The Effect of Layers and Weaving Spacing of 'Mendong' (*Fimbristylis globulosa*) Bio-geotextile on Effectiveness of Soil Erosion Control

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ABSTRACT

The challenge of farming in mountainous areas is soil conservation to avoid erosion. A method to control soil erosion is mulch technology. Mulch can reduce rain energy, preventing damaging the stability of the soil structure. Mulch that is widely used is plastic mulch, but it has several disadvantages. Thus, bio-geotextile is a mulch alternative. Bio-geotextiles can be made from mending, a type of grass belonging to the Cyperaceae family and is originally from Southeast Asia. This study aims to determine the effect of the number of layers and weaving spacing of bio-geotextile in controlling soil erosion and the best treatment of Mendong bio-geotextile in controlling soil erosion. The method used was a Factorial Randomized Block Design (RBD), which consists of two factors, the number of layers (1 - 3 layers) and weaving spacing (0.5-2 cm. It is found that Mendong bio-geotextile with 1 layer and 0.5 cm weaving spacing was the best and most effective treatment in controlling soil erosion. The Mendong bio-geotextile has proven to be effective in reducing soil loss due to erosion. Compared to the soil without bio-geotextile treatment, Mendong's bio-geotextile best treatment can reduce the amount of soil loss up to 98.6%.

Keywords: *Bio-geotextile, Erosion, Mendong, Water holding capacity*

1. INTRODUCTION

A primary cause of soil erosion in mountainous locations is when farmers ignore soil conservation rules, resulting in poor soil quality. Erosion has both off-site and on-site consequences, such as the loss of nutrients and organic material in the soil, as well as a detrimental impact on soil production. The period following sowing until vegetation development is the most sensitive to erosion, necessitating the use of technologies to prevent soil erosion [1]. Long-term soil erosion protection can be provided by a dense, well-established vegetation cowl.

Mulch technology is a technology that can be used to control soil erosion. Mulch can limit rain energy and surface runoff, ensuring that soil structures remain stable. Plastic mulch is the most prevalent type of mulch. The application of plastic on the soil's surface can help to prevent water evaporation [2]. Plastic mulch, on the other hand, is not environmentally friendly and is not permeable. As a result, using bio-geotextiles as a substitute for plastic mulch could be a viable option.

Geotextile is a permeable textile material used on the soil and widely used in civil engineering work. It is derived from two words: 'geo' means 'earth,' and 'textile,' so it is a permeable textile material used on the soil and widely used in civil engineering work [3]. Biodegradable geotextile (Bio-geotextile) is a type of geotextile made from degradable organic materials. When compared to plastic mulch, the advantage of bio-geotextile is that it is permeable, allowing water to absorb into the soil and maintain a hydrological cycle. It is also stronger in protecting the soil from rainwater while still allowing sunlight to penetrate. Bio-geotextiles are made of organic materials that degrade in 6-10 months and produce natural compost [4]. Bio-geotextiles, when degraded, can add organic materials to the soil, increasing microbiological activity [5].

Natural fibers such as hemp, abaca, jute, rice straw, and Mendong straw can be used to create bio-geotextiles. Mendong is a type of grass native to Southeast Asia that belongs to the Cyperaceae family. The District of Wajak, Malang, in East Java, Indonesia, has the highest productivity of Mendong [6]. Mendong straw was chosen as a bio-geo-textile material because it is a local variety and easy to find. Furthermore, Mendong straw has a short growing cycle and can be harvested up to five times in a single planting period. Mendong straw is commonly used as a raw material for mats and handicrafts in the creative industry, but it has been displaced by plastic, so using it as a bio-geotextile raw material can increase its value and has tremendous potential for development.

Separation, filtration, drainage, protection, and reinforcement are some of the functions of bio-geotextiles in general [7]. Bio-geotextiles, on the other hand, can be used to control soil erosion because they can drain water while also absorbing soil particles from surface runoff. High percentage cover, high water holding capacity, and thickness fiber or filament appears to be desirable characteristics of erosion control geotextiles [5]. As a result, more research into the use of bio-geotextile Mendong for soil erosion control is required. The experiment was carried out on a laboratory scale using a rainfall simulator, with the variable and experimental design assuming that the number of layers affected the water-holding capacity and that a bio-geotextile with a high water-holding capacity will increase the weight in a wet condition, increasing the drapability between the bio-geotextile and the soil. The weaving spacing has an impact on the size of the pore openings in Mendong bio-geotextiles, which affects their ability to withstand soil particles. Thus, the number of layers of bio-geotextile and which are the most effective in controlling soil erosion can be determined.

