Silt Pit Application In Tropical Palm Dates Plantation: Case Study In Aceh Province, Indonesia

Devianti, Yuswar Yunus, Ramayanty Bulan, Dewi Sartika T., Agustami Sitorus

Abstract: Palm date (Phoenix dactylifera L.) began to be popularly developed in the wet tropics, especially in Aceh Province. The cultivation is carried out on sub-marginal land that cannot be grown by land cover crops with sloping land more than 10□. Without conservation efforts, gradually, the area used will experience degradation due to monoculture cultivation methods. The unavailability of data and conservation field testing in tropical date palm plantations makes it difficult for decision-makers and researchers to determine appropriate land conservation efforts. Therefore, this study aims to analyze the effect of one of the mechanical conservation methods in the form of silt pits in date palm plantations that are cultivated in the tropics. Two experimental plots (with and without using silt pit) with an area of 88 m2 each was designed at the date palm plantation in Blang Bintang sub-district, Aceh Besar Regency, Aceh Province. The parameters of natural rainfall, surface runoff, and erosion rates are measured, analyzed, and compared during the experiment. The results show that natural rainfall has a very significant effect in causing surface runoff and erosion rates that occur in date palm plantations. The application of the silt pit has been able to reduce the effects of surface runoff and erosion rates of 88.55%, 85.42%, respectively. A model for estimating erosion rates that occur on date palm plantations has also been developed with a reliable level of accuracy.

Index Terms: Conservation, Erosion rates, Natural rainfall, Palm, Surface runoff.

1 INTRODUCTION

At present, the date palm plant (Phoenix dactylifera L.) is widely cultivated in Indonesia, especially in Aceh Province. Based on various local media sources, the date palm plantation area in Aceh Province in 2019 is estimated to reach 100 ha and possibly more. Date palm plantations are cultivated on sub-marginal lands that cannot be grown by other plants and on sloping land more than 10°. The condition of such cultivated land according to Cebro and Sitorus [1], is challenging to apply agricultural technology from land preparation to postharvest [2]. Besides, these factors also resulted in date palm plantations growing monoculture (Figure 1). The accumulation of these factors continuously raises the potential for more considerable degradation of date palm plantations given the amount of rainfall in Aceh Province, which is very high. Indonesia, which is in the wet tropics region, makes Aceh Province get very high natural rainfall. A recent study observed that a total of 78.74 mm of rainfall during an 8-day period caused a greater than 50% loss in date palm yields while 86.36 mm of rainfall in 10 days led to 15% losses in date palm farms in some countries [3, 4]. The impact that occurs with climatic conditions can also increase environmental damage in the form of erosion of the topsoil due to rainfall. Therefore, it is crucial to find the right conservation effort so that it can reduce the impact of environmental damage, especially on date palm plantations.

***Fig. 1**. Condition of tropical date palm plantations in Aceh Province*

In general, soil and water conservation methods that are known today include vegetative conservation methods, technical conservation methods, mechanical conservation methods, and chemical conservation methods. Several studies on the application of conservation methods on agricultural land have been carried out. Jaya, et al. [5] investigated surface runoff and erosion rates occurring at an oil palm plantation in Jalemu Watershed, Central Kalimantan Province. The results show that the surface runoff and erosion rates that occur are 1.98 L/m^2, 46 kg/ha, respectively. This value is significantly higher than the condition; it should be if the land is in a conservation forest condition. Other studies by Sung, et al. [6] investigating several conservation methods that can be applied in oil palm plantations. These methods use mulching of empty fruit bunches (EFB) and EFB mat (Ecomat), construction of soil trenches (silt pits) as soil water and nutrient conservation methods. In the three years of observation, the results were reported that the type of conservation treatment in the form of a silt pit was still useful in the effort to deal with surface runoff even though it was always mentioned to require

