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Effect of Hydro-mulch and Geo-jute Application on the Soil Loss during Cultivation of Corn (*Zea Mays* L.) in Dry Land

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ABSTRACT

Utilization up-land area for cultivating strategic food crops (paddy, corn and soybean) often neglects the rules of conservation so that it caused surface soil loss by run off. These events can reduce the fertility of agricultural land, so that it results in a decrease in land productivity and finally cause critical lands. Alternative conservation techniques that can be carried out through the application of hydro-mulch and geo-jute combination in order to reduce surface soil loss. The purpose of this study is to examine the use of hydro-mulch and geo-jute in reducing soil loss and observing maize growth as one of the effects of soil loss due to erosion. The treatments given are hydro-mulch, geo-jute and combination of hydro-mulch and geo-jute. The study showed that alternative conservation techniques in the form of hydro-mulch and geo-jute application proved to be able to reduce the amount of soil loss. The combination of hydro-mulch and geo-jute has the ability to reduce the amount of soil loss due to rainfall by 31.51%. Plot with geo-jute treatment can reduce soil loss by 21.86%, and plot with hydro-mulch treatment can reduce soil loss by 11.92%. The hydro-mulch and geo-jute combination can increase the growth of corn.

1. INTRODUCTION

Drylands are expanses of land that are never inundated or flooded for most of the year (Adimihardja *et al*., 2000). Drylands, also known as upland plantations or unirrigated lands, lack irrigation facilities (Notohadiprawiro, 2006) and thus rely heavily on rainfall for irrigation. These lands are typically used for cultivating food crops such as corn, beans, and soybeans, in addition to vegetables. The *Pajale* (Padi, Jagung, Kedele) program develop especially paddy, corn, and soybean commodities as the priority for dryland agricultural cultivation in Indonesia, as part of the strategic food supply (Elizabeth & Paramita, 2022).

The utilization of land for agricultural cultivation often neglects conservation principles, especially during soil preparation at the initial growth stage. This practice can lead to an increase in soil loss, reducing the fertility of agricultural land and consequently decreasing land productivity. Continuous neglect can result in critical land conditions, particularly on drylands. Drylands have the potential to become critical lands.

Critical lands are areas where the land's capability no longer matches its usage due to physical, chemical, and biological degradation, rendering it ineffective for agricultural use, water regulation, or environmental protection (Rosyada *et al*., 2015). In 2017, the extent of critical land in Indonesia reached 24.3 million hectares, or 12% of the total forest area in Indonesia (Dirjen PDASHL, 2017).

Applying soil conservation techniques to minimize soil loss on drylands is necessary through various methods and models. Hydro-mulch and geo-jute can be alternative soil conservation techniques. Hydro-mulch is a ground cover made from organic materials such as litter, organic fertilizers, and water mixed with natural adhesives, which are key to its success (Kendarto *et al*., 2017). Geo-jute is a woven coconut fiber netting available in various forms and sizes. The advantage of these alternative conservation techniques is their natural material composition, making them environmentally friendly. Additionally, geo-jute is made from abundant coconut fiber, often considered waste.

Research on the use of hydro-mulch and geo-jute as soil conservation measures is necessary to determine the most effective conservation actions in reducing surface soil loss, especially for strategic food crop cultivation like corn on sloping lands. Therefore, this study is performed to evaluate the effect of soil conservation through the application of hydro-mulch and geo-jute on the soil loss by erosion. This research is important to minimize erosion on sloping lands in an environmentally friendly manner.

2. MATERIALS AND METHODS

2.1. Object Characteristics

This research is a field observation study using erosion plots to examine the relationship between rainfall impact and erosion under different soil protection models. The study was conducted on an erosion plot with an 18% slope at the Universitas Padjadjaran experimental field in Jatinangor, Sumedang, using four plots, each measuring 1 m x 7.9 m. The research location is astronomically located at 6°54'52.15" S and 107°46’27.39” E. Each plot underwent maximum tillage. The erosion plots were planted with corn at a spacing of 30 cm x 60 cm, with approximately 42 corn plants per plot. The treatments for the four plots were as follows: Plot A, experimental plot with hydro-mulch addition; Plot B, experimental plot with hydro-mulch and 3 cm x 3 cm geo-jute mesh; Plot C, experimental plot using 5 cm x 5 cm geo-jute mesh; and Plot D as the control. Hydromulch is formulated by adding an adhesive or guar gum additive which functions as a substitute for adhesive in liquid mulch (Latifah *et al*., 2018). The erosion plots used in this study are permanent with an 18% slope, equipped with tanks to collect surface runoff and erosion from each treatment plot. The collection tanks measure 30 cm x 80 cm x 40 cm, with three 1” pipes to channel excess surface flow from the tanks to other collection points. The erosion plot model is presented in Figure 1.

