the surface runoff. The relationship between rainwater interception by litter and surface runoff has a negative trend, where the higher value of rainwater interception by litter declining the value of surface runoff. One of the functions of litter is to reduce surface runoff, so as thick as litter will increase rainwater interception by reducing runoff yet. This is consistent with the notion that rainwater interception by litter affects the rate of surface runoff [19]. Ground cover and land use affect the surface runoff [34]. Another study supports the results of this study that increasing ground cover by the tree until 50% can increase the runoff reduction by 12% [35]. Runoff reduction is affected by land use change [36,34] where an increase land cover can increase rainwater interception by canopy and litter.

3.5 Effects of Rainwater Interception by Litter on the Soil Moisture

The relationship between rainwater interception by litter and soil moisture (Fig. 4) has a positive tendency with standard deviation 3%. As much as amount of rainwater that intercept by litter can be increase the soil moisture. Rainwater that intercept by litter will be infiltrate into the ground and increase soil water storage. Increasing of soil organic matter by decomposed litter can improve the granular structure and increase the soil porosity so it can be increasing soil moisture. Rainwater that reach surface soil will get into the soil through the soil pores. The more soil pore, the more water infiltrate into the soil. Raat et al. [37] concluded that interception by throughfall and litter layer determine the status of soil moisture. Decomposed litter can protect the soil moisture by its role to decrease evaporation rate, runoff and erosion [38].

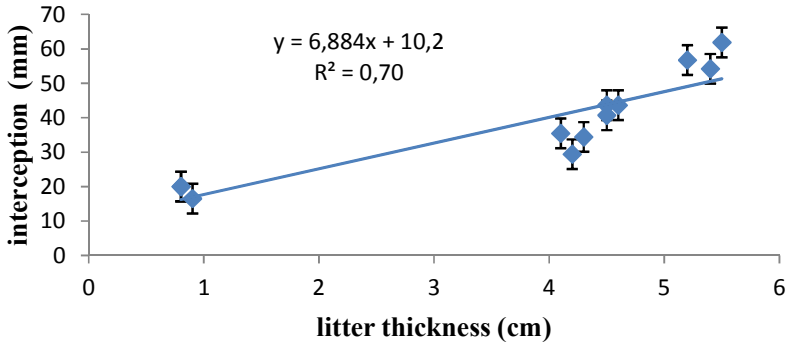

Fig. 2. Effects of litter depth on the rainwater interception

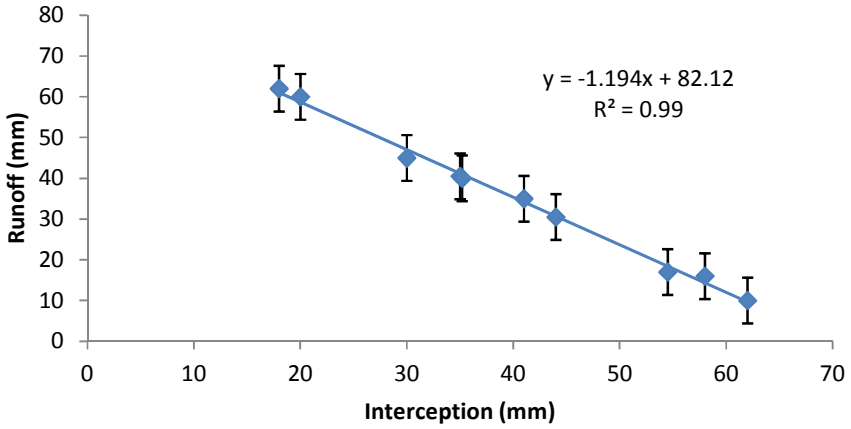

Fig. 3. Effects of rainwater interception by litter on the surface runoff

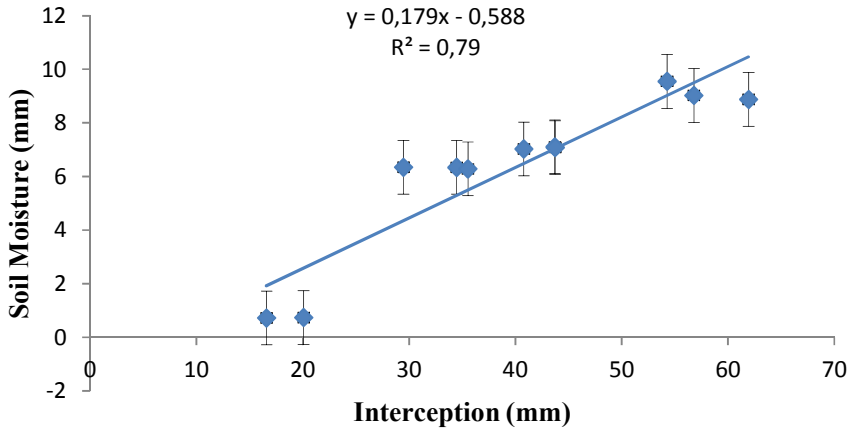

Fig. 4. Effects of rainwater interception by surface litter on the soil moisture

4. CONCLUSION

Land cover influence the production of litter and soil moisture by increasing the rainwater interception. The thickness of litter can intercept more rainwater but reduce surface runoff so it could be increase the soil moisture. Disturbed forest land (HT) produce the thickest litter and the highest interception value (both by water balance approach and gradient water content of litter) than the other plot. The thickness of litter have a positive correlation with interception value (R^2=0.70). Interception value have a negative correlation with runoff (R^2=-0.99), while it have a positive correlation with soil moisture (R^2=0.79).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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