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Soil Erosion Rate and Surface Run Off on Various Forms of Culture

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Cultivation is one of the agricultural systems that is mostly carried out by forest village communities living in and around the watershed area by slashing, cutting and burning forest trees. This study aimed to determine the rate of erosion and runoff from the cultivation type in Olonjonge sub-watershed, Dolago watershed, Central Sulawesi, Indonesia.The method used was a multislot divisor on a plot measuring 2 m x 15 m with 3 repetitions on 3 types of cultivation (peanut, corn and cocoa monoculture (3 years old) on land with a steep slope (25-40%). The largest surface runoff came from peanut land at 79,689.77 liters ha^{-1} followed by corn at 65,704.55 liters ha^{-1} and the smallest from cocoa monoculture (3 years old) at 56,385.23 liters ha^{-1}, while the highest erosion occurred at peanut land area of 195.52 kg ha^{-1} followed by corn field of 165.26 kg ha^{-1}, and cocoa monoculture (3 years old) of kg ha^{-1}. Cocoa planting was more effective in protecting the soil from rain with the potential to protect the soil from erosion and surface runoff.

Keywords: Soil erosion; surface runoff; cultivation; watershed.

1. INTRODUCTION

The increasing of population and the need for food production have led to increased population pressure on land resources so that the land use change for agricultural activities are hard to avoid [1]. Cultivation is one of the most widely practiced agricultural systems conducted by the

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people who live in and around the watershed. This activity is carried out individually or in group in forest areas that are considered fertile by cutting, slashing and burning forest trees. It will cause land use patterns to change with the increase and the proportion of land for agricultural increases that cause the decrease of forest areas [2]. Land use changes for cultivation activities cause the surface of the soil to open, so that falling rainwater can hit the soil surface directly, causing the breakdown of soil aggregates [3]. As a result of the destruction process, soil particles broken from their aggregates and nutrients will be transported to other places by surface runoff (erosion) [3,4].

The process of land use change beside resulting benefits enjoyed by the community but also inseparable from the risk of land damage due to erosion. Erosion is the main factor that causes land degradation [5,6]. Erosion often causes impacts, both at erosion location and outside the location [7]. The impact that is often seen is the occurrence of soil damage such as decreased land productivity, decreased soil infiltration and silting of rivers, reservoirs, and decreased capacity of irrigation channels, decreased water capacity and flooding [8].

Soil erosion starts with the stage of soil destroying or soil aggregates by the collision of rainwater into small loose pieces that are then transported to other places by surface runoff. [9]. In addition to transporting soil particles separated from their aggregates, runoff will also erode the surface of the land passed [10].

One of land use type found in the Olonjonge sub-watershed area is cultivation in the form of cocoa plants and other seasonal crops.According to [11], plant characteristics can increase the rate of runoff and erosion caused by the changes in cover crop vegetation. The decrease in plant productivity is related to the decrease in soil fertility due to the transfer of nutrients and the loss of the nutrient-rich topsoil due to erosion. Nutrients transported by surface runoff and erosion are the biggest nutrient loss factors that may reduce soil fertility and plant productivity [12,13].

The Olonjonge sub-watershed with an area of 3,391.43 ha is one of the priority (critical) watersheds in Central Sulawesi with high erosion rate with a fairly large erosion value [14]. Reported the largest erosion value of 863 tons/ha/year and the smallest of 95 tons/ha/year with a tolerable erosion value of 19.6 – 55.6 tons/ha/year. The effort to prevent and suppress erosion, research and steps are needed to determine the level/rate of erosion in the area concerned, namely the amount of soil mass lost for each period of a certain unit of time. The purpose of this study was to determine the rate of erosion and runoff in 3 types of cultivation in the Olonjonge sub-watershed, Central Sulawesi, Indonesia.

