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Infiltration and Evaporation Rate in Different Landuse in the Bango Watershed, Malang District, Indonesia

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Abstract: **The ability of landuse systems to absorb rainfall depends on characteristics of canopy and root system as soil cover. Vegetation and litter layer protects the soil surface from direct raindrops that can destroy the soil aggregates, so that the soil will be compact. Destruction of soil particles will lead to reduce of soil macropores and inhibit water infiltration therefore runoff will increase. Litter have an influence on air temperature and soil temperature, because the vegetation is able to maintain temperature and humidity of the soil remains cool during the heat. Litter has function to protect soil surface from heat and rainfall. This research aimed to know the influence of some landuse system to : 1)soil properties (BD, C-Organic, Macro pore, soil moisture); 2)vegetation character (portion of land cover, vegetation density, litter layer production); 3) infiltration rate, soil temperature and evaporation rate. The research was conducted in Bango Watershed, Malang District, East Java in January-March 2011. This research conclude that high content of organic-C affects the stability of soil aggregates and macropores content; this may decrease the soil bulk density and increasing soil moisture, while the content of soil organic matter is influenced by the type of landuse. Dryland with predominant bamboo and shrub vegetation (LU-1) apparently showed levels of vegetation cover and vegetation density higher than the setlement land (LU-4) with the dominant shrub vegetation and the soil surface covered with paving. Dryland (LU-1) with the level of vegetation cover and vegetation density has the highest thick litter layer, it also has a high infiltration rate. Residential land (LU-4) with a low level of vegetation cover apparently has a high evaporation rate. Statistical analysis showed a positive correlation (R^2 = 0.74) between the rate of infiltration with litter thickness value. The rate of land cover and litter layer thickness on landuse has a negative relation to soil temperature and air temperature. The higher the level of land cover turns the lower the evaporation rate (R^2 = - 0.77).**

Keywords: **Infiltration Rate, Evaporation Rate, Landuse, Litter.**

I. INTRODUCTION

The landuse systems are impacted on soil erosion rates; levels of soil moisture [29]; availability of soil nutrients [11], [13], [65]; biomass returns into the soil [43]; interception [30]; soil structure [3]. In recent years there have been the changes in landuse, such as changes in forest land into the agricultural land, plantations, residential or industrial areas. Changes in landuse can degrade the quality of the soil and increase soil degradation [2]; serious impacts on the soil physical and chemical characteristics, soil fertility and soil erodibility tend to increase [25], [36], [40], [42], [52]. There is research showing that changes in landuse do not lead to reduce content of soil phosphorus, organic carbon, total nitrogen, and the ratio C / N, but the highest pH found in agricultural land compared to the pasture lands in the southeast of Mexico [19]. Results of other studies indicate that landuse changes in tropical ecosystems causing changes in soil characteristics [22], [33], [60]. The most rapid changes occur in soil chemical and biological characteristics [56]. Changes in forests into coffee plantations increase soil erosion [21], [70] and lower SOM [1]. Conversion of forests to other landuses can increase the bulk density, lower hydraulic conductivity, increase soil erodibility, and lower SOM content [34]. Changes in the deciduous forests become to tea plantations have been impacted on the soil physical and chemical character, especially SOM content, soil acidity, and base saturation [52]. Conversion of natural forests into agricultural land reduce the content of SOM by 60% in temperate ecosystems and 75% in tropical ecosystems [35]. The system of landuse was impacted on soil characteristics, in which multiculture cropping systems and natural fallow are more effectively maintain the soil characteristics in a long enough period of time, compared to monoculture cropping systems in Nigeria [8].

Vegetation and litter layer protects the soil surface from direct blow of raindrops that can destroy soil aggregates, resulting in compaction of topsoil. Crushed particles of this soil aggregates causes blocking the soil macropore and preventing the infiltration of water, thereby increasing surface runoff. Litter has a function as a protector of land surfaces, reducing evaporation, keeping soil temperature, affect the rate of SOM decomposition, affects soil microbial activities, plays a role in nutrient exchange processes, and affect the growth of the seed [66], lowering the soil bulk density, improve the water holding capacity and CEC of soil [51].

