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Abstract For the first time, this experimental research analyzed the efficacy of rice straw fiber as soil cover in controlling slope erosion using a physical model. Three variations of rainfall intensity, soil slope degree, and rice straw fiber were conducted in this research. The results showed that rice straw fiber in the physical model had reduced the amount of erosion significantly. In general, a higher erosion rate was obtained with the increases of rainfall intensity and soil slope degree. The experiment was conducted with the percentage 30%, 60%, and 90% of soil cover using rice fiber straw, reducing erosion rates by 92.09%, 95.55%, and 98.21 %, respectively. Therefore, the higher the percentage of rice straw fiber used as soil cover, the smaller the ground will be affected by erosion. The ratio from the soil affected by erosion was 7.91%, 4.45%, and 1.79%, respectively. The result reveals that there is a significant decrease in erosion due to the increase of fiber used in the experiments. Meanwhile, the amount of erosion in the physical model without soil cover was 98.21% for the same rainfall severity and soil slope degree. This research showed that the application of rice straw fiber as a soil surface shield is highly effective in controlling slope erosion.

Keywords Experimental Research, Rainfall Intensity, Rice Straw Fiber, Slope Degree, Soil Erosion Control

1. Introduction

Soil erosion is an environmental concern that leads to diminishing soil fertility and sedimentation of reservoirs, and it has become a critical problem worldwide, particularly in tropical countries. It has affected over 20 million km^2 of agricultural land globally. The rate is primarily high in developing countries due to increased demand for agricultural land and the increase in deforestation activities [1]. Soil erosion is a process where the soil top layer is moved during the rainfall and runoff events [2, 3]. Besides rainfall intensity, other natural factors such as land cover and soil slope degree may also affect the rate of soil erosion [4, 5-9]. To restrain the soil erosion, several methods have been employed, such as the use of vegetation [10], terracing [11], and soil cover [12].

Researchers have shown that when there is no vegetation available for covering the land, mulches can be applied as soil erosion control due to their capability to maintain the land surface from erosive forces of runoff and precipitation (e.g. [1, 10, 13 - 16]. Several types of mulches (i.e., pine needles, wood, olive, and vegetable residues) have been examined to investigate their potential to maintain and rectify soil quality against erosion. For example, Cerdà and Doerr [10] investigate the land cover effect (i.e., ash and needle) on the rate of erosion and runoff after a wood wildfire in Aleppo, Eastern Spain. They found that the combination of ash and needle cast effectively reduces the soil slope responses to erosion and runoff.

Furthermore, García-Orenes et al., [13] also perform a field-scale experiment. Their study purpose is to examine the effects of straw on some physical and chemical soil characteristics (i.e., soil erosion, soil protein and carbohydrates, soil stability, and total carbon) at the El Teularet-Sierra de Enguera Experimental Station, Spain, by using five years period of data from various agricultural activities. They found that the application of straw as a land cover may increase the soil quality and reduce soil vulnerability to erosion.

Another research study from Prats et al., [14] examined the effectiveness of a type of (i.e., forest residue) widely available in their study area to protect soil quality. They showed that successful decreasing soil losses evidence the straw and runoff coefficient from 5.4 to 0.7 mg/ha and 26 to 15%, respectively. Moreover, Moreno-Ramón et al., [1] conducted an experimental rainfall by designing a greenhouse with 48 cases. They used coffee husks as the main ingredient to control soil erosion and runoff and revealed that coffee husks effectively manage the rate of soil and water loss. However, they cannot completely protect against the effects of crust.

Based on the previous literature related to soil conservation by utilizing straw, it is noticed that there are a few publications available that explore the efficacy of rice straw as a soil coat to control landslides. For example, Adams [17] examines the impact of rice straw on a landslide, soil moisture decimation, and runoff found that the rice straw could decrease the magnitude of runoff and soil erosion. He reports that runoff and erosion from the covered surface plots were lowered by 1% relative to the uncovered surface plots. Likewise, Khan et al. [18] investigate the rice straw as a land cover to control soil erosion by conducting laboratory experiments. Their findings show that the rate of soil erosion was considerably decreased by increasing the rice straw portion, where runoff and soil loss were reduced by 56% and 96%, respectively, with 100% cover showed in their result.

