Analysis of Surface Runoff at Oil Palm Plantation Areas from the Uses of Bio-Pore Infiltration Holes (BIH)

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Abstract— Oil palm (*Elaeis guineensis*) is a particular plantation commodity of Indonesia, especially Aceh province. Therefore it is crucial to support the sustainability of the land even though it is used for the plantation. One of the ways is to continue to make conservation efforts on sloping land that is used as the cultivation of oil palm. The difficulty in cultivating on sloping land is keeping the area from the phenomenon of surface runoff due to rain. High surface runoff can result in erosion and leaching of nutrients in the soil. Therefore, this paper presents an application of biopore infiltration holes (BIH) to be able to control surface runoff in oil palm plantations. The biopore infiltration hole was filled by compost from oil palm empty fruit bunch (EFB). The experimental plots with and without the use of biopore infiltration holes was experimented to determine its effectiveness. The characteristics of biopore infiltration holes are 10 cm in diameter, 60 cm in depth with a total of 5 pieces per area of 135.15 m^2. The study was conducted in three months in 2017 to observe surface runoff caused by rainfall. The results show that the total volume of surface runoff in experimental plots using biopori infiltration holes can reduce surface runoff by 26.50%. It can be a reference for oil palm researchers and farmers to be able to apply biopori infiltration hole conservation methods to reduce surface runoff in oil palm plantations.

Index Terms— Aceh, biopore infiltration hole (BIH), empty fruit bunch, oil palm plantation, surface runoff.

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1 Introduction

High surface runoff can generate erosion, low infiltration rate, percolation and leaching of nutrients at the soil surface if not adequately controlled. It can occur on land designated for residential [1, 2] and agriculture [3, 4]. Land that will be used for residential can cause flooding and landslides at certain times if runoff surfaces are not controlled [1, 5]. In the field of agriculture, it will cause soil nutrient degradation and soil erosion which can cause the land to become marginal land [6, 7]. The results of previous studies show that if agricultural land has become marginal, the application of technology to be able to repair it will be increasingly difficult [6, 8]. Therefore, some researchers try to find a solution so that agricultural land is independent of the influence of the surface runoff.

Surface runoff is rainwater that cannot enter again into the soil or basin and eventually flows directly into the river or sea. The magnitude of surface runoff determines the level of soil damage effect to erosion and flooding. Factors that influence the magnitude of surface runoff according to several researchers [9-11] are forest land cover, bare land cover, and settlement cover. According to Erena and Worku [12], conservation of bare land and rooftop rainwater harvesting are proposed for the best overcoming surface runoff. This research report also states that the rainfall-runoff relationships show that an increase in surface runoff is a point of concern in many catchments around the world. Hence, rainfall-runoff relationships must continue to be studied, especially for oil palm plantations.

Oil palm plantations are one of cultivation that requires intensive agricultural technology both off-farm and on-farm [13, 14]. Oil palm cultivation can be done on all types of land. However, the environmental aspects of this application are important to study so as not to damage the environment. Oil palm cultivation on steep topography land can be taken by applying technology soil and water conservation. One of the methods that can be applied to reduce the runoff caused by planting oil palm in areas is by carrying out conservation actions both vegetatively [15, 16] and mechanically [17, 18].

Vegetative conservation on oil palm plantations is done by cultivating cover crops from Legumes. It makes the raindrops unable to directly touch the ground so that the impact that causes soil surface erosion can be even smaller. On the other hand, the presence of legumes can increase the absorption of water into the soil vertically [19]. Besides being able to become a cover crop, this type of plant can improve soil nutrition by increasing the N-nutrient in the roots of the plant [16]. Therefore, the vegetative conservation method is very suitable for oil palm plantations whose plants require very high N-nutrients.