2. MATERIALS AND METHODS

2.1 Study Location

This research was conducted on three types of cultivation such as: peanuts, corn, and cocoa monoculture (3 years old). In the upstream of Olonjonge sub-watershed located between 120^o 02'24" - 120^o 15'00"E and 0^o 50'24" - 0^o 56'24"S and at an elevation of 800 m ASL. Administratively, it is located in South Parigi District, Parigi Moutong Regency, Central Sulawesi, Indonesia. The research was conducted from March 2021 to November 2021. The planting of the three types of cultivated plants was carried out on farmers' gardens in the upstream area of the Olonjonge sub-watershed with different types and physical properties of the soil which will be analyzed according to the purpose of this study.

2.2 Research Procedure

Measurements of surface runoff and soil erosion were carried out for 30 times of rain on erosion measuring plots measuring 2 m x 15 m with 3 replications on 3 types of cultivation on a slope of 25-40% (steep) [15]. The measurement of soil erosion and surface runoff were measured every 07.00 am if previously there had been rainy that may cause surface runoff and erosion. To determine the amount of eroded soil, water samples were taken from each erosion basin with a diameter of 47.5 cm. Water samples were taken from the tub erosion is carried out by first stirring so that the surface flow suspension becomes homogeneous. The water sample was then filtered, then dried in an oven at 105 ^{o}C for 24 hours until the weight was constant, and finally weighed to determine the weight of the sample (sediment). After taking the water sample, the remaining water in the erosion basin is removed and then cleaned. Data on the volume of rainfall during the observations were collected through a manual rain gauge (ombrometer). In addition to surface runoff and erosion, soil physical characteristics were also measured by taking soil using a random sample ring [16] on each erosion plot for each cultivation system at a depth of 0-10 cm (top soil).

2.3 Data Analysis

Surface runoff is calculated by the equation [17].

$$VRO = V1 + a\ V2 \quad (1)$$

Where: VRO: Total surface runoff volume (L), V1: surface runoff volume in water bucket1 (L), V2: surface runoff volume in water bucket 2 (L). The amount of eroded soil is calculated by the equation [17].

$$Wer = W1 + W2 \quad (2)$$

Where: Wer: weight of eroded soil (g), W1 and W2: weight of soil in buckets of water I and II (g),
W1 and W2 = Ve / Vs x (Wfpd - Wfp),
Ve: volume of water in a bucket (L),
Vs: volume of filtered water (L),
WFPD: filter paper weight and deposit (g),
WFP: filter paper weight (g)

To determine the rainfall on the surface, runoff and erosion on the 3 types of cultivation, analyzed using simple linear regression. From the results of the analysis, it can be found the trend of the relationship so it may help choose the model.

3. RESULTS AND DISCUSSION

3.1 Rainfall

The total rainfall during the study period was 575.9 mm or an average of 19.17 mm with 30 rainy days (Table 1).

In tropical areas such as Indonesia, the erosion is mostly caused by rainfall. Rain factors that determine the strength of the rain dispersion on the soil, the amount and speed of runoff and erosion are the amount of rainfall, the intensity and distribution of rain.

3.2 Soil Characteristics

The results of soil analysis on the three forms of cultivation showed that the type of cultivation did not affect the physical properties of the soil (Table 2). Soil physical properties that affect soil erosion include soil texture. Soil texture in the 3 fields generally showed the same value, namely sandy loam texture with sand values dominating the area ranging from (55.1 – 59.6%). The soil texture that is dominated by the sand fraction has a difficult ability to hold water. It is in line with the opinion of [18] that because sandy soil has a rather large particle size so that each unit of weight has a small surface area so it is difficult to hold water.

Bulk density is seen at the research site with the criteria of a high average at the three locations. The effect of bulk density on the soil is very important and it showed that the soil in the study area was dense. It is in line with [19] opinion that soils with high bulk density value have dense soils that make it difficult for water to pass and penetrate plant roots.

Infiltration velocity analysis showed that the 3 types of cultivation had fast soil ability to pass water because the area was dominated by the sandy loam fraction, where the sandy fraction was dominant with larger soil particles.

