

Experimental Study on Slope Erosion Control with Technology of Straw Fiber Closing Layer

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ABSTRACT: This study aims to analyze the influence of the characteristics of slope erosion rate of the surface layer of silty sand soil cover layer is given with rice straw fiber. This study is testing in the laboratory using a model USLE (Universal Soil Loss Equation) as a comparison to determine the amount of the rate of soil erosion that occurs in silty sand. Research carried out with 3 variations of rainfall intensity is 50 mm/hour, 100 mm/hour and 120 mm/hour and using artificial Rainfall Simulator tool in the Hydraulics Laboratory of State Polytechnic of Ujung Pandang. The physical model used in this study is made of wooden planks shaped box with 1x1x0,5 m. The result showed that the effect of rainfall intensity and slope gradient on soil erosion rate is directly proportional. In high rainfall intensity and the greater the value of the slope will increase the magnitude of the rate of soil erosion also. The magnitude of the rate of erosion that occurs based treatment in the laboratory on successive rainfall intensity I_{50} , I_{100} and I_{120} with 10° slope is $E = 4,100 \text{ gr/m}^2/\text{hour}$, $E = 15,350 \text{ gr/m}^2/\text{hour}$ and $E = 39,250 \text{ gr/m}^2/\text{hour}$. At 20° slope is $E = 5,650 \text{ gr/m}^2/\text{hour}$, $E = 24,800 \text{ gr/m}^2/\text{hour}$ and $E = 54,150 \text{ gr/m}^2/\text{hour}$ and slope of 30° is $E = 35,608 \text{ gr/m}^2/\text{hour}$, $E = 53,500 \text{ gr/m}^2/\text{hour}$ and $E = 94,150 \text{ gr/m}^2/\text{hour}$. Based on the result of the regression analysis on the original land for the determination of the rate of erosion due to changes in rainfall intensity I_{50} , I_{100} and I_{120} with a slope of 10° , 20° and 30° is obtained: $E = 0,8197e^{0,0311(I)}$, $E = 1,1264e^{0,0318(I)}$ and $E = 17,845e^{0,0128(I)}$. For closing 30% of straw fiber row on I_{50} , I_{100} and I_{120} with 10° slope is $E = 0,750 \text{ gr/m}^2/\text{hour}$, $E = 1,050 \text{ gr/m}^2/\text{hour}$ and $E = 1,750 \text{ gr/m}^2/\text{hour}$. At 20° slope is $E = 2,450 \text{ gr/m}^2/\text{hour}$, $E = 3,050 \text{ gr/m}^2/\text{hour}$ and $E = 5,900 \text{ gr/m}^2/\text{hour}$ and slope of 30° is $E = 6,150 \text{ gr/m}^2/\text{hour}$, $E = 9,400 \text{ gr/m}^2/\text{hour}$ and $E = 21,300 \text{ gr/m}^2/\text{hour}$. Based on the result of the regression analysis for the closure of 30% rice straw fiber is obtained: $E = 0,4109e^{0,0111(I)}$. The magnitude of the rate of erosion that occurred in the percentage cover 30% on average by 17,68% of the rate of erosion on rate native soil, in other words the rate of erosion on native soil will be reduced by an average of 82,932% if the land is given a cover layer of rice straw fiber the percentage cover of 30%.

Keywords -Erosion, Silty sand soil type, Rainfall intensity, Slope gradient, Regression analysis

1. Introduction

Erosion is a natural process that causes the loss by erosion in the site induced by rain or wind. In tropical climate such as Indonesia, erosion caused by rainwater is important, whereas erosion caused by wind is not. Erosion may cause the loss of fertile soil which is good for plant growth and it may reduce the soil's ability to absorb and to store water. The transported soil will be washed into the water sources called sediment, and will be deposited in a stream a slow flow; within the streams, reservoirs, lakes, irrigation canals, over farmland and so on. Thus, the damage caused by erosion may occur in two places, namely on land where erosion was occurred (upstream), and at the end point of the transported soil to be deposited (downstream). The eroded soil will be retarded in chemical and physical properties such as loss of nutrients and organic matter, the increasing of soil density and penetration resistance, the decreasing of soil infiltration capacity and the ability of soil to retain water. This event resulted in the decrease of land productivity and groundwater recharge (Arsyad, 2010).