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a higher cost to carry out its maintenance. However, this method has the potential to be developed for other types of perennial plants, especially from the Palmae family. Silt pitting is a soil and water conservation method used in non-terraced plantations on sloping or steep land. According to Moradi, et al. [7], Silt pitting is often recommended as an effective method as a soil water and nutrient conservation practice. However, some researchers have been carried out to confirm their effectiveness. In the setting mentioned that silt pitting is constructing pits or trenches in different sizes and shapes across the hill slopes to reduce the length of a slope so that it decreases the volume and velocity of runoff and to collect runoff water. At the end of the paper, they reported that silt pitting is a productive soil and water conservation method for a reduction in surface run-off and soil loss. It is also a powerful method to conserve water and to improve soil water content. This reinforces that the silt pit method works well to reduce the impact of erosion rates. On the one hand, a study of land suitability for date palms has been investigated by Shabani, et al. [3]. The results show that the Southeast Asian region, especially Indonesia, is not included in the productive date palm cultivation region since the area tends to have a wet tropical climate. It is coupled with the average sloping land for the cultivation of dates is recommended to be at a slope less than 10° and in the temperature range 39-46°C. On the other hand, efforts to conserve land to improve the quality of the soil so that it can be cultivated using palm frond mulch have also been investigated by Ahmed and Al-Dousari [8]. The results show that the use of mulch made from date palm fronds can improve the water use of the land. However, both of these studies were carried out in the dry tropics. From the literature review above, it is known that the silt pit can be used as a mechanical conservation method in Palmae family type plantations. Land conservation studies for date palm plantations in tropical regions, especially in Aceh Province, have not been investigated in depth. Therefore, this paper aims to analyze the effect of mechanical conservation methods in the form of silt pits in date palm plantations that are cultivated in the tropics. The parameters of natural rainfall, surface runoff, and erosion rates are measured, analyzed, and compared to produce comprehensive research. Meanwhile, one model for predictions erosion rates using the USLE method is put forward. It is hoped that the information of this paper may promote the use of mechanical conservation in the form of silt pits in date palm plantations that can be applied to maintain environmental sustainability and the benefits of the research of agricultural sources, especially for the conservation of agricultural land.

2 MATERIALS AND METHODS

2.1 Site Description

This research was conducted at PT. Kurma Lembah Barbatee Plantation located in Blang Bintang District, Aceh Besar Regency, Aceh Province. Coordinate point 5.54° Lattitude, 95.51° Longitude (Figure 2). The date palm plantation area is 320 ha. Soil type at the study site was ultisol type. Palm date on this plantation has a spacing of 8 m × 8 m. The study was conducted for three months and began in March until May 2019.

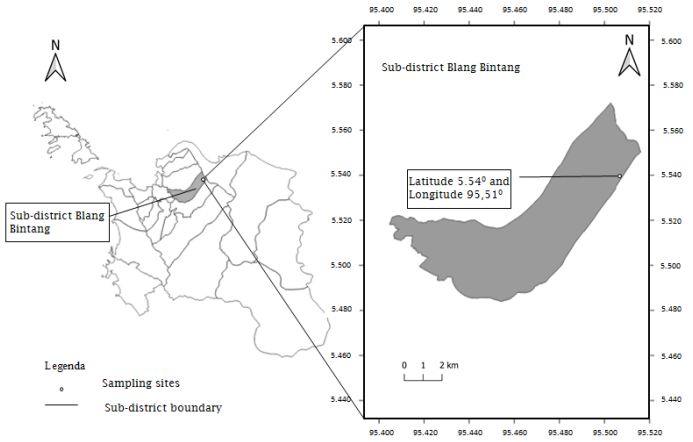


***Fig. 2**. The geographic location of the study region sites*

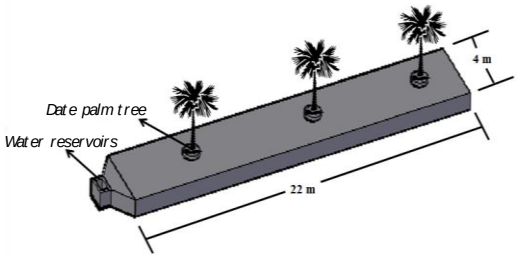
2.2 Determination of surface runoff and erosion rates

This research was carried out in date palm plantations with land topography 25% towards the east. The experimental plot consisted of two: a plot with silt pit and erosion plots without a silt pit (Figure 3). Each experimental plot contained three date-old palm trees. The length and width of the research plot was 22 m × 4 m. Barriers with iron plates are provided around the test plot, so they are not contaminated with the surrounding land. A water reservoir is placed at the end of the lowest part of each experimental plot. The volume of surface runoff was analyzed for each rain event. Rainfall data were recorded during the study using a rain gauge (ombrometer) tipping bucket. Each plot was measured by the volume of collected water and land that had settled in the reservoir. The amount of surface runoff is calculated using Equation 1. Erosion that occurs is also computed using Equation 2.