Mechanical conservation efforts that are mostly carried out on oil palm plantations as well as by farmers are making terraces. Terraces will cause the flow of water to discontinuous when runoff surfaces occur. It will cause the soil to have enough time to absorb water into the soil. However, the dimensions of the terraces are very dependent on the number of oil oil palm trees to be planted so that the amount of runoff surfaces is still occurring frequently. Other researchers tried to overcome this problem by designing holes in oil palm plantations called "rorak" holes or silt pit [18, 20]. The hole has dimensions of length, width, and depth of 3 m × 0.66 m × 0.75 m, respectively. It functions to hold water when it rains, so that surface runoff does not occur. However, if it rains too often, land in a hole will be saturated so that it causes water cannot enter into the soil again. Therefore, the method continues to be developed to overcome the saturation of water in the designed hole.

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From the phenomenon of previous research, it is known that conservation on oil palm plantations is important to be implemented so that cultivation can continue and the land is not degraded. From previous research, it was known that the conservation method carried out was still separate between vegetation conservation methods and mechanical conservation. Hence, in this study, researchers combined two conservation techniques, namely vegetative conservation with cover crops (*Mucuna pruriens* L.) (cover crops) and mechanical conservation namely biopore infiltration holes (BIH) filled with compost from oil palm empty fruit bunches (EFB). The application of biopore infiltration technology aims to increase the number and pore area in the soil. With the increase in the pore area, the volume of water infiltration into the soil will increase so that it can reduce runoff and erosion. Therefore, this study aims to understand the effect of the application of BIH on surface runoff in the oil palm plantations.

2 Material and Methods

2.1 Description of the Research Area

This research was conducted at the oil palm plantation in Sultan Daulat District, Subulussalam City, Aceh Province, Indonesia. The research was conducted from February to May 2017. The geographical location of the study is located at position 02 ° 27 ’30" - 03 ° 00 ’00" North Latitude and 0 97 ° 45 ’00’ - 98 ° 10 ’00" East Longitude with an area of 13,910 ha.

The soil properties of the land used in this study are presented in Table 1. The sand, silt and clay soil fractions in the study locations were 33%, 46%, and 21% respectively. Based on these proportions it can be concluded that the type of soil is included in the clay texture class. The porosity of the land at the study location was 51.07%. Soil permeability at the study site was 2.26 cm·h^{-1}. The content of soil organic matter before the research was carried out was 1.32%.

Table 1. Hydrology of the research area

No	Criteria	Value
1	Texture	33% sand, 46% silt, 21% clay
2	Permeability	2.26 cm·h^{-1}
3	Water transfer rate	0.15-0.30 in·h^{-1}
4	Porosity	51.07
5	Organic matter	1.32
6	Potential Runoff	-
7	Land Hydrology Group	-

2.2 Measurement Procedure

This research was conducted by direct observation in the field. There are two research plots, namely (i) plots on oil palm land with cover crops (*Mucuna pruriens* L.) and (ii) plots on oil palm land that have cover crops of cover crops (*Mucuna pruriens* L.) with biopori infiltration holes (BIH). The plot was designed on a 5-year-old oil palm with a slope of around 27.78%; each plot area was 135.15 m2 with a rectangular area of 132 m2 and a trapezoidal area of 3.15 m2. The distance between two plots is 50 cm. The plot description can be presented in Figure 1. Data measurement is carried out every 24 hours during each rain event. Rainfall is measured using the automatic weather station (AWS).

The runoff plot is designed with a boundary using an iron plate which serves to limit surface runoff. The plate has a height of 20 cm where 10 cm will be plugged into the ground. A 50-liter capacity tank was placed at the end of the experimental plots to accommodate runoff. Biopore infiltration holes are mounted six holes that are 10 cm in diameter. The distance of the hole to the center of the oil palm plant is 4.5 m from the front and 3.8 m from the side. The biopore hole is filled with 3 kg of EFB compost.