The aim of this study was to investigate how the layers and weaving spacing of a Mendong bio-geotextile affect its thickness, water holding capacity, and overall strength. Various parameters (i.e. weight in wet conditions, runoff, and sediment yield) were used to determine the best and most effective treatment of Mendong's bio-geotextile in controlling soil erosion, aiming to reduce waste costs if large quantities of Mendong' bio-geotextile are produced.

2. MATERIALS AND METHODS

2.1. Materials

The study was conducted on the laboratory scale in Hydrological Laboratory Department of Water Resources Engineering Universitas Brawjaya from May to July 2019 using a rainfall Simulator (Armfield S12-MKII) dimension 2 m x 1 m x 0.2 m, and an acrylic test box with dimensions of 1 m x 1.1 m x 0.2 m. Samples have been acquired from the agricultural land in the district of Wajak, Malang, East Java, Indonesia. Samples have been selected within the harvest age of 5–6 months and the length of the straw between 0,7–1 m. Andosol soil obtained in District of Junrejo, Batu, the soil have been taken with depth up to 20 cm from the surface.

2.2. Method

a. Survey

The survey was held in one of the SMEs Mendong mats in Blayu, District of Wajak Malang. The survey was carried out to understand the production process of Mendong mat as the raw material of bio-geotextile.

b. Mendong bio-geotextile production process

The production process of bio-geotextile Mendong from raw material until the final product was only through the physical process. Weaving process was using a traditional loom machine. The process is shown in Figure 1.

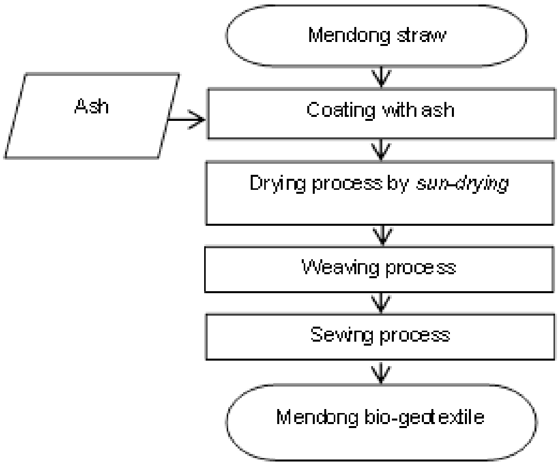

Figure 1 Flow Diagram of Mendong Bio-geotextile Production

2.3. Analysis

a. Thickness Test

The bio-geotextile thickness test refers to the American Standard of Testing Material (ASTM-D5199). The thickness test on bio-geotextile is carried out by observing the perpendicular distance of bio-geotextile surface with the pressure of 2 Kpa using a thickness gauge.

b. Water Holding Capacity Test

The testing method of water holding capacity used is a modification of the soil water holding capacity test method by Bhadha et al. [8]. The sample is cut with dimensions 7x3x*c* cm is (*c* is the value of thickness according to different treatment of layer). The weight of bio-geotextiles in the dry condition was weighed, and the water content was measured. Prepared the measuring glass, funnel, and stopper rubber attached to the neck, then placed the bio-geotextile sample into the funnel. Added 100 mL of water and recorded as the initial volume. Bio-geotextile was soaked for 30 minutes, then removed the rubber and leave until water did not drip on the funnel. Weighed the bio-geotextile in wet weight conditions, then measured the water content. The volume of water attached to the measuring glass was measured and then recorded as the final volume. Then, water holding capacity was calculated using Equation 1. The increasing weight of bio-geotextile in wet conditions was calculated based on Equation 2.

