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# MODELING OF THE EFFECT BY PADDY STRAW FIBERS ON THE COVER OF LAND SURFACE AS A SLOPE EROSION CONTROLLER

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## ABSTRACT

This research aims to the model of the effect by paddy straw fibers on the cover of land surface as a slope erosion controller. This research was tested in the laboratory by using USLE (Universal Soil Loss Equation) model as a comparison to determine the amount of the reduction of the erosion rate that occurs, both on the land without the covering or covering. Research conducted with 3 variations in the intensity of rain that is 50 mm/hour, 100 mm/hour and 120 mm/hour and use artificial rainfall with a Rainfall Simulator. The result of this research showed that the rate of erosion on soil that was given in the form of straw fibers covering layer of the paddy with the cover percentage is 30% dry weight or 38,7gr/$m^2$ had decreased when compared with the rate of erosion occurring on the ground without cover. The magnitude of the rate of erosion that occurred in the cover percentage is 30% dry weight of straw mulch or 38,7 gr/$m^2$averages of 17,068% against the rate of erosion on the ground without cover. In other words, that the rate of erosion on soil without cover will be reduced (decreased) by an average of 82,932% if the land is given a cover layer of paddy straw fibres with a percentage of 30% or cover a dry weight of 38,7 gr/$m^2$. Similarly, the rate of erosion on land given the paddy straw fibres cover layer with the cover percentage respectively 60% and 90% dry weight or each 145,1 gr/$m^2$ and 354,8 gr/$m^2$ also had decreased when compared with the rate of erosion occurring on the ground without cover. The magnitude of the rate of erosion that occurred on land given the cover 60% dry or heavy 145,1 gr/$m^2$ on average by 7,216% and 90% cover on a layer or severe drying 354,8 gr/$m^2$ on average by 4,392%. In other hands, the rate of erosion on soil without cover will be reduced (decreased) by an average of 92,784% on the cover of 60% and an average of 95,608% on the cover of 90%. On the rain intensity of 50 mm/hour, the erosion rate prediction equation that obtained is: $E = 3{,}0273488\ e^{-0{,}1191688(MJ/S)}$, On the rain intensity of 100 mm/hour, the erosion rate prediction equation that obtained is: $E = 6{,}4748371\ e^{-0{,}0824717(MJ/S)}$, and similarly, on the rain intensity of 120 mm/hour, the erosion rate prediction equation that obtained is: $E = 18{,}4374973\ e^{-0{,}0984739(MJ/S)}$.

**Keywords:** Paddy straw fibres, erosion rate, sloping erosion controller, intensity, rain, exponential 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 reduces 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; with in 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 occured (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 [1].

In Indonesia, rice straw has not been assessing 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 cropresidues 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, utilizationof 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 weather process takes a long time. However, if certain treated rice straw will accelerate the structural changes [2].

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 fibers, particularly soil in sloping lands.

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## 2. LITERATURE 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 [3].

Journal [4] suggested that the USLE model is adopting a number of factors and sub factors to estimate the soil loss. The equation for estimating the soil erosion rate (E) in tonnes/ha/year is;

$$E = R.K.LS.C.P \tag{1}$$

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/hour [5], as the following;

$$I = \frac{V}{A.t} \times 600 \tag{2}$$

With I = rain fall intensity (mm/hour), V = volume of water in the cup (ml), A = the total area of the cups ($cm^2$), t = time (minutes).

The Measurement of kinetic energy (Ek) in the rain joule/$m^2$/mm is conducted, as shown in Equation (3) [6], as the following;

$$E_k = 11,87+8,73\log I \tag{3}$$

with I = rainfall intensity (mm/hour).

For the tropical area [7] suggested to use equation 4, as the following;

$$Ek = 29,8 - \frac{127,5}{I} \tag{4}$$

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

The rain fall erosion index (R) is the ability of rainfall to initiate erosion, can be written in the form of equation 5 [8], as the following;

$$R = \frac{E_k.I_{30}}{100} \tag{5}$$

with $E_k$= Kinetic energy of the rain (Joule), $I_{30}$= Maximum intensity of the rain over 30 minutes.