In Indonesia, rice straw has not been assessed as a product that has economic value. Farmers allow anyone to take the hay from his farm. In some areas, farmers even happy when their fields are free of straw. In intensive farming systems, often regarded as the hay crop residues that interfere with tillage and planting rice. Therefore, 75-80% of farmers burning straw in place, a few days after the rice is harvested. Some farmers cut hay and pile on the edge of the mapped fields, and then burn it. Therefore, utilization of rice straw has been used only as an industrial raw material of paper, mushroom substrate material or as fuel in brick making, etc. It is known that the properties of rice straw consisting of leaves, leaf midrib, and sections or books. Where these three elements is relatively strong because it contains silica and high cellulose and weathering process takes a long time. However, if certain treated rice straw will accelerate the structural changes (Makarim, Sumarno and Suyanto, 2007).

Based on the description above, the use of materials mulch or plant remains very possible to do study / research in the laboratory, in order to assess the characteristics of slope erosion rate of the silty sand soil surface is given to cover of mulch or plant residues such as rice straw fiber, particularly soil in sloping lands.

2. Literatur Review

USLE model (Universal Soil Loss Equation) is an equation to estimate the rate of soil erosion that has been developed by Wischmeier and Smith, 1978.

Based on that, Hood, B.C., et. al (2002) suggested that the USLE model is adopting a number of factors and subfactors to estimate the soil loss. The equation for estimating the soil erosion rate (E) in tonnes/ha/year is;

$$E=R.K.LS.C.P \quad (1)$$

with R = rainfall erosivity factor and surface flow (EI), K = soil erodibility factor, LS = length-slope factor, C = factor of land coverage plant and crop management, P = factor of practical conservation measures.

In this study the rainfall that will be used is artificial rainfall generated by rainfall simulation tool (Rainfall Simulator). From this artificial rain, the rainfall factor which is effecting the process of erosion is the rainfall intensity (I) in mm/hr based on (Sri Harto, 1993 in Sucipto, 2007), as the following;

$$I = \frac{V}{A.t} \times 600 \quad (2)$$

with I = rainfall intensity (mm/ h), V = volume of water in the cup (ml), A = the total area of the cups (cm²), t = time (minutes).

The Measurement of kinetic energy (Ek) in the rain joule/m²/mm is conducted, as shown in Equation 3 (Morgan, R.P.C., 1985 in Lambang Goro. G., 2008), as the following;

$$E_k = 11,87 + 8,73 \log I \quad (3)$$

with I = rainfall intensity (mm /hour)

For the tropical area (Hudson, 1971) suggested to use equation 4, as the following;

$$E_k = 29,8 - 127,5/I \quad (4)$$

with I = Rain intensity (mm/hour), Ek= Kinetic energy (Joule)

The rainfall erosion index (R) is the ability of rainfall to initiate erosion, can be written in the form of equation 5 (Suripin, 2001), as the following;

$$R = E_k I_{30}/100 \quad (5)$$

with Ek= Kinetic energy of the rain (Joule), I₃₀ = Maximum intensity of the rain over 30 minutes

Soil erodibility (K), based on the table of soil erodibility (K) in Hardiyatmo, HC (2006) in which the results of soil classification by USCS classification system are categorized into groups of SP (poor graded sand) or poorly graded sand with K values of 0,650.

Slope factor value is determined by the slope length (L) and the slope gradient (S). Goldman et al, (1986 in Hardiyatmo, HC, 2006), said that the influence of these factors combined length and slope with the symbol (LS). Where the S factor is the ratio of soil loss per unit area on the ground to lose ground on the experimental slope along the 22.1 m (72.6 ft) with a slope of 9%. LS is used to calculate similarities 6, the following;

$$LS = \frac{65 s^2 L'}{s^2 + 10.000} + \frac{4,6sL'}{(s^2+10.000)^{0,5}} + 0,065L' \quad (6)$$

with LS = slope length, s = slope (%) and L' = length factor whose value, as shown in Equation 7, the following;

$$L' = \left(\frac{L}{22,1} \right)^m \quad (7)$$

with L = slope length in meters, m = 0.5 (slope, s ≥ 5%).