Another study from Sadeghi et al. [19] also explores the scale model effect in controlling the landslide and runoff with rice straw as a land cover under controlled laboratory conditions. They find that rice straw had a significant influence on lessening the soil erosion and runoff on the coefficient of a 0.25 m^2 plot scale than the 6 m^2. Even though some researchers have begun exploring the possibility of rice straw as a soil protector, none of the research exists yet to examine the applicability of the fiber of the rice straw as a land cover in controlling soil erosion.

Therefore, we propose utilizing rice straw fiber (RSF) as the primary material in this research. We collect our material, the eroded soil, from Parangloe Manuju, Manuju Village, sub-district of Manuju, district of Gowa, province of South Sulawesi, Indonesia, where the area is included in the category of very heavy erosion based on the Erosion Hazard Map (PBE/*Peta Bahaya Erosi*) acquired from the Watershed Management Agency (BPDAS/*Balai Pengelolaan Daerah Aliran Sungai*) Jeneberang-Walanae.

Following a study from Prinz et al. [20] and Darvishan et al., [21], in the current research, a laboratory rainfall simulator experiment was conducted to control hydrological conditions involved in the recent study. Thus, we perform experimental laboratory research at Hydraulic Laboratory, Civil Engineering Department, Politeknik Negeri Ujung Pandang, Indonesia. The objective of the experimental research is to analyze the efficacy of rice straw fiber as a soil cover to control slope erosion by simulating rainfall at specific rainfall intensities and slope conditions.

Besides, surveying and identifying have been conducted to check the soil samples by squeezing with the fingers to determine the color of the soil samples visually. Furthermore, we also have interviews with the local community nearby the area to robust our data collecting. Moreover, the sampling of rice straw was collected from Bila village, district of Dua Pitue, Regency of Sidrap, Province of South Sulawesi, Indonesia. Our result will be shown in the result section.

The rest of the paper is organized as follows. Section 2 is the materials and methods. Section 3 is the result and discussion. Section 4 is conclusions.

2. Materials and Methods

The study was conducted by utilizing a100 x 100 x 50 cm square sample of soil box made of wood, where 100 x 100 cm^2 area is observed using Rayleigh's method of dimension analysis [22], which followed the size of the soil box from a research study by Chul Hee Won et.al., [23]. At the bottom of each of the soil sample boxes, a hole is made to let the water infiltrate into the soil layer, which will then be transported to a container. A 3-inch Poly Vinyl Chloride (PVC) pipe was attached to the downstream side of sample boxes to collect water and eroded soil obtained during the experiment.

A layer of rice straw fiber is spread out over the top of the soil sample with a specific thickness using three portions of rice straw fiber (RSF [%]) such as 30%, 60%, and 90%. These portions were determined using the graph by Arsyad [24] showing the relation of soil cover percentage to the dry weight.

2.1. Main Material

The primary of object material that used in this experiment is the eroded soil. The location of collecting the primary material is at Manuju Village, which is included as the critical land area (i.e., vulnerable to soil erosion) [25]. According to the Erosion Hazard Map (PBE/ Peta Bahaya Erosi) Watershed Management Agency of Jeneberang, this area was under very heavy erosion. The determination of soil sampling location was carried out using the Global

Positioning System (GPS), where the result of coordinate measuring showed 5^{o}17'11,40" S and 119^{o}40'41,90" E. Furthermore, the result was input into the Erosion Hazard Map to confirm whether the sampling location was included in the erosion-prone area with a size area of 121,732 ha.

After determining the location of sampling data collection, we survey and identify the soil samples where visually the sample color is reddish-brown where the local people around the area called it "Red Sand." Whereas, the sampling of rice straw was collected from Bila village, district of Dua Pitue, Regency of Sidrap, Province of South Sulawesi, Indonesia.

Before conducting the simulation, the sample was dried in an oven within one day. After the drying treatment finished, leaves, midribs, and fibers (stems) were separated. Then the fibers were taken (stems) for further analysis as the fiber of rice straw is the main material in this research. Furthermore, the fiber (stem) is cut into the bottom of the hump of rice straw until the length and the weight matches the study's criteria. The size of the fiber length is between 20-25 cm and the weight at the closing percentage of 30%, 60% and 90%, obtained respectively 38.7 gr/m^2, 145.1 gr/m^2, 354.8 gr / m^2. After completing the simulation in the laboratory, both samples without the cover layer (undisturbed soil), with the cover layer of RSF, and chemical properties were tested at the Microstructure Laboratory in Universitas Negeri Makassar.