WHC% = ([100 ml – water drained + water content in biogeotextile previously]/ weight in dry condition (g)) x 100 …………………………………..……..(1)

Increasing weight in wet condition % = ([weight after soaked (g) – weight before soaked (g)]/ weight before soaked (g)) x 100…………………………………………..(2)

c. Rainfall Simulator Simulation

This research was carried out using a rainfall simulator that connected to software equipped with a by test box dimension 1 x 1.1 m. The method refers to the instrument's manual operating procedure. Make sure the software is installed on PC, then calibrate the rainfall simulator. Then place the soil into the test box and measure the water content. The soil is compacted by a 3 kg compactor until soil height reaches 10 cm. Then place the empty tank on the bottom of the instrument to accommodate the abundance of sediment yield. Covered the soil with bio-geotextile and turned on the rainfall simulator. Set the slope to 10^o and rain intensity to 115 mm/h, then turn on the rainfall simulator. Wait until the water passes through the weir on the recorder tank, then click zero and go on the software. After 40 minutes, stop the rainfall simulator and save the data obtained on the software. The water was accommodated on the tank, then allowed for 24 hours, and then filtered its yield sediment. Sediment yield dried up for 24 hours using an oven, then weighed.

d. Statistical Analysis

The data obtained for each parameter was analyzed by software SPSS using factorial randomized block design consisting of two factors which were the number of layers consisting of 3 levels (1 layer, 2 layers, 3 layers) and weaving spacing consisting of 4 levels (0.5 cm, 1 cm, 1.5 cm, and 2 cm). The parameter variables used were thickness, bio-geotextile weight in wet conditions, water holding capacity, sediment yield, and runoff. The data obtained were analyzed by ANOVA and further tested using the Least Significant Difference (LSD) test with p= 0,05.

e. Best Treatment

The determination of the best treatment was using the multiple attribute method [9]. The best treatment is selected by determining the ideal value for each parameter, and each parameter is considered important. The best treatment is chosen based on the treatment, which is thin because it relates to the cost of production, high water holding capacity, so it increases the weight in wet conditions, has low surface runoff, and has good protection due to soil loss.

3. RESULTS AND DISCUSSION

3.1. Thickness of Biogeotextile

Table 1 shows the thickness parameter differed considerably based on the treatment of layers, weaving spacing, and the interaction between these two treatments. The increase of layers and weaving spacing affected increasing the thickness of bio-geotextile, according to LDS test findings (Table 2 and 3). The greater weaving spacing is likely to blame for the bio-geotextile Mendong's increased thickness. Because the weaving process becomes less precise, the Mendong are stacked on top of one another, increasing the biogeotextile's thickness.

Table 1. Thickness of Mendong biogeotextile based on number of layers

Number of layer	Mean of thickness (mm)	LSD
1 layer	2.333^{a}	0.252
2 layers	4.242^{b}	
3 layers	6.642^{c}	

Note: *Mean values followed by the same letters are not significantly different at 0.05 levels according to Least Significant Different (LSD) Test

Table 2. Characteristics of Mendong bio-geotextile

Treatment		Parameters				
Number of layer	Weaving spacing (cm)	Thickness (mm)	Water holding capacity (%)	Increasing Weight in wet condition (%)	Runoff (l/min)	Sediment yield (g)
Control (bare soil)		-	-	-	1.70	170,6
1	0.5	1.47	463.56	161.11	1.60	2.414
1	1	1.93	428.06	154.76	1.86	2.717
1	1.5	2.27	470.48	196.83	1.93	5.744
1	2	3.67	453.54	187.50	1.78	6.460
2	0.5	3.13	349.81	164.90	1.96	2.147
2	1	3.97	388.81	181.84	1.98	2.702
2	1.5	5.07	370.21	177.90	1.96	4.701
2	2	4.80	344.35	174.17	1.84	5.552
3	0.5	4.80	306.25	164.02	1.83	1.931
3	1	6.27	309.76	166.18	1.77	2.679
3	1.5	6.57	240.76	140.76	1.84	5.600
3	2	8.93	249.03	135.13	1.72	6.189

Table 3. Thickness of Mendong biogeotextile based on weaving spacing

Weaving spacing (cm)	Mean of thickness (mm)	LSD
0.5	3.133^{a}	0.291
1	4.056^{b}	
1.5	4.633^{c}	
2	5.800^{d}	

Note: *Mean values followed by the same letters are not significantly different at 0.05 levels according to Least Significant Different (LSD) Test

3.2. Biogeotextile Weight Increase in Wet Condition

Mendong Biogeotextile can absorb water and increase the weight in wet conditions because of their fiber's component dominated by cellulose. According to Suryanto et al. (2016) [10], Mendong straw has cellulose content up to 72% of the total weight. According to ANOVA, there were significantly different among the increasing weight of bio-geotextile in wet condition depending on the different treatment of layers.