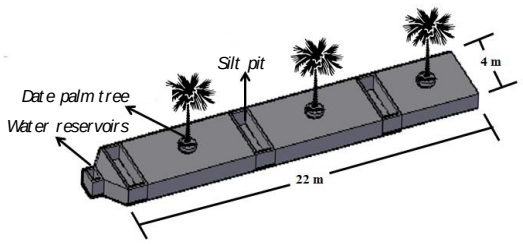
$$V_{SR} = (h \cdot A) - \left(\frac{W_S}{BD_S}\right) \quad (1)$$

$$ER = A \times \left(\frac{C}{B}\right) \quad (2)$$

Where, V_{SR}–volume surface runoff (m^3), h–high water in the reservoir (m), A–area of the water reservoir (m^2), W_S–weight of soil in the reservoir (g), BD_S–soil bulk density (g/m^3), ER–erosion that occurred in the experimental plot (g), A–the weight of the soil obtained from the reservoir (gr), B–sampling of wet soil weight (gr), C–sampling of dry soil weight (g).



(a)



(b)

Fig. 3 *The experimental plot setup (a) without silt pit (b) with silt pit*

Calculation of estimation of erosion of the USLE method is carried out to model the erosion of experimental events with predicted erosion that will occur. Some of the studies that have conducted this get a good estimation model for this. Estimation of USLE erosion can be done using Equation 3 through Equation 6. Plant management factors and soil conservation method factors are predicted based on direct observations in the field which are then adjusted to the land use and conservation tables (Asdak [9] and Hammer 1981 in Pribadi, et al. [10].

$$ER_{USLE} = R \times K \times LS \times C \times P \quad (3)$$

$$R = \frac{2.467(P_d)^2}{0.02727P_d + 0.725} \quad (4)$$

$$K = \frac{1.292\left[\left((2.1 \cdot M^{1.14} \cdot 10^{-4}) \times (12-a)\right) + (3.25(b-2) + 2.5(c-3))\right]}{100} \quad (5)$$

$$LS = L^{1/2} \cdot \left(0.00138S^2 + 0.00965S + 0.0138\right) \quad (6)$$

Where, ER_{USLE}–erosion rates prediction using USLE method (kg/ha), R–coefficients of rainfall erosivity, K–coefficients of soil erodibility, LS–coefficients of sloping land, C–coefficients of plant management, P–coefficients of soil conservation method, M–percentage of particle size (%), a–percentage of organic matter (%), s–coefficient of soil structure, c–soil permeability, L–slope length (m), S–sloping land (%).

3 RESULTS AND DISCUSSION

3.1 Natural rainfall and surface runoff events in the experimental plot

Data on natural rainfall and surface runoff that occurred in the two experimental plots during the study are presented in Figure 4. The most considerable rainfall occurred on April 26 at 42.04 mm and the smallest at 1.27 mm on March 27. The average rainfall during this experiment was 14.11 mm per day. The total rainfall during this study was 423.18 mm. This rainfall is included in the medium category for the tropics [11, 12]. However, an average rainfall of that size according to Jalali [13] could have caused severe damage to agricultural cultivation land if not followed by conservation efforts.

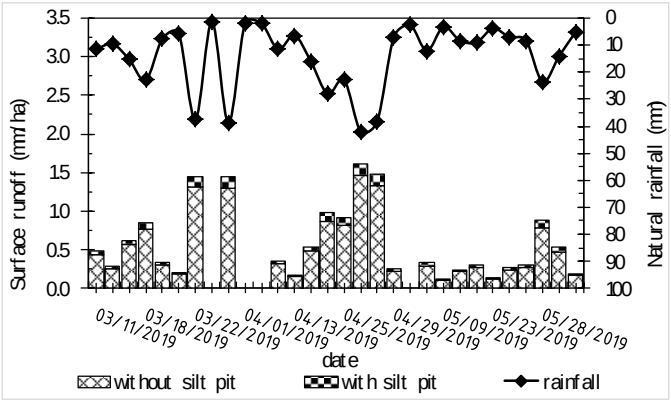


Fig. 4*. Surface runoff and natural rainfall occurred during the experiment*

The highest surface runoff events occurred in the maximum rainfall conditions that are equal to 1.46 mm/ha (plot without silt pit) and 0.16 mm/ha (plot with silt pit). The lowest surface runoff events occur in minimal rainfall conditions that do not cause surface runoff (both plots without and with silt pits). The average surface runoff during the experiments on plots with and without silt pit was 0.05 mm/ha, 0.46 mm/ha, respectively. Surface runoff without the use of silt pit is categorised as high for annual crop cultivation. The results are in line with research Jaya, et al. [5] which received a surface runoff value of 1.98 mm/ha for five-year-old oil palm plants under certain experimental conditions.