2.2. Research Implementation

2.2.1. The erosion Rate Prediction with USLE Model

The prediction of landslide rate is limited by topography/geology factors, vegetation, and meteorology. There are some limitations in determining the erosion rate for some places. However, Wiecshmeier and Smith [26] develop a way to predict the erosion rate using a Mathematical equation known as the USLE equation, as follows:

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

with R denotes the erosivity index of rain and surface flow (EI), K denotes the soil erodibility index, LS denotes the slope length index, C represents the landcover crops index and management, and P denotes the practical conservation treatment index.

2.2.2. Standard of the Observation Area

Rayleigh's dimension analysis method is used to analyze the dimensionless parameter. According to Rayleigh's method procedures, according to [22], Rayleigh's method procedures are: 1) Writing the relation of function with all influencing variables; 2) Formulate equation where variables are exponent with a, b, c,… etc.; 3) formulate the equation by writing all variables in primary dimension forms (M, L, T); 4) calculating the exponential value of a, b, c… by solving equations formed simultaneously, and 5) substituting the obtained exponential value into the central equation.

As for the obtained result, it will indicate that parameters influencing the amount of erosion rate E (gr/m2/h) are rainfall intensity I (mm/h), hillside slope S (% or tan a, dimensionless), RSF dry weight (gr/m2), and the observed area A (m2). Below here is Rayleigh's analysis dimension method:

$$E = f(I, S, RSF, A) \tag{2}$$

If the function has form as follow:

$$E = kI^{a} S^{0} (RSF)^{b} A^{c} \tag{3}$$

With k is a dimensionless constant. If all variables are written down in dimension forms, then:

$$ML^{-2}T = k(LT^{-1})^{a} S(ML^{-2})^{b} (L^{2})^{c} \tag{4}$$

Value of a, b, dan c is obtained by equalizing exponent (M, L, T) in both segments, which is as followed:

$$M: 1 = b, L: -2 = a - 2b + 2c, T: 1 = -a$$

From mentioned analysis, it is obtained that functional relation among erosion rate, rainfall intensity, hillside slope, covering percentage with rice straw fiber dry weight and observed area, and is stated as follows:

$$E = k(RSF / \sqrt{A}) / I.S \tag{5}$$

Where: E = Erosion Rate (gram/m/h), I = Rainfall Intensity (m/h), A = Observed Area (1 m^2), RSF = Rice Straw fiber dry weight (gr/m^2), S = Hillside slope (^{0}), and k = constant

According to the written formulation of relation, a dimensionless parameter can be made among rainfall intensity erosion rate, hillside slope, and cover percentage with rice straw dry weight, so that an equation is obtained as follows:

$$E = k(RSF / I.S) \tag{6}$$

2.2.3. Testing Standard

Testing standard of soil physical and mechanical properties is using ASTM standard [27], as stated in Table 1, as follows:

Table 1. Standard in Soil Testing

No.	Type of Testing Method	No. Standard ASTM
1	Mesh Filter Analysis	C - 136 - 06
2	Atterberg Limit	
	Plastic Limit (PL)	D - 424 - 74
	Liquid Limit (LL)	D - 423 - 66
	Plasticity Index (PI)	D - 4318 -10
3	Soil Specific Gravity (G_s)	C - 127 - 04
4	Wet Weight (γ_{sat})	D - 2216 - 98
5	Water Content (w)	D - 2216 - 98
6	Dry weight (γ_{dry})	D - 854 - 72
7	Pore number (e)	D - 854 - 72
8	Porosity (n)	C - 642 - 97
9	Degree of saturation (S_r)	D - 854 - 72
10	Compressive strength (q_u)	D - 2166 - 00
11	Cohesion (c)	E - 736 - 00
12	Inner Sliding Angle (ϕ)	D - 3080 - 70
13	Permeability Coefficient (k)	D - 2434 - 68
14	Laboratorium Density	D - 1557 - 02
15	Optimum Water Content (W_{opt})	D - 1557

2.2.4. Soil Physical and Mechanical Properties Test

The physical and mechanical properties of the soil were tested according to the test standards, as shown in Table 1. For soil preparation, the soil material was dried in an oven for one day, and the soil grains were crushed. Furthermore, the soil is mixed with water and then put into a sample box that has been prepared following the required volume, then leveled and compacted with a standard compaction system with a drop height of 60 cm. In this experiment, a total of 1120 collisions were given to reach the desired thickness, which is 10 cm per layer of soil sample. This treatment is carried out until it comes the maximum degree of soil density.