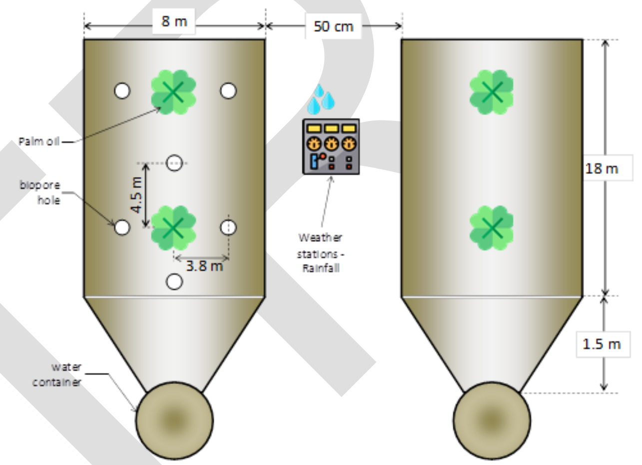

Fig. 1 Experimental research plot

The volume of surface runoff (V_r) is measured for each rainfall event in each plot by measuring the volume of water in the reservoir (V_1) and the sediment soil (V_t). The volume of surface runoff can be determined following Equations 1 and 2 [21].

$$V_r = V_1 - V_t \quad (1)$$

$$V_t = \frac{m}{B_d} \quad (2)$$

where V_r-volume surface runoff (cm^3); V_1-volume of water in the reservoir (cm^3); V_t-volume of sediment (cm^3); m-the soil mass (gr); B_d-bulkdensity ($gr{\cdot}cm^{-3}$).

3 Results and Discussion

3.1 Rainfall Measurement

Rainfall is one type of precipitation in the tropics and is a controlling factor for the hydrological process. Indonesia is in the tropical climate zone. This type of climate usually has a characteristic of seasonal variations, namely high rainfall in the rains season and deficient rainfall in the dry season. Figure 2 shows a graph of rainfall that occurred during the study. During the study, there were 30 rain events with a total rainfall of 779.4 mm. Relative rainfall varies from the highest rainfall of 127 mm, and the lowest rainfall is 1.8 mm. The average rainfall during the study was 25.98 mm.

3.2 Surface Runoff each Experiment Plot

The application of biopore infiltration holes turned out to produce different surface runoff without the mounting of biopore infiltration holes. The application of biopore infiltration holes results in the lower surface runoff than runoff in plots without biopore infiltration holes. Surface runoff in the two experimental plots is shown in Figure 2. These results indicate that the surface runoff produced in plots without biopore infiltration holes is on average higher by 0.008 mm compared to plots using biopore infiltration holes. It indicates that there is an effect of reducing the magnitude of runoff with the application of biopore infiltration holes.

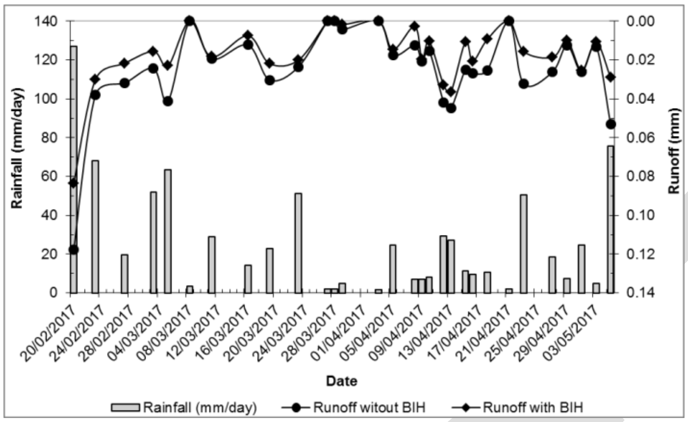

Fig. 2 Rainfall and surface runoff measurement

If observed from the total surface runoff that occurred during 30 rain events between plots without using biopore infiltration holes using biopore infiltration holes there was a difference of 0.23 mm. It indicates that overall surface runoff reduction was 26.50% by applying the biopore infiltration hole. It is thought to be caused by an increase in the content of organic material in the biopore holeThe results showed an increase in the content of organic matter in the experimental plots with biopore infiltration holes become 59.51%. It results in increased effectiveness of BIH in infiltration, besides being a reservoir of water can also increase nutrient levels of soil and plants [22].