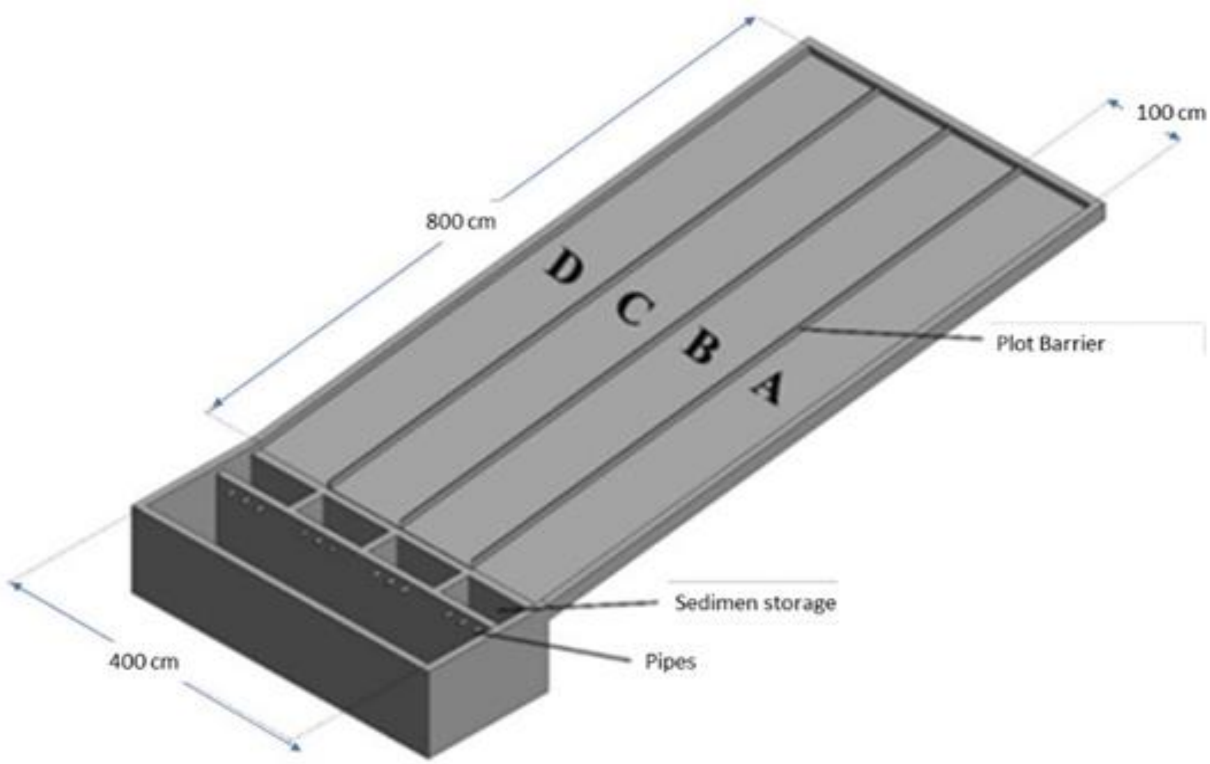

Figure 1. Erosion plot model in the research field.

2.2. Data Collection

The soil used for this study was tested in the laboratory to determine its structure, texture, organic material content, and water absorption capacity. Soil samples were collected using a ring sampler and tested at the Soil Physics and Chemistry Laboratory, Faculty of Agriculture, Universitas Padjadjaran.

Erosion observations included daily rainfall measurements for each rainfall event and observations of the soil particle mass carried by surface runoff collected in the tanks. Observations were made at sunrise around 6:30 AM every day when it rained. The total suspended solids (TSS, g/L) test used the gravimetric method was employed to calculate the amount of erosion in each plot. The gravimetric method calculates soil loss due to erosion using the Equation (1) (Fatimah, 2014), and calculation of sediment yield from erosion used the Equation (2) Hanifah (2016):

$$TSS = \frac{(A-B)\times 1000}{Volume\ of\ sample} \tag{1}$$

$$E = \frac{C_{ap} \times V_{ap}}{Ap} \tag{2}$$

where A is weight of filter paper after oven-drying (g), B is weight filter paper (g), E is erosion (kg/ha), C_{ap} is sediment concentration (kg/L), V_{ap} is volume of surface runoff (L), and Ap is plot area (ha).

Secondary data on corn plant growth included measurements of plant height and corn weight at harvest. Rainfall measurements in the field were taken using a simple ombrometer placed around the erosion plots. Based on Hanifah (2016), rainfall depth (R, mm) was calculated using Equation (3), where V_o is the rainfall volume (mm³), and A_c is the Ombrometer funnel area (mm²):

$$R = V_o / A_c \tag{3}$$

2.3. Data Analysis

Data processing in this study utilized regression analysis and T-tests to examine the relationship between two variables: the independent variable (X) and the dependent variable (Y). The parameters used for data analysis were rainfall data and the amount of eroded soil to determine the relationship between rainfall and erosion for each treatment. The relationship between the independent and dependent variables was calculated using Equation (4):

$$Y = a + bX \tag{4}$$

where Y is dependent variable, a is intercept constant, b is regression coefficient, and X is independent variable

The next step in data processing was the T-test. The T-test is a statistical test to determine the difference between the means of two groups, indicating whether the groups differ significantly. This test was conducted at a 95% of significance level (α = 5%).