2.2.5. Measurement of Soil Density

Determination of soil density percentage either based on soil condition in the field or based on soil condition in the laboratory is obtained [28], i.e.

$$D = \frac{\gamma_{dry} lap}{\gamma_{dry} lab} \times 100\% \quad (7)$$

where: D = Soil density percentage (%), $\gamma_{dry} lap$ = dry soil density in the field (gr/cm^3), and $\gamma_{dry} lab$ = dry soil density in the laboratory (gr/cm^3)

2.2.6. Undisturbed Soil Types and Rice Straw Fibers Chemical Properties Test

The testing procedure for soil investigation, especially the chemical properties of the original soil type and rice straw fiber, was carried out using SEM (Scanning Electron Microscope) and EDX (Energy Disperse X-Ray) photo testing. The types of testing are as follows: 1.) To find out the chemical elements contained in the kind of undisturbed soil and rice straw fibers, such as elements of Oxygen (O_2), Silica (Si), Aluminum (Al), Magnesium, Potassium, Calcium, Fluorine, Chlorine, Titanium, and Iron. 2.) To find out the chemical reaction process between these elements, so that chemical compounds are formed as; Silica (SiO_2), Aluminum Oxide (Al_2O_3), Sodium Oxide (Na_2O), Magnesium Oxide (MgO), Potassium Oxide (K_2O), Calcium Oxide (CaO), Titanium Oxide (TiO_2), and Peroxide (FeO).

2.2.7. Rainfall Intensity Measurement

Before the commencement of the soil erosion test, the rainfall simulator was firstly calibrated to guarantee the rainfall intensity's magnitude (I [L/T]) to be applied (i.e., 10, 20, and 40 mm/h). The schematic picture of the rainfall simulator and its peripherals used in this study are shown in Figure. 1a to 1c. Rainfall intensity was controlled based on the size of the aperture of the disc, the rotation of the disc, and the pump pressure's magnitude. In the experiment, a tilt-adjusting device was used to regulate the soil slope degree (S [°]) at 10°, 20°, and 30° based on the area each with slope level such as sloping slope, slightly steep and steep, [29], was placed inside the rainfall simulator. Then five containers with 7.5 cm of diameter were positioned above the device, one in the middle and two on the right and left sides (see Figure. 1c). In conducting rainfall simulation, the first step was to cover the containers not to be loaded with rainwater. Before the rainfall simulator was switched on, the cover of the containers was removed, and the time was measured. Subsequently, after 10 minutes, the containers were immediately closed. The rainwater in the containers was measured. Since the rainwater volume and time are recorded, therefore, the intensity of rainfall can be calculated.

Rainfall Intensity Measurement is obtained from several experiments using "Rainfall Simulator" equipment/ instrument by setting some combinations of the disc's aperture, the disc's rotation, and the pump pressure's magnitude. Thus, the rainfall intensity level desired can be obtained. As a given rainfall intensity measurement in this research has amounted to 10 mm/h, 20 mm/h, and 40 mm/h according to rainfall condition and intensity representing each other; normal rain, heavy rain, and very heavy rain [30]. Table 2 shows the result of the rainfall intensity measurement.

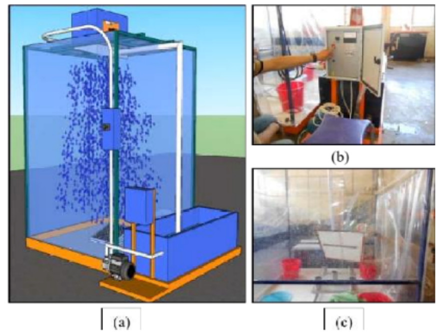

Figure 1. (a) Illustration of rainfall simulator, (b) pump pressure regulator, and (c) placement of containers