Infiltration is the movement of water to penetrate the soil surface [6]. Once the topsoil is saturated, the excess water flows into the deeper soil layers following the gravitational force, it is called the percolation water [7]. According to Hillel [27], capability of soil infiltration is influenced by several factors, including the rain duration or irrigation, soil water content at the beginning, hydraulic conductivity, soil surface conditions and the presence of inhibitors in the ground surface. Several factors affecting the rate of infiltration are characteristic of soil physics, precipitation, vegetation cover and soil moisture at the

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beginning [45]. Landuse systems can be used to determine the soil infiltration characteristics [63].

Evaporation is the change of water become the vapor and moves from the soil surface into the atmosphere [61]. Factors affecting evaporation are solar energy, wind, air humidity and air temperature. The rate of evaporation is affected by soil texture and soil hydraulic conductivity, soil water availability and water movement in the soil.

Different landuses generate different types of land cover, types of canopy, and litter-layer, these are impacted on the infiltration and evaporation rate. This study aimed to determine effects of landuse types on soil characteristics (BD, SOM, macropores, and soil moisture content), characteristic of vegetation (percentage of land cover, vegetation density and litter layer), soil infiltration rate, soil temperature and evaporation rate.

II. Research Methods

The field study was conducted at the sub-watershed Bango in the district of Malang, includes the sub-district of Lawang, Singosari, Karangploso, Pakis, partly Malang city (Subdistrict of Lowokwaru and Klojen), and the Subdistrict of Junrejo – Batu city. Fieldwork was conducted during the months of January 2011 to March 2011. Analysis of soil samples were conducted at the Laboratory of Soil Physics, Soil Department, Faculty of Agriculture, Brawijaya University.

Materials used in this study are map of the location of the study, soil samples and chemicals for soil analysis. Tools used are soil sampling equipments, evaporation equipments for field measurement, infiltrometer to determine the infiltration rate [48], equipments for soil sampling and litter sampling.

The study was conducted in three stages: preparation, field surveys and laboratory analysis. Field observations and measurements were taken at six locations of different landuses. In each of the landuse there are three observation plots measuring of 40 m x 5 m (200 m x m).

Table 1. Landuse systems

Land unit	Landuse	Type of Vegetation	Soil Texture
LU-1	Drylands	Bamboo, Shrubs	Loam
LU-2	Irrigated Sawah	Paddy rice, Shrubs, Banana	Clay
LU-3	Drylands	Cassava, Sengon, Shrubs	Clay
LU-4	Settlement	Shrubs	Loam
LU-5	Plantation	Sengon	Loam
LU-6	Shrubs land	Shrubs	Loam

Variables measured were: soil management, thickness of litter-layer, soil texture, soil BD, soil aggregate stability, soil macropores and soil infiltration. The vegetation characteristics included species of plant, canopy coverage and vegetation density. Analysis of soil samples include content of SOM, soil texture and structure, soil BD, soil porosity and soil moisture content. Samples of litter were taken randomly at each point of observation to be measured the thickness of layer (repeated 10 times) using a "vernier-caliper". Soil temperature measurements were performed using soil thermometer [10] every day at 08:00, 12:00 and 15:00, at 40 cm soil depth. Infiltration was measured by the falling-head methode using a single ring infiltrometer [48]. Philip equation was used to find the constant infiltration rate of different landuse systems [48].

Evaporation rate was analyzed by Soil Moisture Gradient Method, the equation:

$$\Delta S=(P+Ir+U)-(R+D+E+T)_{[48]}$$

ΔS are the change of soil moisture storage; P is precipitation; Ir is irrigation; U is the capillary rise; R is the surface runoff; D is the deep percolation; E is evaporation and T is transpiration (Ir=0, U=0, T=0). In this study, no additional irrigation water, capillary rise, and transpiration, so the equation is used: $\Delta S=P-(R+D+E)$.