3. RESULTS AND DISCUSSION

3.1. Research Location Conditions

Based on laboratory tests, the soil on the research site has physical characteristics of reddish-brown color and a clay texture, with soil fractions consisting of 5% sand, 26% silt, and 69% clay. The soil structure is sub-angular blocky, with a relatively low bulk density of only 1.12 g/cm³. The soil permeability is 0.49 cm/hour, which is considered slow, making the research site highly prone to surface runoff due to the soil's low water infiltration capacity.

3.2. Rainfall Observations

Rainfall data for this study were obtained from direct field measurements during each rainfall event. The rainfall measurement unit used was the rainfall depth. The results of rainfall measurements are presented in Figure 2. The rainfall data recorded 43 rainfall events, with the highest rainfall depth being 93.77 mm/day and the lowest being 2.65 mm/day. Overall, there were 6 days of very low rainfall, 22 days of low rainfall, 12 days of moderate rainfall, and 3 days of somewhat high rainfall.

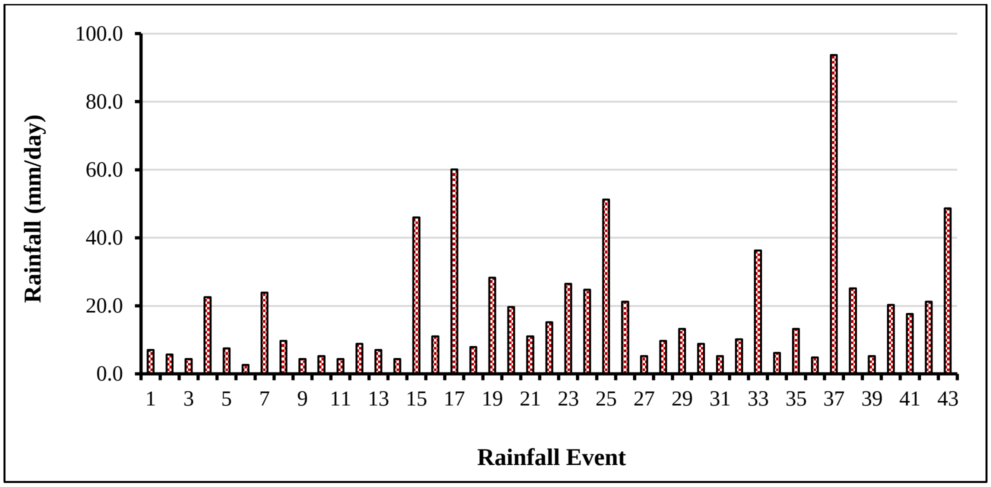

Figure 2. Rainfall measurements at the research location

3.3. Effect of Treatment on Erosion

Erosion is the process of topsoil displacement by the impact of raindrops, which is then transported by surface runoff and gradually settles as sediment. Erosion leads to a decline in land productivity because essential nutrients in the soil are lost, which are crucial for plant growth. The amount of erosion observed for each treatment is presented in the form of a graph in Figure 3. The graph shows that the highest erosion occurred in the Control plot, with an erosion amount of 11.35 ton/ha. The next highest erosion was in Plot A, with the hydro-mulch treatment, showing an erosion amount of 5.56 ton/ha. Plot C, with the geo-jute treatment, and Plot B, with the combined geo-jute and hydro-mulch treatment, had the lowest erosion amounts, with 0.7 ton/ha and 0.4 ton/ha, respectively. Factors influencing erosion in this study include rainfall, treatments such as geo-jute and hydro-mulch, weeds, canopy, and others. The high erosion amount in the Control plot may be due to the absence of ground cover or mulch, which functions as a barrier to the kinetic energy of raindrops, thereby minimizing erosion.