Table 2. Rainfall Intensity Measurement

No.	Variation		Volume Container (Q) V Cont 1 (Ml)	V Cont 2 (ml)	V Cont 3 (ml)	V Cont 4 (ml)	V Cont 5 (Ml)
1	Disc Aperture (°)	10	84	42	30	3	10
	Disc Rotation (rpm)	75					
	Pump Pressure (bar)	0.3					
2	Disc Aperture (°)	15	107	84	96	32	20
	Disc Rotation (rpm)	60					
	Pump Pressure (bar)	0.15					
3	Disc Aperture (°)	15	146	36	86	80	58
	Disc Rotation (rpm)	70					
	Pump Pressure (bar)	0.3					

	Variation		Cont. Area A (cm^2)	Period t (min)	Intensity I (mm/h)	Uniformity Coefficient (Cu)
1	Disc Aperture (°)	10	40.7	10	10	30.888
	Disc Rotation (rpm)	75				
	Pump Pressure (bar)	0.3				
2	Disc Aperture (°)	15	40.7	10	20	50.678
	Disc Rotation (rpm)	60				
	Pump Pressure (bar)	0.15				
3	Disc Aperture (°)	15	40.7	10	40	65.714
	Disc Rotation (rpm)	70				
	Pump Pressure (bar)	0.3				

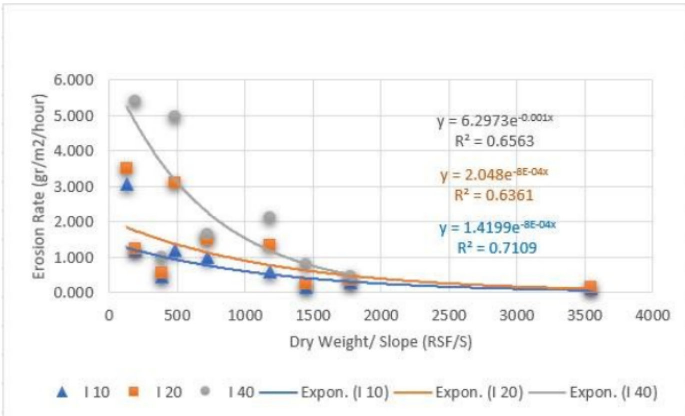

Figure 14. Relation of Erosion Rate toward Ratio of Covering Percentage compared to RSF dry density and Hillside Slope (S)

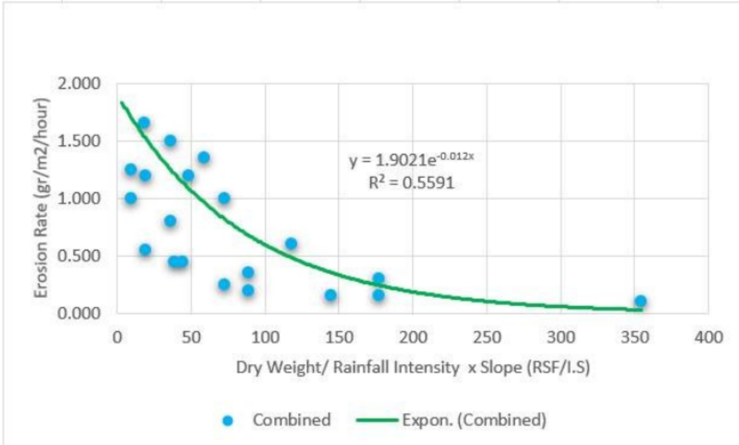

Figure 15. The Relation of Erosion Rate with Proportion between Covering Percentage and RSF dry density, toward the multiplication of Rainfall Intensity and Hillside Slope (S)

3.2. Discussion

3.2.1. The Experiment of Undisturbed Soil Physical and Mechanical Properties

According to the soil physical and mechanical properties (Table 3) with sieve analysis test and gradation curve (ASTM C-136-06) of the soil sample, Coarse Fraction percentage is 98.03 % and Fine Fraction percentage is 1.97 %. According to USCS (Unified Soil Classification System), the soil sample Coarse Fraction percentage (98.03 %) > 50 % and Fine Fraction percentage (1.97 %) < 5 %. Therefore, this soil is included as Sand Poor Graded, SP, or sand-gravel-silt mixture. Moreover, according to Casagrande plasticity diagram [31], with liquid limit (LL) = 54.16 % and plasticity index (PI)= 14.96 %, then the soil is classified into MH dan OH. It resulted that the sample is categorized as "silty sand soil" with less plasticity. For the level of density in the laboratory, either Standard Proctor or Modified Proctor is carried out. The principal of this compaction is to mix an amount of soil with water to gain a purposed compaction level. After reaching optimum water content, maximum dry density value will be gained. According to this result, it will be used as a base to determine density degree. In this research, the soil density degree used is 89.061%. The dry density in the field (γdry) amounted to 1.091 gr/cm3 divided by dry density in Laboratory (γdry) amounted to 1.225 gr/cm3 and then percentage as shown in Eq. 7.