3.3 Surface Runoff

Infiltration velocity analysis showed that 3 types of cultivation had relatively fast soil ability to pass water because the area was dominated by the sandy loam fraction. The sand fraction was dominant and had larger soil particles.

Table 1. Rainfall during Research

Month	Rainfall	Rainy Day
March	79.4	4
April	71.5	4
May	116.6	5
June	160.6	5
July	78.7	5
August	109.8	7
Total	575.9	30
Average	19.17	

Table 2. Soil physcal characteristics

Farming type	Parameter	Score	Criteria
	Texture		Sandy loam
Cocoa monoculture (3 years)	% sand	55.1	
	% dust	28.9	
	% clay	16	
	bulk density : (g/cm^3)	1.44	high
	organic matter : (%)	3.6	High
	infiltration: (mm/hour)	5.7	Farily fast
	permeability: (cm/hour)	12.5	Medium
Peanuts	Texture		Sandy loam
	% sand		
	% dust		
	% clay		
	bulk density : (g/cm^3)	1.35	high
	organic matter : (%)	3.2	High
	infiltration: (mm/hour)	1.82	Farily fast
	permeability: (cm/hour)	11.6	Medium
Corn	Texture		Sandy loam
	% sand	59.6	
	% dust	22.7	
	% clay	17.7	
	bulk density : (g/cm^3)	1.56	high
	organic matter : (%)	2.98	High
	infiltration: (mm/hour)	4.7	Farily fast
	permeability: (cm/hour)	12.4	Medium

Table 3. Soil Erosion and Surface Runoff in Various Types of Cultivation

Farming type	Soil erotion (kg ha^{-1})	Surface runoff (liter ha^{-1})
Peanuts	195.51	79,689.77
Corn	165.26	65,704.55
Cocoa (3 years)	131.28	56,385.23

Based on the results, surface runoff from the cultivated area as shown in Table -3 had different values of surface runoff. Surface runoff on peanut land had the largest volume of 79,689.77 liters ha^{-1}, followed by corn fields with 65,704.55 liters ha^{-1} and the lowest is on 3-year-old monoculture cocoa fields. of 56,385.23 liter ha^{-1} (Table 3) The high runoff in the peanut and corn areas is due to low vegetation cover and medium soil permeability. It is in line with research conducted by [20] that one of the determinants of surface runoff is the presence of vegetation that covers the soil surface. Furthermore, the presence of high organic matter can absorb very high water up to 20 times of the dry weight [21]. Dense cover may cause an increase in biological activity on land due to the availability of organic matter and environmental improvements (micro-climate and environment, humidity), soil biological activity had a positive influence on increasing soil porosity and infiltration speed [21].

3.4 Relation between Rainfall and Surface Runoff

Surface runoff on the 3 types of land use observed during the study period was water that flows over the land surface that is highly dependent on the amount of rainfall.

Fig. 1, showed that the value of R^2 = 0.6512, it means that 65.12% of surface runoff in the peanut area was influenced by rainfall while 34.88% was influenced by other environmental factors with a correlation value of (r) = 0.81 (very strong).

Fig. 2, showed that the value of R2 = 0.5668. It means that 56.88% of surface runoff that occurs in the corn area was influenced by rainfall and 43.12% was influenced by other environmental factors with a correlation value (r) = 0.75 (strong).