3.2 Comparison of surface runoff in the experimental plot

Natural rainfall has a significant role in causing surface runoff. These conditions also depend on the intensity and duration of rain that occurs in certain areas. Date palm plantation areas in tropical regions make surface runoff unavoidable. The weak ability of date palm plants to absorb water is also a contributing factor [14-16]. Therefore, mechanical conservation efforts on date palm plantations in the tropics are essential. Surface runoff measurements that are affected by natural rainfall are presented in Figure 5. It is conducted to be able to make the best decisions in the application of land conservation in the date palm plantation. The results of this study indicate that surface runoff has a very close relationship with natural rainfall. Surface runoff increases linearly with increasing natural rainfall. The relationship is presented in Equation 7 in plots without using silt pits and Equation 8 in plots using silt pits. It shows that natural rainfall greatly influences the surface runoff that occurs in tropical date palm plantations. It is estimated to be due to the ability of the date palm tree to be able to absorb very limited water.

$$SR_{WOSP} = 0.035R_F - 0.035 \quad R^2 = 0.9895 \quad (7)$$

$$SR_{WSP} = 0.004R_F - 0.003 \quad R^2 = 0.9922 \quad (8)$$

Where, SR_{WOSP}–surface runoff without silt pit (mm/ha), R_F–natural rainfall (mm), R^2–coefficient of determination, SR_{WSP}–surface runoff with silt pit (mm/ha).

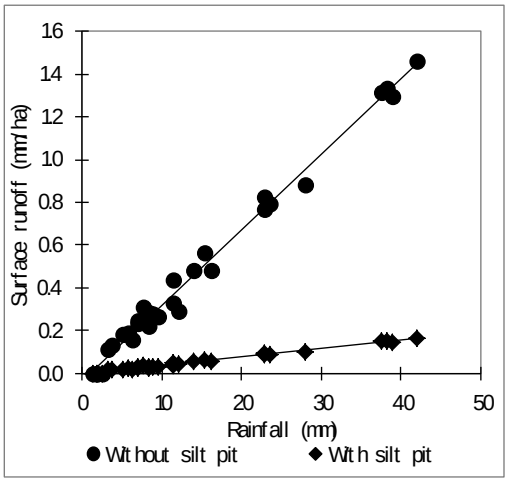


Fig. 5*. The rainfall vs surface runoff relationship occurred in the two*

The application of silt pit conservation method according to several research results [17-20] shows that it can reduce the height of surface runoff. It is in line with the results of this study which uses silt pit to minimise surface runoff in tropical date palm plantations. The average difference in a surface runoff with and without using a silt pit is 0.41 mm/ha. Overall, the surface runoff that occurred in the experimental plot using silt pit was 88.55% smaller compared to the plot without using silt pit. It shows a very significant reduction from the application of silt pit in tropical date palm plantations.

3.3 Comparison of erosion rates in the experimental plot

Surface runoff in tropical date palm plantations results in the carrying of topsoil material to a lower place. This phenomenon can be seen with the erosion parameters measured from the results of this study (Figure 6). The results show that the most significant erosion occurs in conditions of maximum rainfall also that is equal to 271.92 kg/ha (without silt pit), 39.64 kg/ha (with silt pit). That is thought to be due to the narrow canopy area of the date palm tree so that it cannot reduce the impact force of rainwater before it reaches the ground surface. The impact of large rainwater on the ground causes the topsoil to be destroyed so that the flowing rainwater easily carries it. It is supported by the results of research Keesstra, et al. [21] which states that soil surfaces that are not protected by plant canopy will have more potential for erosion due to the vertical force of impact from raindrops directly. Natural rainfall has a linear relationship with the amount of erosion that occurs in tropical date palm plantations. Increased natural rainfall will increase erosion in both trial plots. The relationship between natural rainfall and erosion rates is presented in Equation 9 (without silt pit) and Equation 10 (with silt pit). This shows that there is a very close relationship between natural rainfall and erosion rates in tropical date palm plantations with the coefficient of determination with and without the use of silt pits of 0.9566 and 0.9971, respectively. This is in line with the results of several studies [5, 22] which found a close relationship between rainfall and erosion rates in various experimental conditions that have been carried out.

$$ER_{WOSP} = 6.15R_F - 11.4 \quad R^2 = 0.9711 \tag{9}$$

$$ER_{WSP} = 0.78R_F - 1.50 \quad R^2 = 0.9566 \tag{10}$$

Where, ER_{WOSP}–erosion rates without silt pit (kg/ha), ER_{WSP}–erosion rates with silt pit (kg/ha).