Table 2. Analytical methods for research variables

No	Variables	Analytical methods
1	Soil Texture	Pippete [5]
2	Bulk Density (ρb)	Cylinder
3	Particle Density (ρρ)	Picnometer [4]
4	Aggregate stability (DMR)	Wet Sieving [50]
5	Soil C-organic	Walkey and Black [17]
6	Macro pore	pF0 - pF2.5 [62]
7	Litter depth	vernier-caliper
8	Initial soil moisture	Gravimetric [57]
9	Infiltration rate	Falling head infiltrometer [48]
10	Evaporation rate	Soil Moisture Gradient [48]

Data were analyzed by using the analysis of variance (ANOVA) method, followed by the analysis of LSD 5% [26]. The relationship between research variables we analyzed by the correlation and regression methods.

III. Result and Discussion

Soil characteristic differences between the landuse system is indicated by the results of measurements of soil texture, content of SOM, bulk density (BD) and soil moisture (Table 3).

The highest soil bulk density (1.36 g.cm^{-3}) is contained in observation plots LU-2 and LU-4, while the lowest bulk density (1.19 g.cm^{-3}) is contained in the observation plots LU-1, but not significantly different from LU -5 and LU-6. BD value reflects the density of the soil, the higher value BD the more solid ground and lower porosity [54]. Organic C content is highest in the observation plots LU-1 is equal to 2.24%, but not significantly different from the LU-5, while the C-organic content was lowest for the observation plots LU-6 is equal to 0.90% but not significantly different from the LU-2 , N-3 and N-4.

The highest percentage of macropores contained in LU-1 is equal to 9.29% and significantly different from the other locations, while macropores prosentase lowest for the LU-4 is equal to 1.85% and significantly different from the other locations. The high organic content of C-level effect on aggregate stability and macro pore formation. It is evident from the results of the analysis that the dryland with clay texture containing the highest SOM content also showed the largest macropores (9.29%).

The moisture content of the soil is highest in LU-1 is equal to 9.30 mm but not significantly different from the LU-2, while the soil moisture content was lowest for the LU-4 in the amount of 3.18 mm and not significantly different from the LU-6. Soil moisture states the amount of water stored in the soil pores [14]. It is evident from the findings that the use of dry land with clay texture containing macropores high of 9.29% turned out to have a soil moisture values were also highest in the amount of 9.30 mm. The higher content of SOM, usually the more stable soil aggregates and macropores more and more, lower value of soil bulk density and increasing soil humidity.

Table 3. Characteristics of soil at different landuse systems, depth of 20 – 40 cm.

LU	BD ($g.cm^{-3}$)	C-Org (%)	Macro pore (%)	Soil moisture (mm)
LU-1	1.19 a	2.24 b	9.29 e	9.30 c
LU-2	1.36 c	1.04 a	5.01 b	5.78 c
LU-3	1.31 b	1.26 a	3.77 b	4.00 b
LU-4	1.36 c	1.14 a	1.85 a	3.18 a
LU-5	1.23 a	1.62 b	7.01 d	6.15 b
LU-6	1.24 a	0.90 a	5.62 c	3.99 a
LSD	0.0495	0.4058	1.326	0.63

Notes: LU-1 (drylands loam texture); LU-2 (irrigated sawah clay texture); LU-3 (drylands clay texture); LU-4 (setlement loam texture); LU-5 (plantation loam texture); LU-6 (shrubs loam texture). The different letters suggest the significant different ($p<0.05$), ns = not significant.