Soil erodibility (K), based on the table of soil erodibility (K) [9] in which the results of soil classification by USCS classification system are categorized in to 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) [9], 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;

$$LS = \frac{65,41\, s^2 L'}{s^2 + 10.000} + \frac{4,56\, s L'}{(s^2+10.000)^{0,5}} + 0,065L' \tag{6}$$

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

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

with L = slope length in meters, m = 0,5 (slope, s ≥ 5%).

Based on previous research conducted by; 1). Studies [10], 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/hour; 2). Studies [11], 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/hour 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 gr/$m^2$ 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.

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### 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, compaction, specific gravity 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 m x 1,0 m x 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 [12], namely;

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

with W = mass of soil, V = volume of soil, $\gamma$ = wet unit weight and w = water content.

#### 3.3.3 Measurement of intensity

Before starting the study which was conducted with 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 ± 48 hours. Furthermore, the soil sample is placed in a cup, then dried using an oven for ± 24 hours.
b) Once dried and then weighed to obtain total weight.

## 4. RESULTS AND DISCUSSIONS

### 4.1 Results of research

#### 4.1.1 Soil test result

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 [9], 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 gr/cm$^3$ with a water content of 25,5%, while the weight of the contents of the field is obtained by 1,091 gr/cm$^3$. 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

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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/$m^2$/hour. Factors erosion of rain (R), the value of R in the USLE equation as given in equation 5. Erosion (R) for the value of $I_{30}$, adapted to the respective intensity values, this means that the value of $I_{30}$ 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 30º 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 DISCUSSIONS OF RESEARCH RESULTS

Based on the Table-1 ($I_{120}$,$S_{10}$), ($I_{120}$,$S_{20}$), ($I_{100}$,$S_{30}$) and ($I_{120}$,$S_{30}$) shown that the results of the erosion rate calculation according to the equation of USLE is smaller than the erosion rate research in the original soil. The average differences between the erosion rate research and the erosion rate by USLE is about 13,173%. This is caused of the erosion rate calculation by USLE is based on an average yearly erosion. Rain erosivity index (R) is calculated based on the amount of yearly precipitation is not evenly distributed all around the year. Whereas in this research erosivity rain index (R) is calculated based on a constant rain intensity during the test of erosion rate.

In Table-2, also seen that the erosion rate of soil which covered by paddy straw fibers with 30% covering percentage has decreased when compared to the erosion rate and occurs in the original soil. The average amount of erosion rate in the 30% covering percentage is about 17,68% to the erosion rate in the original soil, in other words mean the erosion rate in original soil will be reduced by an average of 82,932%, if the land is covered by paddy straw fibers in the 30% covering percentage. The results of this research have strengthened by the research results of studies [10] by using straw mulch we can reduce the erosion rate on about 63,24%.

**Table-1.**The results of erosion rate by USLE model and research results.

| Model | USLE | RESULT OF RESEARCH | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | NATIVE SOIL | HORIZONTAL | | | VERTIKAL | | |
| | (gr/m2/hour) | | 30% | 60% | 90% | 30% | 60% | 90% |
| | | (gr/m2/hour) | (gr/m2/hour) | (gr/m2/hour) | (gr/m2/hour) | (gr/m2/hour) | (gr/m2/hour) | (gr/m2/hour) |
| P1 ($S_{10}$ , $I_{50}$) | 14,030 | 4,100 | 0,75 | 0,400 | 0,150 | 0,450 | 0,150 | 0,100 |
| P4 ($S_{20}$ , $I_{50}$) | 15,783 | 15,350 | 1,05 | 0,500 | 0,200 | 0,550 | 0,250 | 0,150 |
| P7 ($S_{30}$, $I_{50}$) | 17,537 | 39,250 | 1,75 | 0,900 | 0,250 | 1,000 | 0,800 | 0,200 |
| P2 ($S_{10}$ , $I_{100}$) | 30,087 | 5,650 | 2,45 | 1,100 | 0,900 | 1,200 | 1,000 | 0,300 |
| P5 ($S_{20}$ , $I_{100}$) | 33,848 | 24,800 | 3,05 | 1,650 | 1,000 | 1,250 | 1,500 | 0,350 |
| P8 ($S_{30}$ , $I_{100}$) | 37,609 | 54,150 | 5,90 | 1,750 | 1,650 | 5,400 | 1,650 | 0,450 |
| P3 ($S_{10}$ , $I_{120}$) | 36,666 | 35,608 | 6,15 | 2,900 | 1,750 | 3,050 | 1,200 | 0,600 |
| P6 ($S_{20}$ , $I_{120}$) | 41,250 | 53,500 | 9,40 | 3,200 | 1,850 | 3,500 | 3,100 | 1,350 |
| P9 ($S_{30}$ , $I_{120}$) | 45,833 | 94,150 | 21,30 | 5,800 | 2,400 | 9,850 | 4,950 | 2,100 |