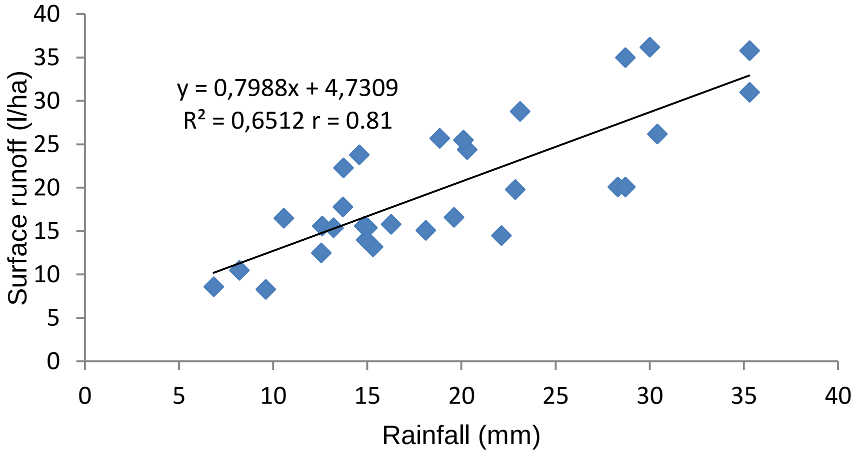

Fig. 1. Relation between rainfall and surface runoff of Peanut Land Area

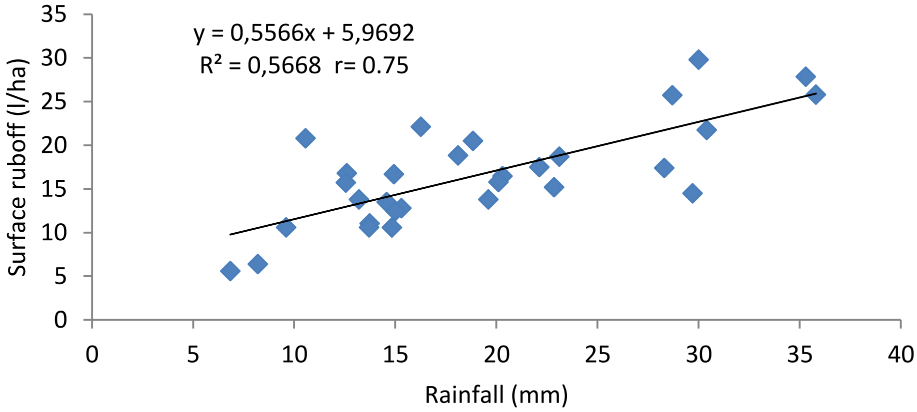

Fig. 2. Relationship between rainfall and surface runoff in Corn area

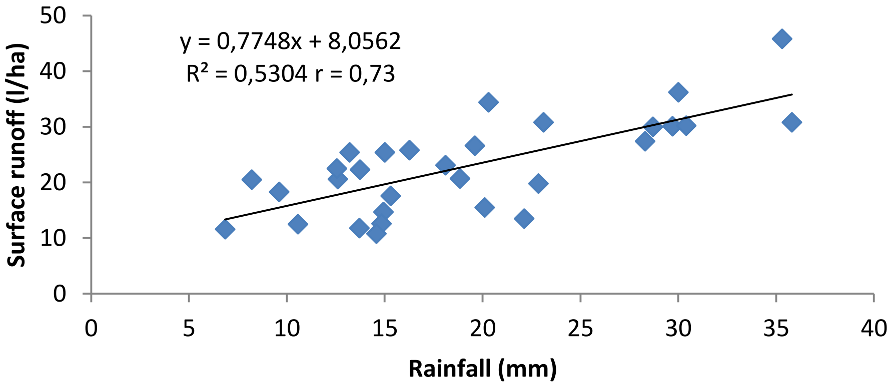

Fig. 3. Relationship between rainfall and surface runoff in monoculture cocoa area (3 years old)

Fig. 3, showed that the value of R^2 = 0.5304, it means that 53.04 % of surface runoff in monoculture cocoa areas (3 years old) was influenced by rainfall while 46.98% by other environmental factors with a correlation value (r) = 0.73 (strong)

The value of the coefficient of determination of the effect of rainfall on other surface runoff is thought to have an effect on increasing infiltration velocity [22]. States that rain that falls on the ground will seep into the soil after being restrained by the plant crown. The infiltration process will occur until the field capacity is met. If the field capacity met and the rain is still in progress, then the excess rainwater still infiltrates into the percolation water and other water will fill the basin or deposit depression. Furthermore, after the deposit depression is filled, the excess water will become a puddle or surface mooring and before becoming a runoff, the excess water will evaporate even though the amount is very small. states that rain that falls on the ground will seep into the soil after being restrained by the plant crown. This infiltration process will occur until the field capacity is met. If the field capacity has been met and the rain is still in progress, then the excess rainwater still infiltrates into the percolation water and other water will fill the basin or deposit depression. Furthermore, after the deposit depression is filled, the excess water will become a puddle or surface mooring and before becoming a runoff, the excess water will evaporate even though the amount is very small.