Quantity and quality of the soil organic matter is influenced by landuse system, where the value of the biological properties of soil parameters is highest in soil under pasture land use and fallow compared with vacant land around setlement in South Africa [38]. The system of landuse affect the physical and chemical character of the soil in China [72]. Bulk density and the highest content of organic matter found in soils used for cropping systems of monoculture and significantly different from the other observations in the secondary forest soil, cropping systems and natural fallow multicultural in Nigeria [8]. Bulk density showed significant differences between the different uses of land, where the remnant forest BD 40% lower than the coffee-based agroforestry plantation in West Lampung [23]. Improved BD, decreased porosity and aggregate stability is the impact of changes in forest to agricultural land [28]. C-organic content of the soil is highest on the use of forest land, Calliandra, whereas the C-organic content was lowest for the use of young coffee plantation in West Lampung [11]. Some characters chemistry (organic matter, total N, P and K content) and soil physics in Eucalyptus plantations are lower when compared by dry dipterocarp forests in Thailand [41]. Changes in land cover of natural forests to plantations of tea and Eucalyptus promote changes in soil properties (content of Mg, Ca, P, soil organic matter, soil pH, and BD) in Uganda [37]. Effective in increasing the tree canopy interception of rain [30] so that the soil moisture is also maintained. The use of land with vegetation canopy that meeting will not cause loss of nutrient elements through runoff during the rainy season and evaporation during the dry season [29]. Soil organic matter content is highest in plots with dense vegetation cover level, while the lowest content of organic material contained in the dryland plots in Iran [2]. Landuse can affect soil moisture due to differences in vegetation cover lead to the differences in rainwater infiltration, surface runoff and rate of evapotranspiration [49].

Table 4. Characteristics of landuse systems

Land unit	Coverage level (%)	Density level ($tree.m^{-2}$)	Litter layer (cm)
LU-1	86.47 f	0.28 b	4.20 d
LU-2	21.13 b	0.03 a	0.54 a
LU-3	69.36 d	0.12 ab	2.03 b
LU-4	11.55 a	0.02 a	0.29 a
LU-5	76.63 e	0.24 b	2.97 c
LU-6	63.05 c	0.08 ab	1.60 b
LSD	1.788	0.1891	0.6467

Notes: LU-1 (drylands loam texture); LU-2 (irrigated sawah clay texture); LU-3 (drylands clay texture); LU-4 (setlement loam texture); LU-5 (plantation loam texture); LU-6 (shrubs loam texture). The different letters suggest the significant different ($p<0.05$), ns = not significant.

Based on Table 4 it is known that the highest percentage rate of land cover found in the observation plots LU-1 is equal to 86.47% and significantly different from the other observations plot, while the lowest percentage rate of land cover found in the observation plots LU-4 that is equal to 11.55% and significantly different other observations plot. Level vegetation density was highest in the observation plots LU-1 is 0.28 $tree.m^{-2}$ and not significantly different from LU-5, while the lowest levels of vegetation density plot observations contained in LU-4 is equal to 0.02 $tree.m^{-2}$ and not significantly different from the LU-2. The highest layer of litter found in the observation plots LU-1 is equal to 4.20 cm and significantly different from the other observations plot, while the lowest layer of litter found in the observation plots LU-4 is 0.29 cm but not significantly different from the LU-2. Moor landuse system with the dominant vegetation of bamboo and shrubs (LU-1) appeared to indicate the level of cover and

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vegetation density higher than the use of land as setlement (LU-4) with the dominant shrub vegetation and soil are generally covered with paving. The high-level vegetation cover directly proportional to the litter layer produced by vegetation. This is in accordance with the opinion Saputra [54] which indirectly dense forest cover affects the amount of litter input to the soil, as well as a land of grain rain protector. Reference [24] also stated the same thing that the transfer of forest land to agriculture decrease the thickness of the litter on the soil surface, due to changes in the amount and composition of litter fall inputs (branches, twigs, leaves, flowers and fruit). A research concluded that changes in landuse and land management systems adversely affected vegetation characteristics of pasture ecosystem [20].