**Table-2.**The comparison of erosion rate between soil that covered with30% paddy straw fibers horizontally against erosion rate without covering.

| Rainfall Intensity | Slope | Erosion Rate (gr/m2/hour) | | % $E_0$ | % Reduction | Average |
|---|---|---|---|---|---|---|
| (mm/hour) | | $E_0$ | $E_{30H}$ | | | (%) |
| 50 | 10 | 4,100 | 0,750 | 18,293 | 81,707 | 82,932 |
| | 20 | 15,350 | 1,050 | 6,840 | 93,160 | |
| | 30 | 39,250 | 1,750 | 4,459 | 95,541 | |
| 100 | 10 | 5,650 | 2,450 | 43,363 | 56,637 | |
| | 20 | 24,800 | 3,050 | 12,298 | 87,702 | |
| | 30 | 54,150 | 5,900 | 10,896 | 89,104 | |
| 120 | 10 | 35,608 | 6,150 | 17,271 | 82,729 | |
| | 20 | 53,500 | 9,400 | 17,570 | 82,430 | |
| | 30 | 94,150 | 21,300 | 22,623 | 77,377 | |

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**Table-3.** The comparison of erosion rate between soil that covered with 60% paddy straw fibers horizontally against erosion rate without covering.

| Rainfall Intensity (mm/hour) | Slope | Erosion Rate (gr/m2/hour) $E_0$ | Erosion Rate (gr/m2/hour) $E_{60H}$ | % $E_0$ | % Reduction | Average (%) |
|---|---|---|---|---|---|---|
| 50 | 10 | 4,100 | 0,400 | 9,756 | 90,244 | 92,784 |
| | 20 | 15,350 | 0,500 | 3,257 | 96,743 | |
| | 30 | 39,250 | 0,900 | 2,293 | 97,707 | |
| 100 | 10 | 5,650 | 1,100 | 19,469 | 80,531 | |
| | 20 | 24,800 | 1,650 | 6,653 | 93,347 | |
| | 30 | 54,150 | 1,750 | 3,232 | 96,768 | |
| 120 | 10 | 35,608 | 2,900 | 8,144 | 91,856 | |
| | 20 | 53,500 | 3,200 | 5,981 | 94,019 | |
| | 30 | 94,150 | 5,800 | 6,160 | 93,840 | |

**Table-4.** The comparison of erosion rate between soil that covered with90% paddy straw fibers horizontally against erosion rate without covering.

| Rainfall Intensity (mm/hour) | Slope | Erosion Rate (gr/m2/hour) $E_0$ | Erosion Rate (gr/m2/hour) $E_{90H}$ | % $E_0$ | % Reduction | Average (%) |
|---|---|---|---|---|---|---|
| 50 | 10 | 4,100 | 0,150 | 3,659 | 96,341 | 95,608 |
| | 20 | 15,350 | 0,200 | 1,303 | 98,697 | |
| | 30 | 39,250 | 0,250 | 0,637 | 99,363 | |
| 100 | 10 | 5,650 | 0,900 | 15,929 | 84,071 | |
| | 20 | 24,800 | 1,000 | 4,032 | 95,968 | |
| | 30 | 54,150 | 1,650 | 3,047 | 96,953 | |
| 120 | 10 | 35,608 | 1,750 | 4,915 | 95,085 | |
| | 20 | 53,500 | 1,850 | 3,458 | 96,542 | |
| | 30 | 94,150 | 2,400 | 2,549 | 97,451 | |

Based on Table-2 until Table-4 shows a comparison of the erosion rate of soil which covered by paddy straw fibers with the cover percentage of 30%, 60%, and 90% against the soil without covering.