Based on previous research conducted by; 1). Leila Ghomalia, Hamidrez * a and Mehdi Sadeghi Homaeab (2012), they studied on Straw Mulching Effects on Splash Erosion, Runoff, and Sediment Yield from Eroded Plots. The variables used in this research is sandy loam, mulch hay, 30% slope, rainfall intensity, respectively 30, 50, 70, and 90 mm / hour. Research results showed that straw mulch has a significant effect in reducing surface runoff and erosion rates at 99% confidence level. Maximum increase in runoff start time (110.10%) was observed for the intensity of rainfall 90 mm / hour. Runoff coefficient decreased maximum rainfall intensity of 30 mm / hour and 90 mm / hour. The maximum decrease in the sediment yield (63.24%) also occurred in the intensity of rainfall 90 mm / h; 2). Hee Chul Won, Yong Hun Choi, Min Hwan Shin, Kyoung Jae Lim, Dae Joong Choi (2012), they studied the effect of Rice Straw Mats on Runoff and Sediment Discharge in a

Rainfall Simulation Laboratory. The variables used are sand clay soil, rice straw, slope 10% and 20%, the intensity of rain 30 and 60 mm / hour. Research results show the simulated rainfall intensity of 30 mm / h produced only a little sediment on slope of 10% and 20%, and no sediment discharge is generated if given a cover layer of rice straw with a dry weight of 900 g / m² to 60 mm / hour of rain intensity with a 20% slope. Concentration of suspended density plots closed significantly lower than in the controlled.

3. Research Methodology

3.1. The Time and Place for Research

For the implementation of the research conducted during the nine-month (June 2013 to March 2014) at the Laboratory of Soil Mechanics and Hydraulics Laboratory Department of Civil Engineering, Polytechnic of Ujung Pandang .

3.2. Primary Material

The main material of this research is the silty sand soil taken from the Parangloe-Manuju sundistrict, Manuju Village, District Manuju, regency of Gowa, South Sulawesi Province which is prone to erosion. According Erosion Hazard Map (PBE) were obtained from the Center for Watershed Management Jeneberang-Walanae, that the area is categorized as very severe erosion.

3.3. Implementation Research

3.3.1. The Study of Soil Mechanics

Laboratory testing of soil characteristics in Soil Mechanics, form; sieve analysis, moisture content, Atterberg limits of, compaction, density and density. For the preparation of the soil, the soil material was dried until it reaches the air dry condition then the grains of soil destroyed with a hammer until it passes the filter no. 4 (four). Furthermore, the soil is mixed with water evenly and then put in a box with a sample size of 1.0 mx 1.0 mx 0, 5 m in accordance with the required volume then leveled and compacted with a compaction system with a standard height of 60 cm and a falling number of collisions as much as 1120 time of the collision until it reaches a thickness of 10 cm each layer of soil samples. This test is done to achieve the maximum degree of soil density of 89.1%.

3.3.2. Measurement of Density

Determination of the percentage of the maximum density based on existing soil conditions in the field soil density of 89.1%. To Obtain the

mass of soil (W) = volume of soil multiplied by the unit weight of dry (Das, BM, 1993) [3], namely;

$$W = V \times \left(\frac{\gamma \times 100}{100 + w} \right) \quad (8)$$

with W = mass of soil, V = volume of soil, γ = wet unit weight and w = water content