3.2.2. The Experiment of Undisturbed Soil Chemical Properties

According to Figure 3, 4, and 5 from the undisturbed soil chemical properties experiment (without coverage layer) using SEM and EDX photo test, the results are in Table 4. Table 4 robust the investigation results toward chemical elements contained in the soil. The chemical compounds are formed through the chemical reaction process between the elements, as shown in Table 4. This result revealed that the undisturbed soil without covering layer contains the highest chemical compound; Silica Oxide (SiO_2), which amounted to 38.73%, showing eroded soil sample as silty sand soil, according to Casagrande plasticity diagram [31]. This soil is included in silica sand as the high-concentrated content is silica. This silica sand consists of some mineral particle granules and rocks. However, some of this sand granule consists of other components like Aluminium (Al) = 17.71%, Feldspar dan Iron 15.36%.

3.2.3. Experimentation of Undisturbed Soil Chemical Properties

According to Figure 6, 7, and 8 of the RSF chemical experiment using SEM and EDX photo test, the result is obtained as stated in Table 5. The chemical compound is formed through chemical processes, namely Silica Oxide (SiO_2), which amounted to 71.88%. This research shows similar as explained by Makarim et al. [32], that RSF contains high-concentrated Silica Oxide (SiO_2), and the corrosion process takes a long time. However, at the time, RSF is given a specific treatment. Therefore, it will accelerate the structure-changing process.

3.2.4. Experimentation of Undisturbed Soil Chemical Properties toward Rice Straw Fiber (RSF)

According to Figure 9, 10, and 11 regarding undisturbed soil chemical properties with RSF coverage layer, SEM and EDX photo test. Through chemical processes among the elements, chemical compounds are formed, which is shown in Table 6. This result is obtained after 54 treatments with observing time every 15 minutes for 2 hours. It is found that RSF as a coverage layer sticks directly to the soil surface and divergently spread raindrops on the soil surface. The result supported by the study of Suripin [33] stated that crop residues applied on the soil surface as mulches have more effectivity in erosion control than plant canopy with the same percentage. As mulches stick directly to the surface, energy from raindrops befalling the soil is equal to zero. Furthermore, mulches are also valuable for improving surface runoff with the result that it will reduce loading speed and capacity.

3.2.5. USLE Model Erosion Rate and Research Result

In Table 7 and Figure 12 (I_{40},S_{10}), (I_{40},S_{20}), (I_{20},S_{30}) and (I_{40},S_{30}), it can be seen that erosion rate analysis result according to USLE-based equation is more diminutive than research-based erosion rate on the undisturbed soil. The average value of research-based erosion rate and USLE-based erosion rate amounts to 90.448%. While in Table 8, erosion rate results according to USLE are smaller than research-based erosion rate on the undisturbed soil. The average research-based erosion rate and USLE-based is 13.173% for the undisturbed soil and 92.09% for the 30% RSF-covered soil layer. This result occurred because the USLE-modeled erosion rate calculation is based on the annual erosion average. The rainfall erosivity index (R) is calculated according to the yearly fluctuating rainfall rate. In this study, the rainfall erosivity index (R) is designed according to constant rainfall severity during the experiment of erosion rate.

In Table 9, it can be seen that erosion rate in RSF cover-layered with cover percentage amounted to 30% is decreasing if compared to erosion rate occurring on undisturbed soil. The erosion rate occurring on 30% cover percentage averagely amounts to 7.91% toward erosion rate on undisturbed soil. In other words, the erosion rate on undisturbed soil will be averagely diminished by 92.09% if the soil is given an RSF-coated layer with 30% cover. This research has been strengthened by research done by Gholami et al. [15] using straw mulches to reduce erosion rate in the amount of 63.24% adequately.