In Table-2 shows that the erosion rate of soil which covered by paddy straw fibers with a covering percentage of 30% or at dry weight of 38,7g/m$^2$ have decreased if compare to the erosion rate of soil without covering. The amount of erosion rate that occurs in the covering percentage of 30 % or at dry weight of straw mulch 38,7 gr/m$^2$ on average is about 17,068% against the erosion rate of soil without covering layer. Furthermore, the erosion rate of soil without covering will be reduced (decreased) on average of 82,932% if that soil is covered by paddy straw fibers with 30% covering percentage or at the dry weight of 38,7 gr/m$^2$.

The same case is shown in Table-3 and Table-4, the erosion rate in soil that covered by paddy straw fibers with covering percentage of 60% and 90% or at dry weight of each is 145,1 gr/m$^2$ and 354,8 gr/m$^2$ also having decreased if compared to the erosion rate of soil without covering layer. The amount of erosion rate that occurs in the covering percentage of 60% or at dry weight 145,1 gr/m2 on average is 7,216% and in the covering percentage of 90% or at dry weight 354,8 gr/m$^2$ on average is 4,392%. In other words, the erosion rate of soil without covering will be reduced (decreased) on average of 92,784% at 60% covered and on average of 95,608% at 90% covered. The results of this research have strengthened the research results of study [10] by using straw mulch we can reduce the erosion rate on about 63,24%.

In Figure-1 describe a graph of relation between the erosion rate with the covering percentage and rain fall intensity on each slope of 10$^o$, 20$^o$, and 30$^o$. This three graphs formed the regression equation which has the same tendency to follow the pattern of exponential and the coefficient of determination ($R^2$) that are approaching. The three regression equation is as below;

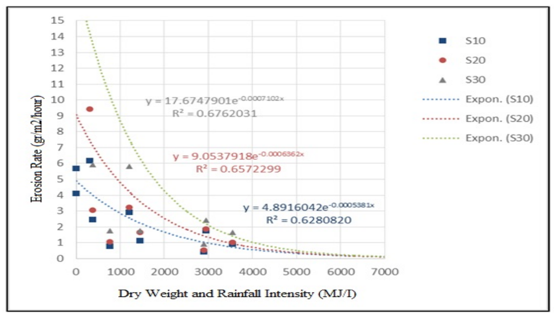


**Figure-1.** The relation of erosion rate with the covering percentage and dry weight and rain fall intensity.

On the slope of 10°, the erosion rate prediction equation that obtained is: $E = 4{,}8916042\ e^{-0,\ 0005381(MJ/I)}$, with requirement (MJ>0, I>0) in the wide area of observationis 1 m$^2$. The coefficient of determination ($R^2$) = 0.6280820 or R = 0.7925 (>0.60 and close to 1), this means that the ratio of covering percentage by paddy straw fibers with rainfall intensity has a strong influence to the erosion rate on slope of 10$^o$. From the relation graph shows that more bigger the covering percentage by paddy straw fibers and more smaller the rainfall intensity, the ratio of these two parameters will more larger and the erotion rate will more smaller. It will strengthens the hypothesis that the addition of the covering percentage by paddy straw fibers can reduce the erosion rate and the increasing of rainfall intensity can increase the erosion rate.

On the slope of 20°, the erosion rate prediction equation that obtained is: $E = 9{,}0537918\ e^{-0,\ 0006362(MJ/I)}$, with requirement (MJ>0, I>0) in the wide area of observation is 1 m$^2$. The coefficient of determination ($R^2$) = 0,6572299 or R = 0,8107 (>0.60 and close to 1), this means that the ratio of covering percentage by paddy straw fibers with rainfall intensity has a strong influence to the erosion rate on the slope of 20$^o$. From the relation graph shows that more bigger the covering percentage by paddy straw fibers and more smaller the rainfall intensity, the

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ratio of these two parameters will more larger and the erotion rate will more smaller. This will strengthens the hypothesis that the addition of the covering percentage by paddy straw fibers can reduce the erosion rate and the increasing of rainfall intensity can increase the erosion rate.