Table 5. Infiltration rate and evaporation rate at different landuse systems

Land unit	Constant infiltration rate ($mm.hr^{-1}$)	Evaporation rate ($mm.hr^{-1}$)
LU-1	198 e	0.67 a
LU-2	24 ab	1.29 c
LU-3	30 b	0.99 b
LU-4	18 a	1.47 c
LU-5	84 d	0.72 a
LU-6	48 c	1.02 b
LSD	14.7	0.2356

Notes: LU-1 (drylands loam texture); LU-2 (irrigated sawah clay texture); LU-3 (drylands clay texture); LU-4 (setlement loam texture); LU-5 (plantation loam texture); LU-6 (shrubs loam texture). The different letters suggest the significant different ($p<0.05$), ns = not significant.

Table 5 shows that the highest infiltration rate of the soil contained in LU-1 is equal to 198 $mm.hr^{-1}$ and significantly different from the other observations plot, while the infiltration rate was lowest for the LU-4 at 18 $mm.hr^{-1}$. Drylands (LU-1) with the level of the highest vegetation cover and vegetation density produce high litter layer were affecting soil infiltration rate is high. Infiltration rate of the soil is mainly influenced by the character of the physical properties of the soil, the level of precipitation, vegetation cover, initial moisture content, type of landuse and vegetation types [45]. Rainwater had interception by the canopy, canopy and litter that will affect the infiltration rate of the soil. The use of land with dense vegetation cover can increase the infiltration capacity of the soil beneath it due to an increase in water absorption capacity in the event of rain [58]. The rate of infiltration at land use as agricultural land showed the lowest value of infiltration, the infiltration pasture showed intermediate values while in the forest showed the highest infiltration rate in Calabar Nigeria [6]. Infiltration capacity of the timber was the highest, while the infiltration capacity at the lowest turns pine plantations in North Carolina [64]. Coffee plantation with different systems and levels of tree age in West Lampung may increase the infiltration rate and reduce the potential for erosion [23]. Table 5 shows the evaporation rate is highest in the observation plots LU-4 is equal to 1.47 $mm.hr^{-1}$ but not significantly different from the LU-2, while the evaporation rate was lowest for the observation plots LU-1 is equal to 0.67 $mm.hr^{-1}$ but not significantly different from the LU-5. This suggests a negative relationship between the rate of infiltration and evaporation rate on the observations. The setlement lands (LU-4) with the low level of vegetation cover can increase the rate of evaporation. Low levels of vegetation cover influence on litter production, litter where one of the functions is its role as a mulch can keep soil temperature, soil humidity, thus slowing the evaporation rate [39].

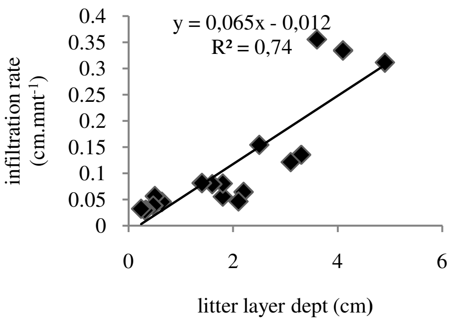

Figure 1. Effects of litter layer depth on the infiltration rate.

Statistical analysis showed a positive correlation (R^2 = 0.74) between the rate of infiltration with litter thickness value (Fig. 1). Based on Table 4 and Table 5 note that the observation plots LU-1 had the highest litter layer and the highest rate of infiltration as well. Differences in landuse produce different litter layer also affects the difference in the rate of infiltration. Differences in vegetation and soil characteristics influence the differences in infiltration capacity [69]. Previous studies conclude that Callitris litter the main factors that affect the rate of infiltration [12]. The mean rate of infiltration in the forest observation plots with vegetation meeting higher than the infiltration rate in the observation plots of land with sparse vegetation and vacant land in Nigeria [15]. Soil infiltration rate on land with vegetation covered perennial crops is higher than the land with vegetation of annual crops in China [46].