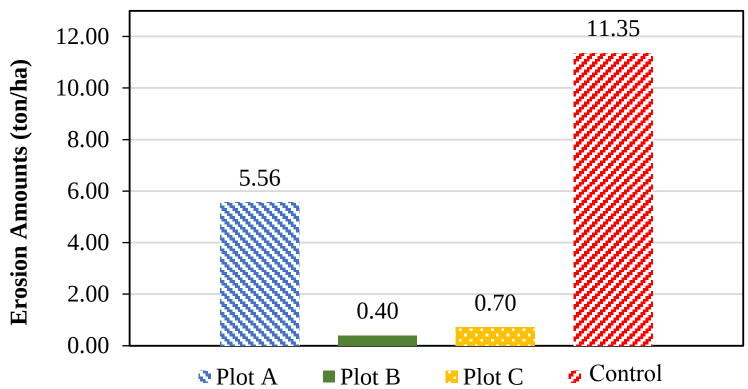

Figure 3. Comparison of erosion amounts for each treatment

3.3.1. Effect of Hydro-Mulch Treatment on Erosion

The comparison of erosion amounts between treatments and the Control aims to determine the extent of the difference between plots with conservation measures and those without. The comparison of erosion amounts between the hydro-mulch treatment and the Control is presented in the graph in Figure 4. Observations showed that the highest erosion in Plot A occurred on the 17th day of rainfall events, with an erosion amount of 1.57 ton/ha and rainfall of 60.16 mm. This result is still lower compared to the erosion amount in the Control plot on the same day, which was 2.29 ton/ha. The difference in erosion amount was 0.72 ton/ha (Figure 4). Plot A (the plot with the hydro-mulch treatment) can

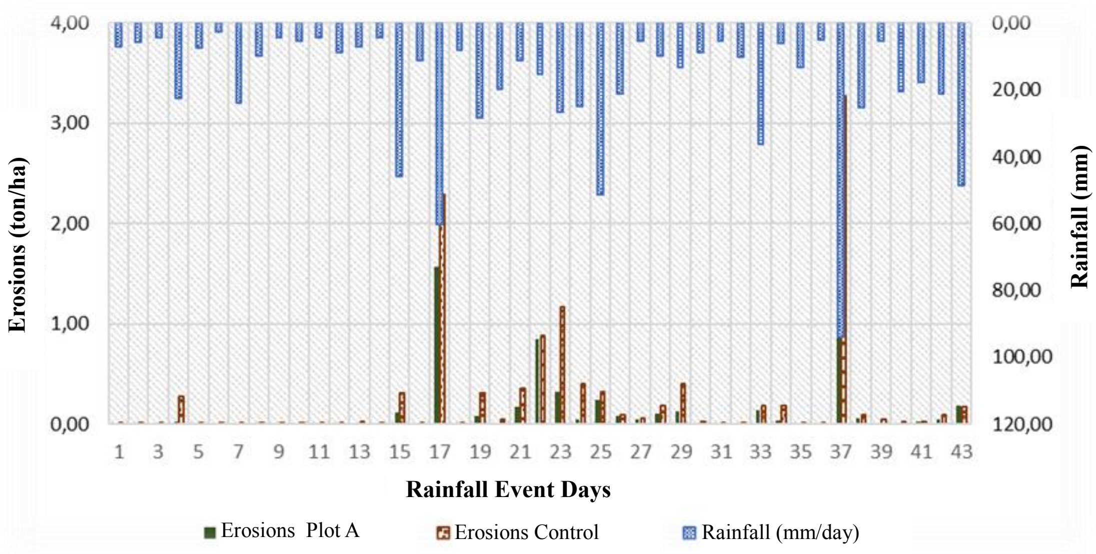

Figure 4. Comparison of daily rainfall and erosion in Plot A and Control

reduce erosion because the guar gum additive in the hydro-mulch acts as an adhesive between soil fractions, making the soil more resistant to the kinetic energy of rain. Plot A, with the hydro-mulch treatment, can reduce erosion by 51.04% compared to the erosion in the control plot. Rainfall intensity shows a very positive correlation with the loss of TN associated with slope runoff and sediment (Wang *et al*., 2023).

The *T*-test results showed that the *T*-calculated value of 1.2 was lower than the *T*-table value (1.9). The *T*-calculated value falls in the area where Ho is accepted, indicating that the erosion amount in Plot A with the hydro-mulch treatment compared to the Control plot does not significantly differ. Although Plot A with the hydro-mulch treatment proved effective in reducing erosion during the planting period, the reduction was not significant.

3.3.2. Effect of Geo-jute Treatment on Erosion

The alternative conservation technique using geo-jute is one of the environmentally friendly conservation methods. Comparing this technique with the Control aims to determine how effectively geo-jute can reduce soil erosion on agricultural land. The results of erosion measurements over 43 rain events are presented in Figure 5. Observations show that the highest rainfall, occurring on the 37^{th} day with 93.77 mm, resulted in the highest erosion amount in the Control plot, which was 3.27 ton/ha. Meanwhile, Plot C with the geo-jute treatment resulted in an erosion amount of 0.043 tons/ha, with a difference of 3.23 ton/ha.

The low erosion amount in Plot C can be attributed to the applied geo-jute breaking up raindrops during rainfall, significantly reducing the kinetic energy of water hitting the soil. Geo-jute also slows down surface runoff, thus impeding the transportation of eroded soil. This aligns with the study by the Bureau of Research and Standards (BRS) of DPWH (2005), which showed that geo-jute is crucial for protecting vegetation development from water and wind erosion by providing the soil surface with spatial cover and maintaining soil moisture. T-test results show that the T-calculated value is higher than the T-table value, indicating that using geo-jute and hydro-mulch can effectively reduce erosion. *T*-test analysis results show that the *T*-calculated value of 2.62 is smaller than the *T*-table value of 1.99, meaning that the erosion amount in Plot C with the geo-jute treatment compared to the Control plot significantly differs (*T*-calculated > *T*-table).