Similarly, on the slope of 30°, the erosion rate prediction equation that obtained is: 17,6747901 $e^{-0,0007102(MJ/I)}$, with requirement (MJ>0, I>0) in the wide area of observation is 1 $m^2$. The coefficient of determination ($R^2$) = 0,6762031 or R = 0,8223 (>0.60 and close to 1), this means that the ratio of covering percentage by paddy straw fibers with rainfall intensity has a strong influence to the erosion rate on the slope of 20°. From the relation graph shows that more bigger the covering percentage by paddy straw fibers and more smaller the rainfall intensity, the ratio of these two parameters will more larger and the erotion rate will more smaller. This will strengthen the hypothesis that the addition of the covering percentage by paddy straw fibers can reduce the erosion rate and the increasing of rainfall intensity can increase the erosion rate.

In Figure-2 describe a graph of relation between the erosion rate with the covering percentage and rainfall intensity on each intensity of 50 mm/hour, 100 mm/hour, and 120 mm/hour. This three graphs formed the regression equation which has the same tendency to follow the pattern of exponential and the coefficient of determination ($R^2$) that are approaching. The three regression equation is as below;

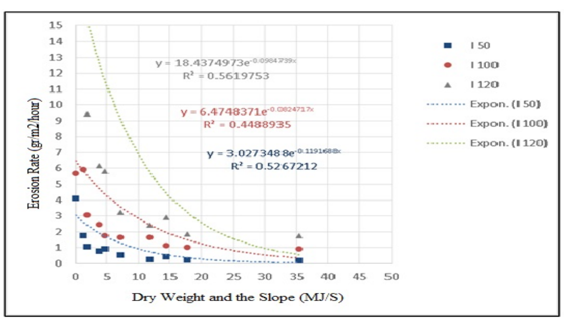


**Figure-2.**The relation of erosion rate with the covering percentage and dry weight and the slope.

On the rain intensity of 50 mm/hour, the erosion rate prediction equation that obtained is: E = 3,0273488 $e^{-0,1191688(MJ/S)}$, with requirement (MJ>0, I>0) in the wide area of observation is 1 $m^2$. The coefficient of determination ($R^2$) = 0,5267212 or R = 0,7257 (>0.60 and close to 1), this means that the ratio of covering percentage by paddy straw fibers with the slope has a strong influence to the erosion rate on the rain intensity of 50 mm/h. From the relation graph shows that more bigger the covering percentage by paddy straw fibers and more smaller the degree of slope, the ratio of these two parameters will more larger and the erotion rate will more smaller. This will strengthens the hypothesis that the addition of the covering percentage by paddy straw fibers can reduce the erosion rate and the increasing of slope degree can increase the erosion rate.

On the rain intensity of 100 mm/hour, the erosion rate prediction equation that obtained is: E = 6,4748371 $e^{-0,0824717(MJ/S)}$, with requirement (MJ>0, I>0) in the wide area of observation is 1 $m^2$. The coefficient of determination ($R^2$) = 0,4488935 or R = 0,6699 (>0.60 and close to 1), this means that the ratio of covering percentage by paddy straw fibers with the slope has a strong influence to the erosion rate on the rain intensity of 100 mm/h. From the relation graph shows that more bigger the covering percentage by paddy straw fibers and more smaller the degree of slope, the ratio of these two parameters will more larger and the erotion rate will more smaller. This will strengthens the hypothesis that the addition of the covering percentage by paddy straw fibers can reduce the erosion rate and the increasing of slope degree can increase the erosion rate.

Similarly, on the rain intensity of 120 mm/hour, the erosion rate prediction equation that obtained is: E = 18,4374973 $e^{-0,0984739(MJ/S)}$, with requirement (MJ>0, I>0) in the wide area of observation is 1 $m^2$. The coefficient of determination ($R^2$) = 0,5619753 or R = 0,7496 (>0.60 and close to 1), this means that the ratio of covering percentage by paddy straw fibers with the slope has a strong influence to the erosion rate on the rain intensity of 120 mm/h. From the relation graph shows that more bigger the covering percentage by paddy straw fibers and more smaller the degree of slope, the ratio of these two parameters will more larger and the erotion rate will more smaller. This will strengthens the hypothesis that the addition of the covering percentage by paddy straw fibers can reduce the erosion rate and the increasing of slope degree can increase the erosion rate.