Tables 10 and 11 showed that erosion rate in RSF layer-covered soil with each cover percentage are 60% and 90% or the dry weight each 145.1 gr/m2 dan 354.8 gr/m2 are also diminished if compared to the erosion rate occurring on soil without cover layer. Erosion rate occurring in 60% covered the soil, or the dry weight is 145.1 gr/m2 with average amounted of 4.45% and 90% covered soil, or the dry weight of 354.8 gr/m2 with average amounted 1.79%. Therefore, the erosion rate on soil without cover layer will be reduced with 95.55% p 60% covered layer soil and averagely amounted to 98.21% on 90% covered layer soil. This research result is supported by Chul Hee Won et al. [23], where their result showed no sediment discharge produced when given RSF covered layer with dry weight amounting to 900 gr/m2 on a rainfall intensity of 60 mm/h and hillside slope of 20%.

Figure 13 describes the relation of erosion rate toward the ratio of covering percentage compared to RSF dry density and rainfall intensity on each hillside slope of 10°, 20°, and 30°. The three lines on the graphic form regression equations with the same inclination following exponential pattern and coefficient of (R2) that approach each other. The three regression equations are as follows:

On hillside slope of 10°, the obtained erosion rate prediction equation is: $\mathbf{E = 0.5853\ e^{-0.063(RSF/I)}}$, on condition (RSF>0, I>0) an observation area of 1 m^2. Coefficient of determination (R^2) = 0.7076 or R = 0.841189634 (>0,60 and approaching 1), this shows that the proportion of RSF covering percentage and rainfall intensity influence heavily toward erosion rate in hillside slope of 10°. The graphic shows that the higher the RSF cover layer percentage is and the lower the rainfall intensity is, these parameters' ratios will be higher, and the erosion rate will be lower.

On a hillside slope of 20°, the obtained erosion rate prediction equation is $\mathbf{E = 1.9901\ e^{-0.061(RSF/I)}}$, on condition (RSF>0, I>0) on observation area of 1 m^2. Coefficient of determination (R^2) = 0.5644 or R = 0.751265599 (>0.60 and approaching 1), this shows that the proportion of RSF covering percentage and rainfall intensity influences heavily toward erosion rate in hillside slope of 20°. This graphic shows that the higher the RSF cover layer percentage is and the lower the rainfall intensity is, these parameters' ratios will be higher, and the erosion rate will be lower.

Likewise, on a hillside slope of 30°, the obtained erosion rate prediction equation is $\mathbf{E = 5.5258\ e^{-0.072(RSF/I)}}$, on condition (RSF>0, I>0) on the observation area of 1 m². Coefficient of determination (R^2) = 0.8279 or R = 0.909890103 (>0,60 and approaching 1), this shows that the proportion of RSF covering percentage and rainfall intensity influences heavily toward erosion rate in hillside slope of 30°. This graphic shows that the higher the RSF cover layer percentage is and the lower the rainfall intensity is, these parameters' ratios will be higher, and the erosion rate will be lower. These results robust the hypothesis that the additional percentage of RSF can reduce erosion rate, and the increment of rainfall triggers the increasing rate of erosion.

Figure 14 describes the relation of erosion rate toward the ratio of covering percentage compared to RSF dry density and Hillside slope on each value of 10 mm/h, 20 mm/h, and 40 mm/h. The three lines on the graphic form regression equation have the same tendency following exponential pattern and coefficient of determination (R^2) approaching each other. These three regression equations are as follows:

For rainfall intensity 10 mm/h, erosion rate prediction equation obtained is: $\mathbf{E = 1.4199\ e^{-8E\text{-}04(RSF/S)}}$, on condition (RSF>0, S>0) on observation area of 1 m^2. Coefficient of determination (R2) = 0.7109 or R = 0.84314886 (>0,60 and approaching 1), this shows that the proportion of RSF covering percentage and hillside slope influences heavily toward erosion rate. This graphic shows that the higher the RSF cover layer percentage is and the lower the hillside slope is, these parameters' ratios will be higher, and the erosion rate will be lower.