3.3 Correlation between Rainfall and Surface Runoff

Rainfall that exceeds infiltration capacity will cause surface runoff and it is little will enter the soil as groundwater. The increase in surface runoff in line with the increase in rainfall can be seen in Figure 3. Rainfall that occurs in a long time will produce a large surface runoff even though it still depends on the intensity of the rainfall and the quantity of rainfall that happens. Extreme events during rain were 127 mm and produced surface runoff of 0.118 mm in plots without using biopore infiltration holes. This is caused by rainfall that occurs in a long time and is close to a constant infiltration capacity resulting in high surface runoff. It is in line with the results of several researchers [23, 24] which states that the surface runoff is very closely related to the intensity of rainfall. Therefore, methods to reduce the impact of the rain intensity of essential to continue being developed.

The coefficient of determination of the relationship between rainfall and surface runoff that occurs in plots without using biopore infiltration holes is 76.31%. However, the coefficient of determination of rainfall relations with surface runoff in plots that have biopore infiltration holes is 69.00%. It indicates that there is a strong relationship between rainfall and runoff in plots without using biopore infiltration holes. Furthermore, this relationship begins to decrease if compared with the experimental plot that uses biopore infiltration holes. It is thought that it was caused by runoff in the experimental plot using biopore infiltration holes not only affected by the magnitude of rainfall. It is in line with the results of the research [25] which reported that the phenomenon of the decrease in the relationship between rainfall and runoff can be caused by factors such as increased organic matter, changes in physical, mechanical and chemical properties of the soil content. It makes the soil in the plots that use biopore infiltration holes better at absorbing water than without using biopore infiltration holes. Thus, it causes lower runoff.

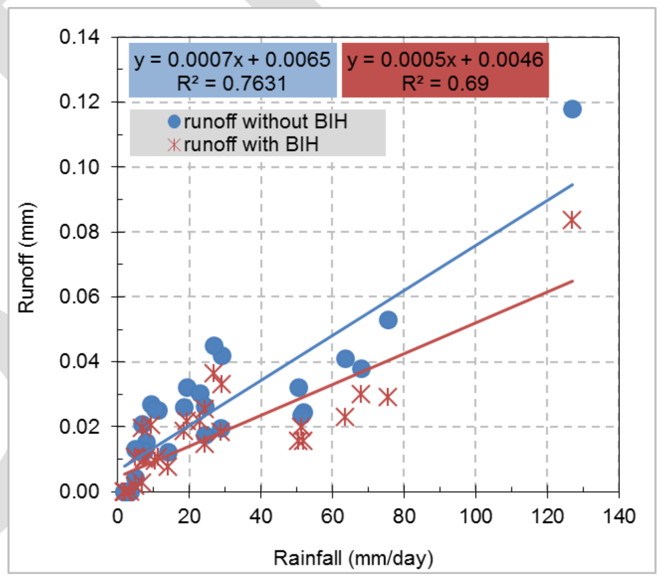

Fig. 3 Correlation rainfall with surface runoff

4 Conclusion

The application of biopore infiltration holes (BIH) filled with empty fruit bunch (EFB) compost can reduce surface runoff until 26.50%. Decreasing the quantity of runoff occurs because of the ability of the soil to enter water into the soil through biopore infiltration holes. The rainfall that occurs in the experimental plot correlates with the amount of surface runoff in the plot with BIH and without BIH. The coefficient of determination with BIH is 9.58% less than without using BIH. It shows that the occurrence of surface runoff in the use of BIH can reduce its association with rainfall. Therefore, it can be concluded that efforts to control surface runoff by applying biopore infiltration holes are quite effective in reducing surface runoff on oil palm plantation areas that are steep topographical. It can be a reference for oil palm farmers to control adverse runoff on their oil palm plantations.

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Nomenclatures

V_r Volume surface runoff *(cm³)*
V_1 Volume of water in the reservoir *(cm³)*
V_t Volume of sediment *(cm³)*
m The soil mass *(gr)*
B_d Bulkdensity *($gr \cdot cm^{-3}$)*
R^2 Coefficient of determination

Abbreviations

BIH Biopore Infiltration Holes
EFB Empty Fruit Bunch
AWS automatic weather station

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