3.5 Soil Erosion

Soil erosion is the loss of the topsoil (tops oil) transported by the water or by wind. The results of soil erosion measurements for each rain event are presented in Table 3.

Based on table 3, it showed that the largest erosion occurred in peanut land, amounting to 195.51 kg ha^{-1}, followed by corn at 165.26 kg ha^{-1} and monoculture cocoa (3 years old) at 131.28 kg ha^{-1}. The high erosion in peanut and corn fields is caused by the opening of the soil surface due to the lack of adequate litter as a ground cover [23] and the lack of leaves and a canopy system from these vegetation that is able to protect the soil surface from the blows of rainfall that has high destructive power. This is supported by the opinion of [24,25] that litter, leaves and vegetation canopy are able to protect the soil surface from rainwater with high destructive power.

The existence of human activities in land management that is not in accordance with soil conservation rules, especially on land for planting peanuts and corn can increase erosion (Table 3), this is in accordance with the opinion [26] that changes in land use can accelerate land degradation, including soil erosion so that productivity decreases

3.6 Relation between Rainfall and Soil Erotion

The results showed that the relationship between rainfall and soil erosion had a strong (positive) relationship in the 3 types of cultivation, namely; Peanut, Corn and cocoa monoculture (3 years old), It is explained further in Figs. 4, 5 and 6.

Based on the results of the analysis in Fig 4, it showed that the correlation value (r) in peanut land was 0.90 with the coefficient of determination (R^2) was 0.8164. It means that 81.64%, soil erosion was determined by rainfall conditions (Fig. 4)