For rainfall intensity 20 mm/h, erosion rate prediction equation obtained is: $\mathbf{E = 2.048\ e^{-8E\text{-}04(RSF/S)}}$, on condition (RSF>0, S>0) on observation area of 1 m^2. Coefficient of determination (R2) = 0.6361 or R = 0.797558775 (>0,60 and approaching 1), this shows that the proportion of RSF covering percentage and hillside slope influences heavily toward erosion rate. This graphic shows that the higher the RSF cover layer percentage is and the lower the hillside slope is, these parameters' ratios will be higher, and the erosion rate will be lower.

Likewise for rainfall intensity 40 mm/h, erosion rate prediction equation obtained is: $\mathbf{E = 6.2973\ e^{-0.001(RSF/S)}}$, on condition (RSF>0, S>0) on observation area of 1 m^2. Coefficient of determination (R2) = 0.6563 or R = 0.810123447 (>0,60 and approaching 1), this shows that the proportion of RSF covering percentage and hillside slope influences heavily toward erosion rate. This graphic shows that the higher the RSF cover layer percentage is and the lower the hillside slope is, both parameters' ratios will be higher, and the erosion rate will be lower. These results robust the hypothesis that RSF cover percentage addition can reduce erosion rate, and the increment of hillside slope triggers the increasing rate of erosion.

While regression analysis between erosion rate (E) with the ratio of the cover percentage of dry weight and multiplication of rainfall intensity and hillside slope ($\frac{RSF}{I.S}$) on all levels of hillside slope is shown in Fig. 16.

Figure 15 describes the functional relationship between erosion rate with the ratio of the cover percentage of dry weight and multiplication of the rainfall severity and hillside slope on the whole level. The combination graphic follows a trend which is an exponential pattern with regression form of erosion rate toward the ratio of RSF cover percentage with rainfall intensity is $\mathbf{E = 1.9021e^{-0.012(RSF/I.S)}}$, on condition (RSF>0, I>0, S>0) on observation of 1 m^2. Coefficient of determination (R^2) = 0.5591 or R = 0.747729898 (>0.60 and approaching to 1), this means that ratio of cover percentage with dry weight and multiplication of rainfall intensity and hillside slope correlates strongly toward erosion rate on each value of hillside slope and rainfall intensity. The graphic shows that the higher the RSF cover percentage and the lower the rainfall severity and/or hillside slope, the higher the ratio of the three parameters will be, and the contrary happens on erosion rate. The result confirms the hypothesis that the additional RSF cover percentage can reduce erosion. The rainfall intensity and/or the increment of hillside slope would trigger the increment of erosion rate.

4. Conclusions

The purpose of this experimental study is to determine the efficacy of RSF as a land cover to control slope erosion by simulating rainfall at specific rainfall intensities and slope conditions. The results of the experiment revealed that the landslide rate excalated in line with the rise of soil slope degree and rainfall intensity in the model. The surge of rate of soil erosion due to the rainfall intensity is caused by the multiplying number of strokes and rainwater splashing on the soil surface, which generates kinetic energy and makes the soil particles exposed and detached.

While in response to the soil slope degree, the greater the angle of inclination of the ground, the greater the component of the flow forces in the direction of the slope of the soil, which will make the soil particles be displaced more quickly and flow with the surface runoff.

This study also showed a decrease in the rate of erosion along with an increase in the percentage of soil cover using rice straw fiber. The percentages of soil cover using rice straw fiber used in this study were 30%, 60%, and 90%, reducing erosion rates by 92.09%, 95.55%, and 98.21%, respectively. Thus, the higher the percentage of rice straw fiber used as ground cover, the lower the soil will be affected by erosion. With the percentage of land cover using rice straw fiber, the results obtained from soil that was affected by erosion were 7.91%, 4.45%, and 1.79%, respectively. Thus, these results indicate that rice straw fiber is very effective in overcoming the problem of erosion.

Meanwhile, the increase in rainfall intensity and soil slope can trigger the growth of erosion rate. Furthermore, our result found that the maximum erosion reduction is occurred at 90% of rice straw fibers as a land cover, with the rainfall intensity of 10, 20, and 40 mm/h with at 10^{o}, 20^{o}, and 30^{o} of soil slope was 98.21%. The result is higher than the results obtained by Gholami et al. [15], which ranges around 63.24%. Even though the results of the experiments have shown the efficacy of raw straw fiber in controlling landslide, field implementation of this material is still required to investigate its efficacy in field-scale settings [34].

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