The LSD test results (Table 4) show that as the layer of bio-geotextile increases, the weight of the bio-geotextile increases less in wet conditions. The decrease in bio-geotextile weight in wet conditions as the number of layers of bio-geotextile increases is presumably due to the fact that the more layers of bio-geotextile there are, the thicker the bio-geotextile becomes, and this has an effect on water absorption in bio-geotextile. Furthermore, the chemical components contained within the bio-geotextile Mendong, such as cellulose, hemicellulose, and lignin, are preserved during the manufacturing process of bio-geotextile Mendong from the raw material to the final product. Lignin has a hydrophobic area that may obstruct water absorption, preventing bio-geotextiles from absorbing as much water as they should. Lignin has a hydrophobic area that inhibits water absorption and reduces the ability of bio-geotextiles to absorb water [11].

Table 4. Weight of Mendong biogeotextile based on number of layers in wet condition.

Number of layer	Mean of biogeotextile increasing weight in wet condition (%)	LSD
1 layer	175.0500^b	20.342
2 layers	174.7025^b	
3 layers	151.5225^a	

Note: *Mean values followed by the same letters are not significantly different at 0.05 levels according to Least Significant Different (LSD) Test

3.3. Water Holding Capacity

According to ANOVA, there were significantly different among the water holding capacity parameter depending on the different treatment of layers. LSD testresult (Table 5) show that the increasing layer of bio-geotextile then the water holding capacity is decreasing.

The number of fibres conceived by Mendong influences the water holding capacity of bio-geotextiles; cellulose is one of the fibres that can absorb water. Mendong fibre contains up to 72 percent cellulose and makes up the majority of the total fibre conceived by Mendong [10]. Cellulose is hygroscopic, meaning it can absorb water molecules, and many of its chains contain a hydroxyl group (OH) that can form a hydrogen bond with water. Fiber can bind water in a variety of ways, including hydrogen bonds [12]. Hydrogen bonds are formed when hydrogen (H) is bound to an element with high electronegativities, such as carbon (C), oxygen (O), or fluorine (F).

Table 5. Water holding capacity of Mendong bio-geotextile based on number of layers

Number of layer	Mean of water holding capacity (%)	LSD
1 layer	453.9117^c	77.478
2 layers	363.2942^b	
3 layers	276.4483^a	

Note: *Mean values followed by the same letters are not significantly different at 0.05 levels according to Least Significant Different (LSD) Test

There is a link between the weight of a bio-geotextile in a wet state and its water holding capacity. Bio-geotextiles with high water holding capacity will increase the weight in wet conditions, and the two factors are interrelated. According to Rickson [5], water holding capacity and bio-geotextile weight in wet conditions are related. Products with higher water holding capacity become heavier in wet conditions.

As shown in Table 5, as the number of layers increases, the water holding capacity decreases, presumably because the bio-geotextile becomes thicker. The absorption of water by cellulose is affected by the thickness of the bio-geotextile as it relates to the surface area in direct contact with water. Furthermore, evaporation on the surface of the bio-geotextile is likely to be the cause of the decreased water holding capacity. It is caused by the weak hydrogen bonds that occur between cellulose and water. Evaporation can occur due to the heat in the atmosphere, even if there is no additional heat. The water content of cellulose will be balanced in atmospheric conditions, depending on relative humidity [13]. At a given relative humidity, cellulose will absorb less water than it loses (RH). It means that cellulose has the ability to release more water than it can absorb.

3.4. Sediment Yield

There were significant differences among the sediment yield parameter depending on the different treatment of layers and weaving spacing. When compared to the control treatment, the use of bio-geotextile can reduce soil erosion by up to 26.4 – 88.4 times, as shown in Table 6 (bare soil without bio-geotextile treatment). According to the LSD test results, the sediment yield is higher when the bio-geotextile spacing is wider. It is assumed that the wider the spacing of bio-geotextile, the greater the chance of soil eroding; as the spacing of bio-geotextile widens, the bio-geotextile becomes more porous, allowing soil particles to be restrained and carried away with surface runoff.

Table 6. Sediment yield of Mendong bio-geotextile based on number of layers and weaving spacing.

Number of layer	Mean of sediment yield (g)	LSD
1 layer	4.3338^{b}	0.469
2 layers	3.7755^{a}	
3 layers	4.0996^{ab}	

Note: *Mean values followed by the same letters are not significantly different at 0.05 levels according to Least Significant Different (LSD) Test

The pore size of bio-geotextiles affects the number of soil particles that can pass [14]. The larger the pore size, the more soil particles can pass through, and vice versa. Table 6 shows that the highest amount of sediment yield comes from one layer of bio-geotextile, followed by three and two layers. It is thought that increasing the number of layers in a bio-geotextile can reduce sediment yield because bio-geotextile is thicker and less porous, increasing its ability to withstand soil particles. A thick geotextile with a small opening pore size can reduce the number of soil particles that pass-through surface runoff when compared to a thin geotextile with a large opening pore size [14].