3.3.3. Measurement of Intensity

Before starting the study, conducted rainfall simulator testing tools to ensure the amount of intensity that will be used. The magnitude of the intensity of rain is based on the determination of the aperture disk, the rotation, and the magnitude of the pressure pump and the diameter of a grain of rain. A regulating device was built at a slope of rainfall simulator. Putting five pieces of container with a diameter of 7.5 cm at the top of the instrument, 2 on the right side, 2 on the left and one in the middle. Rainfall simulator is turned on and the intensity-modulated. Close the container first with plywood cover that was filled with water, when rainfall simulator tool is turned on, open the container and turn on the stopwatch to determine the time. After 10 minutes take place immediately closed container, rainfall simulator is turned off and the water in the container is measured with a measuring cup put in and recorded. Thus the volume and time has been known that the rainfall intensity can be determined. To obtain the desired rainfall intensity it is necessary to experiment repeated. The intensity of rain is desired based on equation 2, obtained 50 mm / hour, 100 mm / hour and 120 mm / hour.

3.3.4. Implementation of Running

- a. Having obtained the desired rainfall intensity, which is 50 mm / hour, 100 mm / hour and 120 mm / hour, then measured for 2 hours. Every 15 minute measurement of the volume of runoff water collected using a bucket container, then water reservoir sediment deposited for collection. After 15 minutes, the water reservoir is replaced with a new water reservoir to accommodate runoff in the next 15 minutes. The samples were then deposited on a place for \pm 48 hours. Furthermore, the soil sample is placed in a cup, then dried using an oven for \pm 24 hours.
- b. Once dried and then weighed to obtain total weight.

4 . Result and Discussion

4.1. Results of Research

4.1.1. Soil test results

Based on testing and curved gradation sieve analysis (ASTM-D1140-54 422-63) of the soil samples, obtained percentage = 98.03% coarse fraction and a fine fraction = 1.97%. Based on the soil Classification system according to USCS (Unified Soil Classification System) of the soil samples with coarse fraction percentage (98.03%) > 50% and the percentage of fine fraction (1.97%) < 5%, then this land belongs to the category " Sand Gradation Poor (Poor Graded Sand, SP) "or a mixture of gravel-sand-silt. Then based on the Casagrande plasticity chart, 1948 (in Hardiyatmo. HC, 2006), with a liquid limit (LL) = 54.16% and plasticity index (PI) = 14.96%, then the land was acquired on the MH and OH. It can be concluded that this land including soil type "Organic silty Sand" with low plasticity.

Density test results obtained in the laboratory with a maximum density values obtained from soil samples was 1.225 g / cm³ with a water content of 25.5%, while the weight of the contents of the field is obtained by 1, 091 g / cm³. Based on the value of this maximum density, and the presence of heavy contents of the field, then the degree of density obtained was 89.1%. Test results on the ground that the sieve analysis of soil retained on 200 sieve (coarse fraction) was 98.03%. Test results obtained Atterberg limits of plastic index (IP) by 14.96% or 200 sieve .

4.1.2. Measurement of intensity

This experiment was performed several times with several combinations of aperture disc set, the rotation speed and pressure of the water, so we get some rainfall intensity level desired. Rainfall intensity used was 50 mm/hour, 100 mm/hour and 120 mm/hour.

4.1.3. Estimated number USLE erosion model

Total rate of soil erosion is obtained by measuring the runoff water for 2 hours, every 15 minutes was measured runoff water being stored in the container, then water bin for collection of sediment deposited there (erosion). The calculation of the rate of erosion can be known through a series of laboratory tests using a rainfall simulator aid, in addition to the magnitude of the erosion rate can be calculated using equation 1. Comparison between test results and calculations based on various parameters will be included in equation 1 as follows; Total erosion rate (E) for the conditions of research and USLE models used unit g/m²/hour. Factors erosivitas rain (R), the value of R in the USLE equation as given in equation 5. Erosivitas (R) for the value of I₃₀, adapted to the respective intensity values, this means that the value of I₃₀ were used in USLE models is equal to the variation

of each rain intensity. Soil erodibility (K), based on the USCS classification system into groups classified into types of SP or poorly graded sand with a K value of 0.650. Slope length factor (LS) is obtained by using equations 6 and 7 to be used 1.0 m, L equals the length of the sample. While the value of S used 10°, 20° and 30° in accordance with the slope in this research. So the value of LS for a slope of 10° is 0.599, the value for the LS 20° slope is 1.966 and the value of LS for 30° slope is 3.956. Vegetation management factor (C) is used land without vegetation so that the value of C = 1 factor is the implementation of erosion control (P) is assumed to be ground without erosion control measures, so that the value of P = 1 This is the same as the intensity of eroded soil, slope and density without any effort to reduce erosion.