3.3.3. Combination of Hydro-Mulch and Geo-Jute Treatment

This comparison aims to determine the effectiveness of the combined hydro-mulch and geo-jute conservation technique in reducing soil erosion compared to the Control plot. The comparison of erosion amounts between the Plot

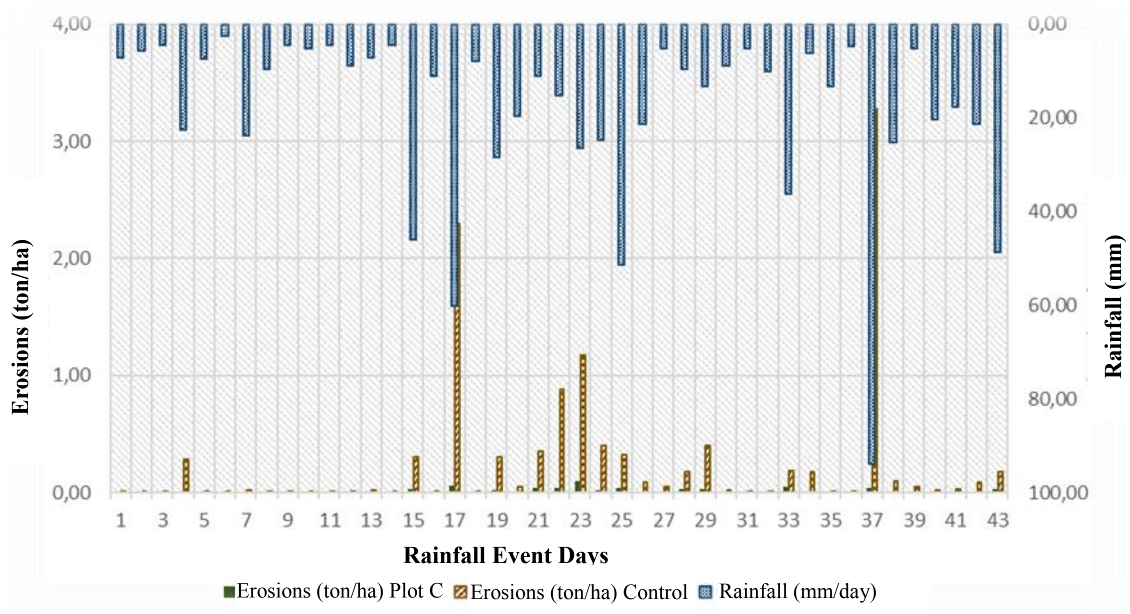

Figure 5. Comparison of rainfall and erosion in plot C and Control.