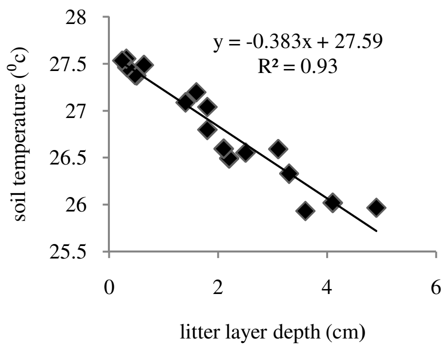

Figure 2. Effects of litter layer depth on the soil temperatur

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Data regression results indicate that the rate of land cover and landuse of the thickness of the litter has a negative relation to soil temperature (Fig. 2). The existence of differences in landuse will affect the soil temperature and air temperature, especially litter inputs in each landuse. In the study conducted, the temperature of the soil in the morning (8 hours) have almost the same value on all the good treatment that has a high litter thickness and the thickness of the litter has a low, but there is a considerable difference in the day (12 hours) and little difference in the afternoon (3 hours). The results showed that the rate of land cover and the thickness of the litter affects the air temperature and soil temperature, where the rate of land cover meeting the input level of litter will also be higher where one function of litter is to maintain the soil temperature.

Soil temperatures are influenced by the type of litter, number and size of litter [59]. Ground cover vegetation can affect soil temperature, can produce a litter on the soil surface which reduces fluctuations in daily and monthly temperature [31], [47]. Changes in vegetation type, land cover and litter layer as a result of human activities can alter soil temperatures [18], [32]. The different types of litter can influence the light interception differences, differences in soil temperature and soil moisture conditions [16]. The ability of the litter as a buffer for the soil temperature caused by litter reduces evaporation through the soil surface and radiation interception [44], [55]. Litter can maintain soil moisture by reducing evaporation of soil, but also able to reduce the entry of rain water through the process of interception [57]. The results of the study support this observation is that the disposal of litter can raise the soil temperature at 5-8^0 C in a meadow in early growth [16]. Another study concluded that the soil temperature at multistory forests and coffee plantations with shade almost the same as the air temperature on the same day, while the soil temperature at the coffee plantation monoculture relatively higher than the air temperature of the system when compared with other coffee plantation in West Lampung [23].

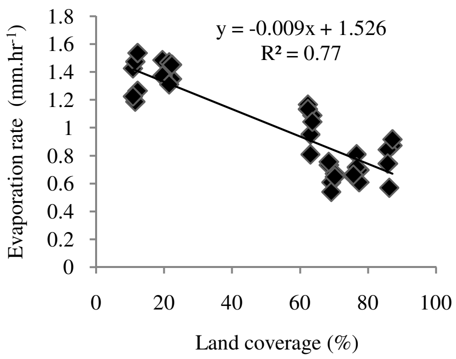

Figure 3. Effects of land coverage on the evaporation rate.

Level of the land cover showed a negative correlation with the rate of evaporation (Fig. 3). The higher level of land cover, the evaporation rate will be low (R^2 = - 0.77). The presence of litter-layer on the soil surface can control the rate of evaporation through two mechanisms, namely: (1) keep the exit-entry of solar radiation through the soil surface [9], [71]; (2) keep the soil moisture so that no excessive evaporation [53]. Land cover and the thickness of the litter layer on a certain landuse can protect the soil surface from effects of solar radiation and wind, so as to reduce evaporation. The process of evaporation is very active if there are the direct radiation, because soil absorbs more heat and lead to higher soil temperatures, so that changes in water molecules become vapor are more and more. The existence of land cover and the thickness of litter-layer, reduced evaporation due to the more dense and diverse surface vegetation can serve as a protective cover against the effects of solar radiation. One of important utilization of litter-layer is as the natural mulches. These mulches can slower evaporation [39]. Previous studies concluded that shade of the canopy of Acacia erioloba can reduce the rate of evaporation and keep the moisture in the topsoil layer in South Africa [38], [67]. The rate of evaporation on land without litter-layer is higher than the lands covered with litter-layer in North America [68].

IV. Conclusion

The result of this research could be use for manage of availability soil water content. Evaporation and infiltration were main hydrology component in a watershed.

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