4.2. Discussion of Results.

In Figure 1, Figure 2 and Table 1 (I₁₂₀, S₁₀), (I₁₂₀, S₂₀), (I₁₀₀, S₃₀) and (I₁₂₀, S₃₀) is seen that the results of the calculation of the rate of erosion by USLE equation is smaller than the rate of soil erosion research original. The average difference in the rate of erosion of research results to the rate of erosion by USLE is equal to 13,173%. This is caused by the calculation of the rate of erosion by USLE based on the average annual erosion. Rain erosivitas Index (R) is calculated based on the amount of annual rainfall is not evenly distributed throughout the year. While in this study erosivitas rain index (R) was calculated based on a fixed rainfall intensity during erosion testing. In Table 1, it appears also that the rate of soil erosion at a given layer of cover in the form of rice straw fiber with 30% closing percentage has decreased when compared to the rate of soil erosion that occurs in the original. The magnitude of the rate of erosion that occurred in the percentage cover of 30% on average by 17.68% of the rate of erosion on native soil, in other words the rate of erosion on native soil will be reduced by an average of 82.932% if the land is given a cover layer of rice straw fiber the percentage cover of 30%. The results of this study have confirmed the results of the study by Leila Ghomalia, Hamidrez * a and Mehdi Sadeghi Homaeab (2012) by using straw mulch can reduce the erosion rate of 63.24%.

Table 1. The results of the model USLE erosion rates and the results of research

Experimental Model (EM)	USLE Model (gr/m ² /jam)	RESULT OF RESEARCH						
		NATIVE SOIL (gr/m ² /jam)	HORIZONTAL			VERTICAL		
			30%	60%	90%	30%	60%	90%
		(gr/m ² /jam)	(gr/m ² /jam)	(gr/m ² /jam)	(gr/m ² /jam)	(gr/m ² /jam)	(gr/m ² /jam)	(gr/m ² /jam)
EM ₁ (S ₁₀ , I ₅₀)	14,030	4,100	0,75	0,400	0,150	0,450	0,150	0,100
EM ₄ (S ₂₀ , I ₅₀)	15,783	15,350	1,05	0,500	0,200	0,550	0,250	0,150
EM ₇ (S ₃₀ , I ₅₀)	17,537	39,250	1,75	0,900	0,250	1,000	0,800	0,200
EM ₂ (S ₁₀ , I ₁₀₀)	30,087	5,650	2,45	1,100	0,900	1,200	1,000	0,300
EM ₅ (S ₂₀ , I ₁₀₀)	33,848	24,800	3,05	1,650	1,000	1,250	1,500	0,350
EM ₈ (S ₃₀ , I ₁₀₀)	37,609	54,150	5,90	1,750	1,650	5,400	1,650	0,450
EM ₃ (S ₁₀ , I ₁₂₀)	36,666	35,608	6,15	2,900	1,750	3,050	1,200	0,600
EM ₆ (S ₂₀ , I ₁₂₀)	41,250	53,500	9,40	3,200	1,850	3,500	3,100	1,350
EM ₉ (S ₃₀ , I ₁₂₀)	45,833	94,150	21,30	5,800	2,400	9,850	4,950	2,100