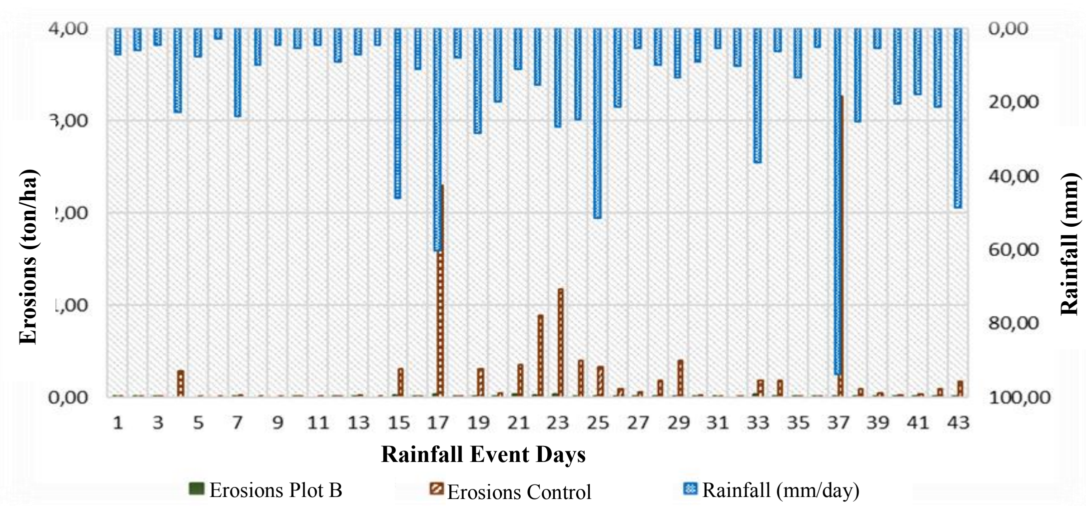

Figure 6. Comparison of rainfall and erosion in plot B and Control

B (combined hydro-mulch and geo-jute treatment) and the Control is presented in the graph in Figure 6. The measurements show that Plot B, in overall, reduced the amount of eroded soil compared to the Control plot, both at the beginning of planting and until harvest. The highest rainfall resulted in erosion in the Control plot amounting to 3.27 ton/ha, while Plot B with the combined hydro-mulch and geo-jute treatment resulted in erosion of 0.014 ton/ha. The low erosion amount in Plot B can be attributed to the geo-jute's ability to absorb water, preventing raindrops from directly impacting the soil. Additionally, the guar gum in the hydro-mulch helps the soil become more resistant to erosion due to its adhesive properties. This is in good agreement with Cereno *et al*. (2015), who stated that the mesh in geo-jute acts as a runoff breaker from heavy rains and dissipates the energy of surface runoff. The *T*-test analysis results showed that the *T*-calculated value (2.7) was higher than the *T*-table value (1.9), indicating that the erosion amount in Plot B with the combined hydro-mulch and geo-jute treatment significantly lower than that of the Control plot. The significance value was lower than 0.05, indicating a significant difference in erosion results.

3.4. Relationship of Rainfall and Treatment on Erosion

The relationship between rainfall and erosion amount is analyzed using regression correlation and determination tests. This analysis aims to determine the strength of the relationship between erosion and rainfall, as well as the extent of rainfall's impact on erosion for each treatment, indicated by the correlation coefficient and determination coefficient. Conservation measures like hydro-mulch, geo-jute, and the combination of the two can reduce erosion amounts, but each treatment has a different impact on erosion reduction. The comparison of rainfall and erosion amounts between treatments is presented in Figure 7.

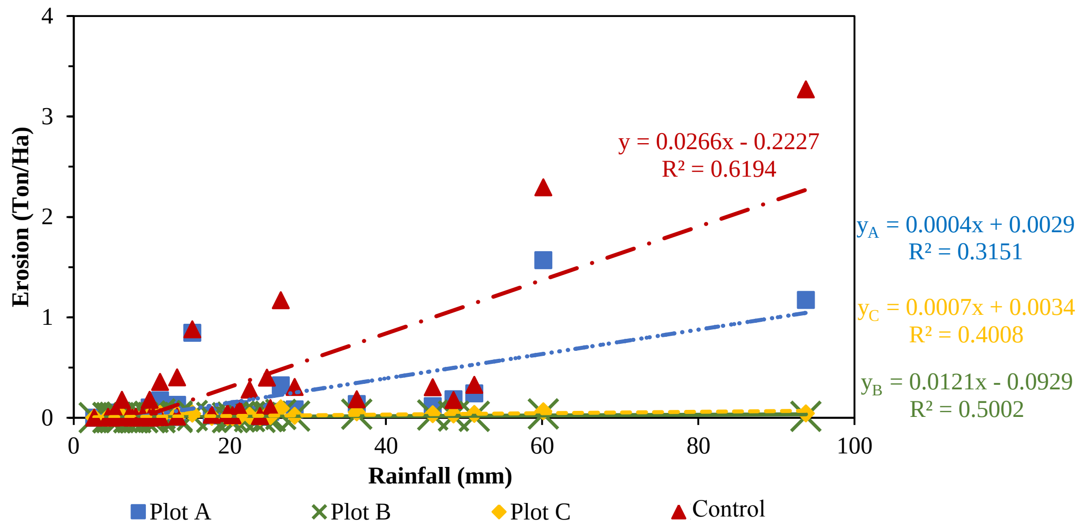

Figure 7. Comparison of erosion amounts between treatments

Regression analysis show that the Control plot has the strongest relationship with rainfall, with a correlation coefficient (R) of 0.79 and a determination coefficient (R^2) of 0.62. This indicates a strong relationship between erosion in the Control plot and rainfall. According to Sugiyono (2007), a correlation coefficient in the range of 0.60-0.799 is considered strong, meaning that the erosion in the Control plot increases with higher rainfall and vice versa. The determination coefficient value for the Control plot and rainfall is 61.94%, indicating that 61.94% of the erosion in the Control plot is influenced by rainfall, while 38.06% is influenced by other factors such as weed growth, canopy cover, and micro-relief. Micro-relief, which refers to surface undulations, is effective in reducing erosion by providing more time for water infiltration, although it is not effective in controlling soil loss during heavy or prolonged rainfall (Zhao *et al*., 2021). Increased rainfall intensity results in the highest amounts of eroded sediment, total runoff, and sediment concentration, followed by an increase and subsequent decrease in intensity (Mohamadi & Kavian, 2015).

Plot A, treated with hydro-mulch, has a correlation coefficient (R) of 0.71, indicating a strong relationship between Plot A and rainfall. The determination coefficient for Plot A is R^2 = 50.02%, meaning that 50.02% of the erosion in Plot A is influenced by rainfall. The difference in determination coefficients between Plot A and the Control plot is 11.92%, indicating that the hydro-mulch treatment reduces the impact of rainfall-induced erosion by 11.92%. This value is lower compared to other treatments because hydro-mulch is less resistant to high rainfall compared to geo-jute. Hydro-mulch with carboxymethyl cellulose (M-CMC), consisting of carboxymethyl cellulose (CMC) and polyacrylamide (PAM), has been found to significantly reduce long-term erosion (Yang *et al*., 2019).