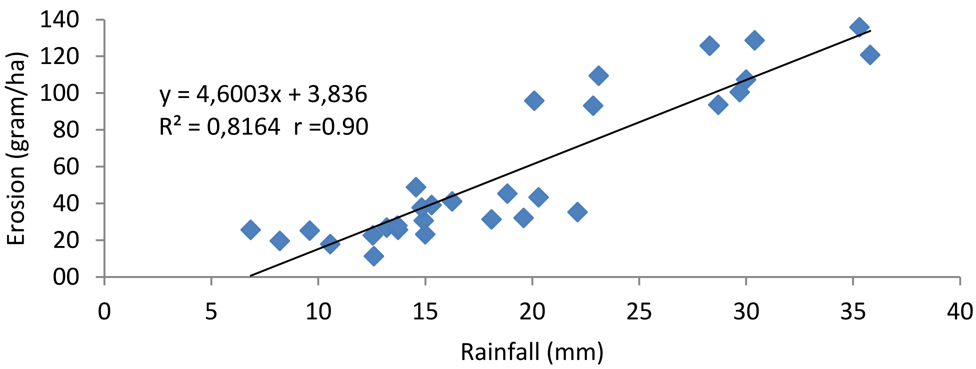

Fig. 4. Relationship between Rainfall and Soil Erosion in Peanut Land

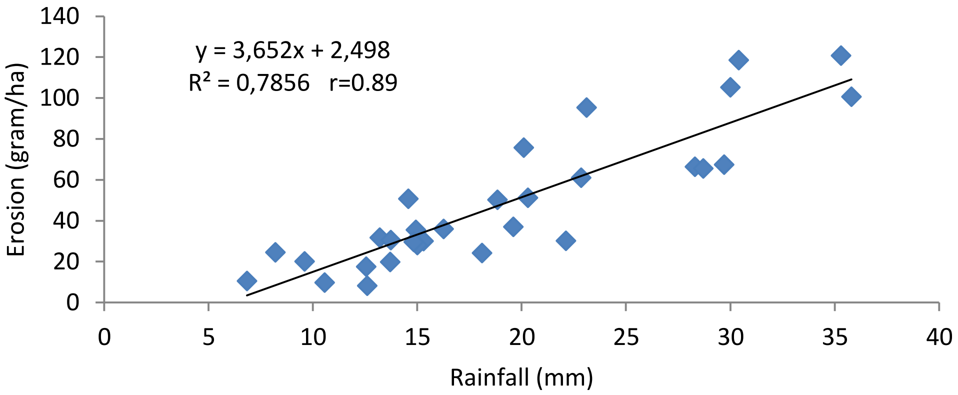

Fig. 5. Relationship between Rainfall and Erotion of Corn Area

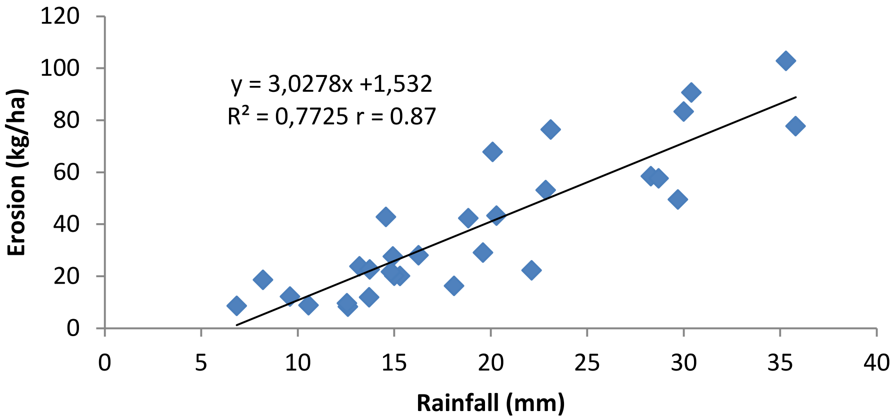

Fig. 6. Relationship between Rainfall and Soil Erosion in Monoculture Cocoa (Age 3 years)

Based on the results of the analysis in Fig. 2 showed that the magnitude of the correlation value (r) in corn fields was 0.89 with the coefficient of determination (R2) was 0.7856. It means that 78.56%, soil erosion was caused by rainfall conditions (Fig. 5).

The correlation value (r) in monoculture cocoa plantations (3 years old) was 0.87 with the coefficient of determination (R^2) was 0.7725. It means that the magnitude of surface erosion was 77.25% determined by the rainfall conditions (Fig. 6). Based on (Fig.4, 5 and 6) the correlation between rainfall and soil erosion in all types of cultivation showed a positive correlation (very strong). It is supported by [25] that concludes the climatic conditions in this case were the amount of rainfall and the intensity of rain effect on soil erosion. In addition to rainfall, the type and growth of vegetation, as well as soil type, also affects soil erosion in the tropics [19].

This cultivation type of cocoa plants was better than peanuts and corn. Cocoa can be more effective in controlling surface runoff and erosion, it is because the canopy system in cocoa can be more effective in protecting the soil surface from the impact of rainfall. It is in line with research conducted by [27] that the canopy on vegetation can break the kinetic energy of rain that has the potential to destroy soil aggregates. Furthermore, the root system in cocoa plants can improve the physical properties of the soil, thereby increasing water infiltration into the soil [28].

4. CONCLUSION

Farming activities with monoculture cocoa plants (3 years old) were more effective in controlling the runoff and erosion than peanuts and corn. Agroforestry systems need to be applied to farming systems in order to minimize runoff and erosion. The increase of soil erosion is in line with the amount of surface runoff in 3 types of cultivation such as peanuts, corn and pure cocoa (3 years old). It is recommended that to minimize runoff and erosion, the ground cover vegetation needs to be maximized, especially on woody plants

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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