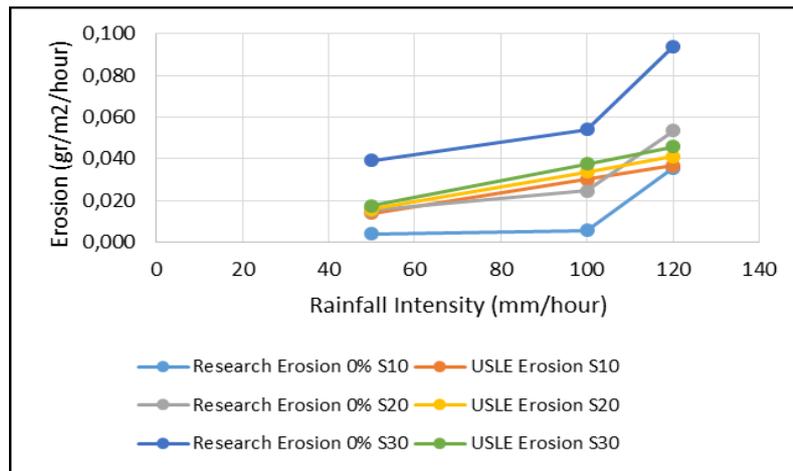


Figure 1. Graph – comparison of erosion between USLE model and research on native soil

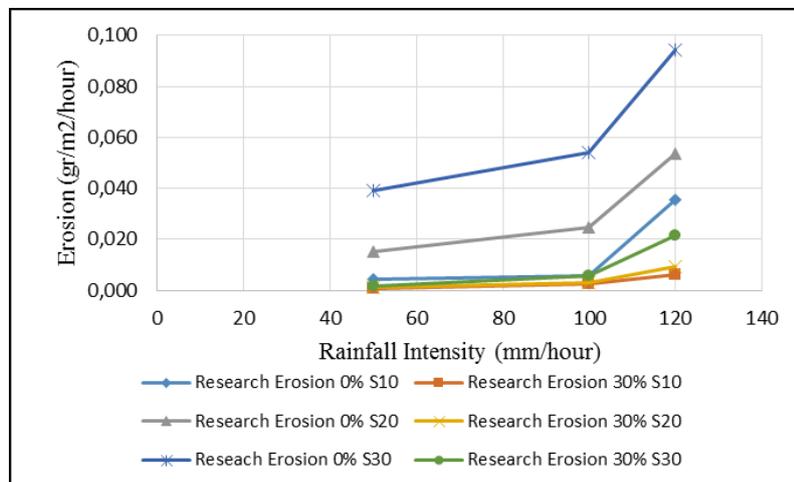


Figure 2. Graph – comparison of erosion between research on native soil and research with 30% closure of fiber straw