Whereas the regression analysis between the erosion rate (E) with the ratio of the covering percentage with dry weight and multiplication between the rainfall intensity and the slope ($\frac{MJ}{I.S}$) on all levels of slope shown in Figure-3 below:

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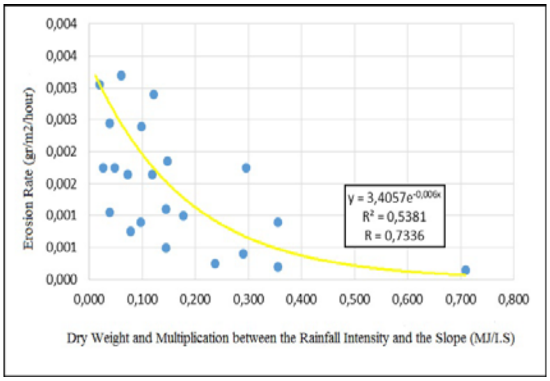


**Figure-3.**The relation of erosion rate by the ratio between the covering percentage with dry weight and multiplication between the rainfall intensity and the slope.

In Figure-3, describe the functional relation between the erosion rate by the ratio between the covering percentage with dry weight and multiplication between the rainfall intensity and the slope on all levels of slope and rainfall intensity. This composite graph also follow the trend i.e. the pattern of exponential with the form of regression equation from the erosion rate to the ratio of covering percentage by paddy straw fibers with the rainfall intensity is: $E = 3,4057e^{-0,006(MJ/I.S)}$, with requirement (MJ>0, I>0, S>0) in the wide area of observationis 1 $m^2$. The coefficient of determination ($R^2$) = 0,5381 or R = 0,7336 (>0.60 and close to 1), this means that the ratio of covering percentage with dry weight and multiplication between the rainfall intensity and the slope, strongly correlated to the erosion rate on every degree of slope and rainfall intensity. From therelation graph shows more bigger the covering percentage by paddy straw fibers, more smaller the rainfall intensity and/or the degree of slope, the ratio of these three parameters will more larger and the erotion rate will more smaller. This will strengthens the hypothesis that the addition of the covering percentage by paddy straw fibers can reduce the erosion rate and theincreasing of rainfall intensity and/or slope degree can increase the erosion rate.

If we compare between the three models of erosion rate which generated in Figure-1 and Figure-2 with the model of erosion rate which generated in Figure-3 can be learned at least two things; (1) The model of $E = 3, 4057e^{-0,006(MJ/I.S)}$, is more general and can be used on any level of slope and rainfall intensity, but the results are less thorough than the first and second six models. Based on that, can be seen from the coefficient of determination is smaller than the coefficient of determination from the first model. (2) The model of $E = 4,8916042\ e^{-0,0005381(MJ/I)}$, $E = 9,0537918\ e^{-0,0006362(MJ/I)}$, and $E = 17,6747901\ e^{-0,0007102(MJ/I)}$, this three models is most appropriate to used in each slope degree of 10°, 20° and 30° or on degree of slopes which approaching these third-degree slope above. (3) the model of $E = 3,0273488\ e^{-0,1191688(MJ/S)}$, $E = 6,4748371\ e^{-0,0824717(MJ/S)}$, and $E = 18,4374973\ e^{-0,0984739(MJ/S)}$, this three models is most appropriate to use in each level of rainfall intensity of 50 mm/h and 120 mm/h, except on the rainfall intensity of 100 mm/h which has a coefficient of determination (R) is smaller than the coefficient of determination (R) from the ratio of the erosion rate to the covering percentage with dry weight and mutiplication between the rainfall intensity and the slope ($\frac{MJ}{I.S}$).

## 5. CONCLUSIONS AND SUGGESTIONS

### 5.1 Conclusions

From the discussion and analysis of research results can be concluded as belows;

a) The effects of paddy straw fibers as a cover of land surface against the erosion rate in sloping land with covering percentage of each 30%, 60% and 90% or at dry weight of each 38,7 gr/$m^2$, 145,1 gr/$m^2$, and 354,8 gr/$m^2$ have decreased if compared to the erosion rate that occur in the land without covering.
b) The erosion rate of soil which covered by paddy straw fibers shows a tendency to decrease together with the increasing of covering percentage by paddy straw fibers.
c) The effects of rain intensity and the slope against the erosion rate is directly proportional. High rain intensity and high value of slope will be increase the erosion rate.

### 5.2 Suggestion

a) For further research can be assessed by increasing the density variation.
b) It is recommended to use a cover with another straw fiber.
c) 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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