3.5. Runoff

There were significant differences in the runoff parameter depending on the treatment of layers and weaving spacing, according to ANOVA. Table 1 shows that the runoff value between the control treatment (bare soil without bio-geotextile treatment) and the soil treated with bio-geotextile is not significantly different; however, while the runoff value is not significantly different, the surface runoff is higher in the bio-geotextile treatment than in the control treatment.

According to the LSD test results (Table 7), it is presumably due to the thickness of the bio-geotextile material, which is less porous than andosol soil, which has a high porosity, allowing rainwater to be stimulated into the soil. This, combined with the presence of slope, causes the water to not directly absorb into the soil, resulting in a higher surface runoff.

Furthermore, it is believed that the number of layers influences the amount of water absorbed by bio-geotextiles, which is linked to the amount of surface runoff. One layer of bio-geotextile has a high-water holding capacity (Table 5), making it superior to two and three layers in terms of water absorption. In addition, one layer of bio-geotextile has a high water-holding capacity. Rainwater can still be absorbed into the soil and maintain the hydrological cycle when simulated using a rainfall simulator, as opposed to two and three-layered bio-geotextiles, which are less porous and allow rainwater to flow into the ground, causing high surface runoff. Bio-geotextiles, that can absorb more water, can reduce the amount of face runoff [15].

Table 7. Runoff of Mendong biogeotextile based on number of layers and weaving spacing.

Weaving spacing (cm)	Mean of sediment yield (g)	LSD
0.5	2.1638^{a}	0.541
1	2.6990^{b}	
1.5	5.3486^{c}	
2	6.0672^{d}	

Note: *Mean values followed by the same letters are not significantly different at 0.05 levels according to Least Significant Different (LSD) Test

3.6. Best Treatment

The combination of one layer and 0.5 cm of weaving spacing yielded a Mendong bio-geotextile with a best-selected parameter using the multiple attribute method. Mendong bio-geotextile with 1 layer and 0.5 cm weaving spacing has a thickness of 1.47 mm, a water holding capacity of 463.56 percent, and an increasing weight in wet condition of 161.11 percent, as shown in Table 8. The best treatment compared to jute geotextile soil savers, which have been widely used in Europe and America since 1950 to control rain-induced soil erosion, particularly on slopes [16].

The Mendong bio-geotextile has been shown to be very effective in reducing soil loss due to erosion, with only 2.41 g of soil loss and 1.60 L/min of runoff. It has been proven that when compared to bare soil without bio-geotextile treatment, Mendong bio-geotextile with the best treatment can reduce soil loss due to erosion by up to 98.6%. Mendong bio-geotextile equivalent is even slightly superior to geotextile soil Saver's Type 1 in terms of thickness and water holding capacity parameters.

Table 8. Lists of the characteristics of the saver's soil

Properties	Mendong bio-geotextile (best treatment result of the current study)	*Soil Saver's* Type 1	*Soil Saver's* Type 2	*Soil Saver's* Type 3
Thickness (mm)	1.47	2	4	6
Water Holding Capacity (%)	463.56	400	500	500
Weight (g/m^2) *at* 20% M.R	-	292	500	730
Threads/dm (MD X CD)	-	12 X 12	6.5 X 4.5	7 X 7
Width (m)	-	1.22	1.22	1,22
Strength (kN/m) [MD X GD]	-	10 X 10	10 X 7.5	12 X 12
Open Area (%)	-	60	50	40
Maximum durability (yrs)	-	2	2	2

4. CONCLUSION

The thickness of bio-geotextile is significantly affected by the different number of layers and weaving spacing. The increase of layers in bio-geotextile was significantly affected the water holding capacity and weight in wet condition. The sediment yield and surface runoff were significantly affected by various layers and weaving spacing. 1-layer bio-geotextile treatment with a weaving spacing of 0.5 cm is the best and most effective treatment for controlling soil erosion. Scale-up research to compare bio-geotextile effectiveness when applied in the field is suggested as a future study related to the topic. The rate of bio-geotextile degradation is required further investigation.

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