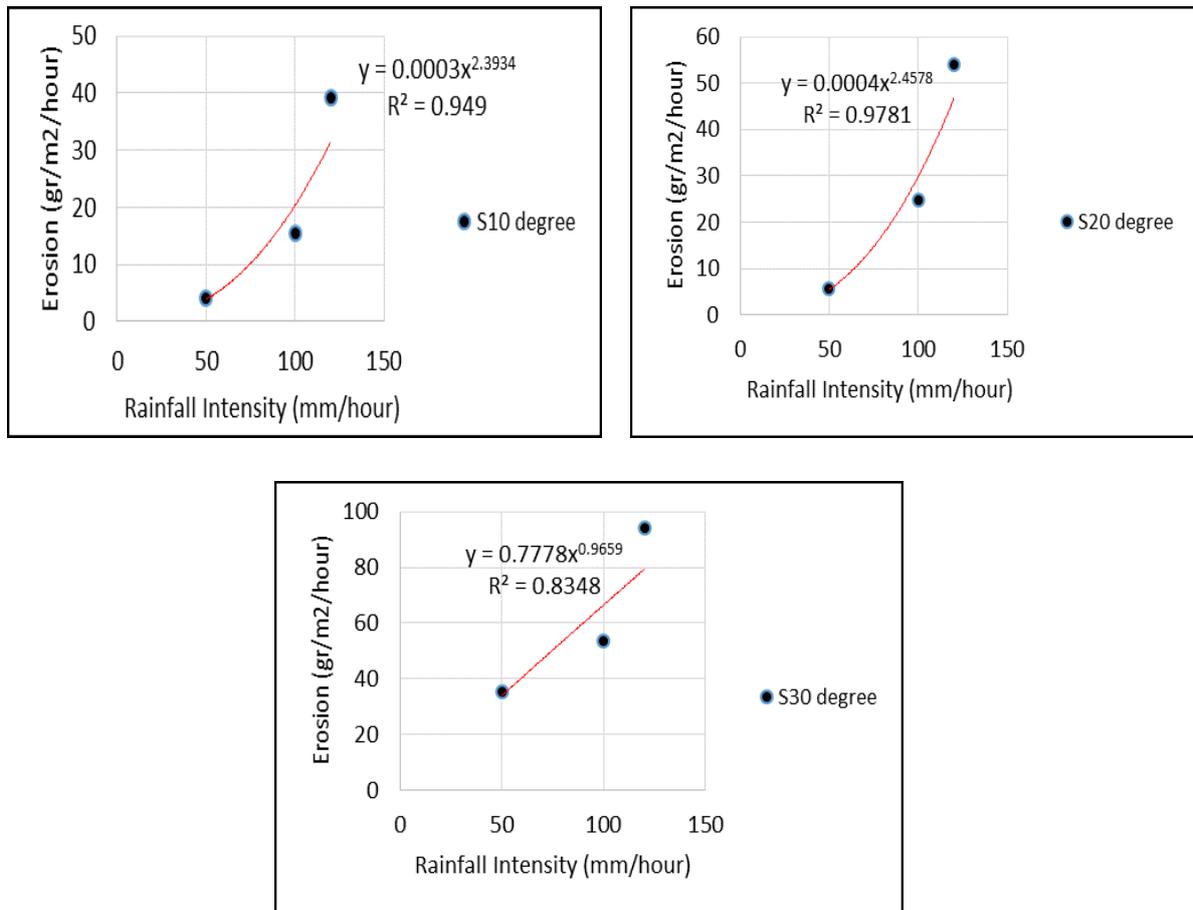
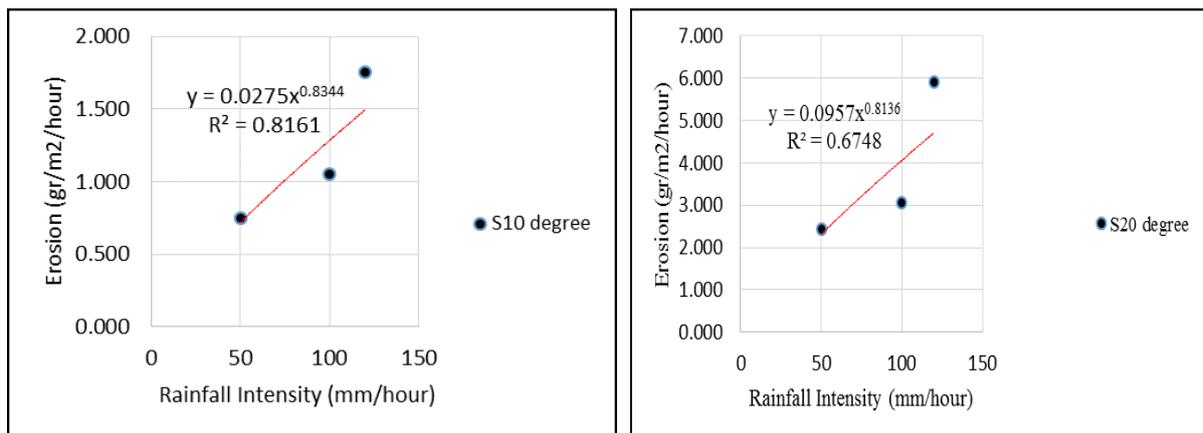


Figure 3. The graph between the rate of erosion by rainfall intensity on a slope of 10, 20 and 30 degrees on native soil