Plot B, treated with a combination of hydro-mulch and geo-jute, has the lowest regression coefficient among the treatments at 0.561, indicating a moderate relationship. The determination coefficient for Plot B is R^2 = 31.51%, meaning that Plot B can reduce erosion due to rainfall by up to 30.43%. Plot C, treated with geo-jute, has a determination coefficient of R^2 = 40.08%. Plot C can reduce erosion due to rainfall by 21.86%. Adding hydro-mulch to Plot B reduces the amount of erosion due to rainfall by only 8.75%. Therefore, the combination of hydro-mulch and geo-jute is the most effective in reducing erosion due to rainfall. The use of geo-jute is increasingly effective in reducing erosion when applied to gentle slopes (Song *et al*., 2021). This indicates that using hydro-mulch and geo-jute together is more effective in reducing erosion compared to using them individually.

Based on observations in Figure 7, the erosion amounts in Plots B and C are not significantly different from Plot A. Plot A, treated with evenly spread hydro-mulch, still shows relatively high erosion compared to the geo-jute or the combination of hydro-mulch and geo-jute treatments. Understanding erosion processes and implementing erosion practices on slope and channel systems are important research areas: 1) the impact of upland runoff on lower slope erosion processes; 2) the relationship between hydraulic flow characteristics and erosion processes on the slope-channel system scale; 3) the physical mechanisms of different vegetation patterns on slope-channel erosion processes (Zhu *et al*., 2021).

The differences in erosion values can be attributed to the higher land cover percentages in plots B and C due to the application of 5-mesh geo-jute, which enhances the soil's ability to withstand erosion. This is consistent with the study by Song *et al*. (2021), which states that high slopes increase erosion. Higher land cover percentages reduce erosion potential as raindrops do not directly destroy the topsoil.

Table 1. *T*-Test analysis results for Plot A, Plot B, and Plot C

	Significance		
	Plot A	Plot B	Plot C
Plot A (Hydro-mulch)	-	0.014*	0.021*
Plot B (Hydro-mulch + Geo-jute 3cm x 3cm)	-	-	0.052
Plot C (Geo-jute 5cm x 5cm)	-	-	-

*Significant at 5% confidence level

The results of the statistical *T*-Test analysis are presented in Table 1. The table shows significant differences in erosion outcomes between Plot A compared to Plot B and Plot C. However, the erosion outcomes between Plot B and Plot C are not significantly different. This indicates that the alternative conservation technique combining hydro-mulch and geo-jute significantly reduces erosion compared to hydro-mulch alone. Geo-jute treatment alone also shows significant results compared to hydro-mulch alone, but the combination of hydro-mulch and geo-jute in Plot B does not significantly reduce erosion compared to geo-jute alone in Plot C. Three types of polymers, xanthan gum, guar gum, and anionic polyacrylamide polymers, can be used to enhance soil strength properties (Bozyigit *et al*., 2023).

3.5. Growth of Corn Plants in Response to Treatments

Corn plant growth parameters were measured by plant height. The height of corn plants was measured using a ruler or measuring tape from the base of the stem at ground level to the tip of the longest leaf. Each plot had a population of 42 corn plants. Plant height measurements were taken for all corn plants in each plot. The average weekly plant height is shown in Figure 8.

Measurement data show significant differences among treatment plots. Plot B, with the combination of geo-jute and hydro-mulch, had the highest average corn plant height of 185.4 cm at the end of the planting period. This was followed by Plot C with geo-jute treatment, with an average corn plant height of 175.6 cm. Growth measurements indicate that plant height within a plot, particularly in Plots B and C, was more uniform compared to Plot A and the Control plot, as shown by the standard deviation of each height measurement from 7 to 84 days after planting. Plots A and the Control plot had the lowest average corn plant heights of 157.4 cm and 150.3 cm, respectively, with larger standard deviations than Plots B and C. The lower plant height in these plots can be attributed to their outermost locations, making them more susceptible to pest attacks, as well as the higher erosion levels in the Control plot and Plot A, which could lead to reduced average corn plant growth.

The differences in plant yield may be attributed to variations in soil erosion occurring in each plot. This aligns with Nursa'ban (2006) statement that the topsoil layer is highly susceptible to erosion by rain, then carried away by surface runoff. Erosion occurring in the topsoil layer leads to soil infertility as only the subsoil remains, directly impacting plant productivity.