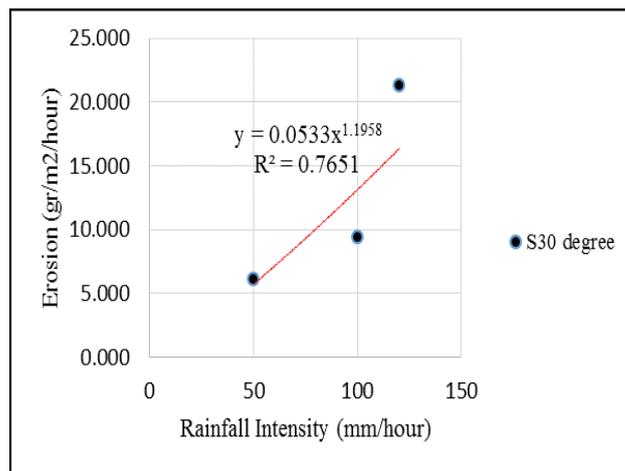


Figure 4. The graph between the rate of erosion by rainfall intensity on a slope of 10, 20 and 30 degrees on the ground with the closure of 30%

From Figure 3 and Figure 4 it appears that in general the rate of erosion increased with increasing rainfall intensity. The increase in the rate of erosion is likely to increase and this provides information that strongly influences the intensity of rain erosion. Of the control level according to the calculation of the correlation coefficient (R) sternyata regression equation gives a fairly good representation of the data of this study deskrip. It is characterized by the value of R which is almost close to 1 Results of the analysis of the original land for the determination of the rate of erosion due to changes in rainfall intensity I_{50} , I_{100} and I_{120} with a slope of 10° , 20° and 30° is obtained: $E = 0,8197e^{0,0311(I)}$ and $R^2 = 0.979$, $E = 1,1264e^{0,0318(I)}$ and $R^2 = 0.9956$, $E = 17,845e^{0,0128(I)}$ and $R^2 = 0.8912$. Based on the analysis to the closure of 30% rice straw fiber obtained $E = 0,4109e^{0,0111(I)}$ and $R^2 = 0.8754$, $E = 1,3146e^{0,011(I)}$ and $R^2 = 0.7493$, $E = 2,5474e^{0,016(I)}$ and $R^2 = 0.8311$.

5. Conclusions and Suggestuion

5.1. Conclusions

From the discussion of the results of research and analysis the following conclusions can be drawn;

1. Effect of rainfall intensity and slope gradient on soil erosion rates are directly proportional. High rainfall intensity and the greater the slope will add great value to soil erosion.
2. The amount of erosion rate based treatment in the laboratory on successive rainfall intensity I_{50} , I_{100} and I_{120} at 10° slope is $E = 4.100$ grams/m²/hour, $E = 15,350$ grams/m²/hour and $E = 39,250$ grams/m²/hour. At 20° slope is $E =$

$5,650$ g/m²/h, $E = 24,800$ grams/m²/hour and $E = 54,150$ grams/m²/hour. And slope at 30° is $E = 35,608$ grams/m²/hour, $E = 53,500$ grams/m²/hour and $E = 94.150$ grams/m²/hour. For closing 30% of rice straw fiber row on I_{50} , I_{100} and I_{120} at 10° slope is $E = 0.750$ grams/m²/hour, $E = 1.050$ grams/m²/hour and $E = 1.750$ grams/m²/hour. At 20° slope, $E = 2,450$ grams/m²/hour, $E = 3,050$ grams/m²/hour and $E = 5,900$ grams/m²/hour. At 30° slope, $E = 6.150$ grams/m²/hour, $E = 9,400$ grams/m²/hour and $E = 21,300$ grams/m²/hour.

3. Based on the analysis on the original land for the determination of the rate of erosion due to changes in rainfall intensity I_{50} , I_{100} and I_{120} with a slope of 10° , 20° and 30° is obtained: $E = 0,8197e^{0,0311(I)}$, $E = 1,1264e^{0,0318(I)}$ and $E = 17,845e^{0,0128(I)}$. And based on the results of the analysis for the closure of 30% rice straw fiber obtained $E = 0,4109e^{0,0111(I)}$, $E = 1,3146e^{0,011(I)}$ and $E = 2,5474e^{0,016(I)}$.

5.2. Suggestion

1. For further research can be assessed by increasing the density variation.
2. It is recommended to use a cover with another straw fibers.
3. Future studies should be done in the field of applications to see how far the differences in the results obtained in the laboratory

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