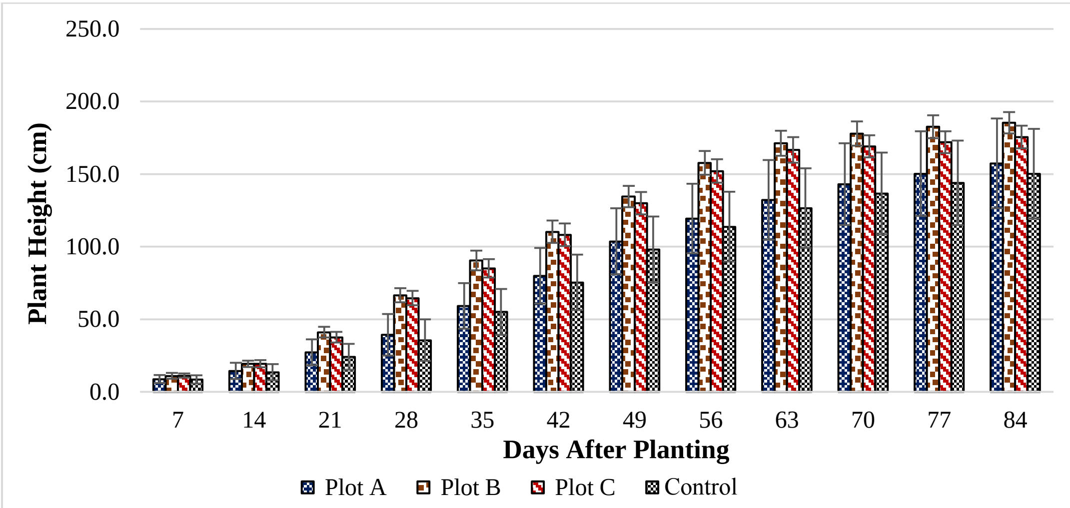

Figure 8. Average Corn plant height in each plot over days after planting

Plant productivity parameter was measured through data on corn cob weight after harvesting. The analysis of plant productivity measurement data shows highly varied values and does not reflect a positive relationship between growth and productivity, consistent with Masruhing *et al.*'s (2018) research, which generally indicates a positive relationship between growth and plant productivity, and Hubbert *et al.*'s (2012) statement, indicating that hydro mulch effectively reduces erosion, provides groundwater, and enhances plant growth response and recovery.

Corn plant yield measurements were conducted at the age of 90 days after planting. The purpose of measuring corn crop yields was to ascertain the influence of erosion on corn production in each treatment plot. Decreases in productivity in Plot A (hydro mulch plot) and C, lower than the Control Plot, may suggest that during flowering, climate or weather disturbances, especially air temperature, can impact the productivity of some corn plants (Herlina & Prasetyorini, 2020). Therefore, in subsequent research, detailed measurements of productivity parameters such as cob weight, cob length, and seed weight need to be conducted in accordance with the research. Plant productivity is also influenced by planting distance and seed quantity (Kantikowati *et al.*, 2022). The results of corn cob weight measurements at harvest are presented in Table 2.

Table 2. Measurement results of corn cob weight at harvest

Plot	Corn Weight (Kg/plot)	Growth Rate (cm/day)
Plot A (Hydro-mulch plot)	3.50	1.87
Plot B (Combined hydro-mulch and geo-jute with 3 cm x 3 cm mesh)	5.83	2.21
Plot C (Geo-jute plot with 5 cm x 5 cm mesh)	3.120	2.09
D (Control)	4.265	1.79

Table 2 shows a negative correlation between growth values and production quantity per plot (Plot A, Plot C, and Control), which contradicts some research findings stating that higher growth leads to better results. Growth parameters, such as leaf count, can reduce seed weight/production because the higher the leaf count, the greater the competition for photosynthates, leading to reduced carbohydrate reserves. Plant density and weeds cause optimum population photosynthesis activity, thus affecting plant metabolism processes that impact differences in plant production. This condition can be due to increased nutrient levels that can enhance weed growth, thus competing with main plants during corn cob filling (Novrika *et al.*, 2016). One growth parameter, canopy density, results in lower yields at higher plant densities compared to lower plant densities, possibly because the leaves in that population shade each other, allowing only the upper leaves to receive sunlight (Wahyudin *et al.*, 2016; Kartika, 2018). Therefore, further studies need to be conducted, especially regarding plant production parameters.

4. CONCLUSION

Alternative conservation techniques such as the application of hydro mulch and geo-jute have been proven to reduce the amount of erosion caused by rainfall. The combination of hydro mulch and geo-jute in Plot B shows the most optimal combination in reducing erosion, with a decrease of 31.51%, and the t-test results show significant values (significance value of 0.014). Plot C, treated with geo-jute, can reduce erosion by 21.86% with a significance value of 0.021, and Plot A, treated with hydro mulch, can reduce erosion by 11.92%, but statistically shows no significant difference. The application of alternative conservation techniques, a combination of hydro mulch and geo-jute in Plot B, has been proven to increase plant height and corn crop yield. Plot B, with the combination treatment, achieved the highest average plant height at 185.4 cm and the highest crop yield at 5.83 kg.

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