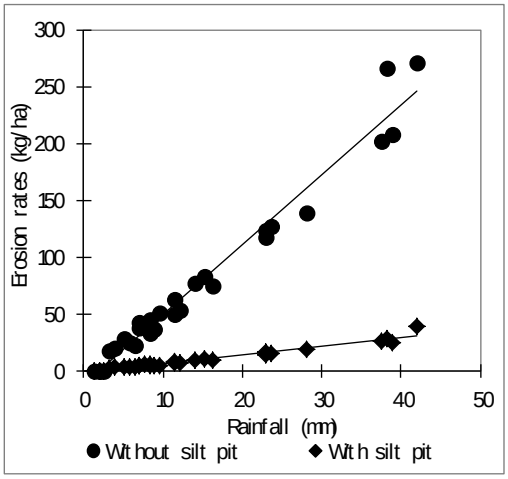


Fig. 6*. Relationship of rainfall vs erosion rates occurred in the two experimental plots*

Silt pit conservation has a very significant effect on reducing erosion on agricultural land. The average erosion difference between experimental plots with and without using silt pit is 65.90 kg/ha. In the experimental plot using silt pit, there was a reduction in erosion rates of 85.42% compared to using silt pit. This is caused by the trapping of surface runoff that carries erosion material to provide an opportunity for rainwater to infiltrate into the soil. The erosion material will settle and become sediment in the silt pit. Furthermore, the study of Braga, et al. [23] states that the erosion sediments can be reused to cultivated tillage fields.

3.4 Relationship between surface runoff and erosion rates

The relationship between surface runoff and erosion rates that occurred in the plotted experiment is presented in Figure 7. It is found that there is a very close relationship between surface runoff and erosion rates in both trial plots. Erosion rates increase with increasing linear surface runoff in both test plots. Relationships for experimental plots without using silt pit are presented in Equation 11. Relationships for experimental plots using silt pit are shown in Equation 12. Equation 12 and Equation 8 can explain that the same erosion rates as an experiment plot without silt pit will give surface runoff and natural rainfall of 1.39 mm/ha, 349.29 mm, respectively or greater than 8.31 times the natural rainfall that occurred in this study. It proves that the application of silt pit can reduce the impact of erosion by 8.31 times in tropical date palm plantations. It has been more significant than the results of a study conducted by Jaya, et al. [5] which obtain reduction impact of 3.54 times in oil palm plantations.

$$ER_{WOSP} = 174.17SR_{WOSP} - 5.21 \quad R^2 = 0.9772 \tag{11}$$

$$ER_{WSP} = 195.70SR_{WSP} - 0.92 \quad R^2 = 0.9635 \tag{12}$$

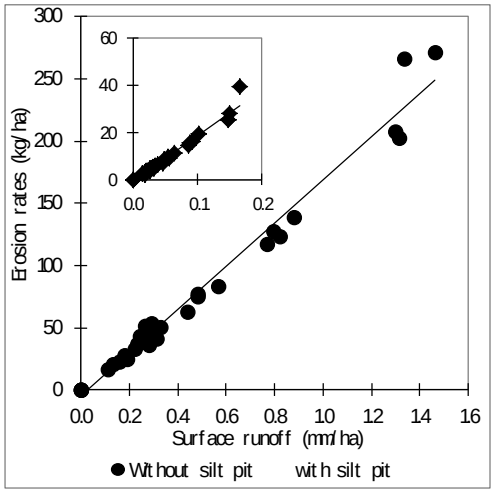


***Fig. 7**. Relationship between surface runoff vs erosion occurs in the two experimental plots*

3.5 Model estimation of erosion rates using USLE methods

A model of the relationship between measured natural rainfall in the experimental plot and the estimated erosion rates using the USLE method for each experimental plot has been developed (Figure 8). A model of the relationship of natural rainfall with experimental plots with and without silt pit is presented in Equation 6 and Equation 5. The results show that the USLE erosion estimation method has a very close relationship with natural rainfalls that occur in the experimental plot. The result of USLE erosion estimation is 78.92% smaller than the actual erosion value obtained in the experimental plot without silt pit and 56.61% smaller in the experimental plot with silt pit. The results of this study are in line with the findings of Rizeei, et al. [24] who reported that the use of USLE erosion estimation methods was smaller than the erosion conditions obtained through experimental results. It was estimated because the precision of the type of plant coefficient and the coefficient of the type of soil conservation method used on the land for the USLE equation are therefore necessary to calibrate the value of these factors for further research.

$$ER_{WOSP-USLE} = 1.36R_F - 7.61 \quad R^2 = 0.946 \qquad (13)$$

$$ER_{WSP-USLE} = 0.41R_F - 2.28 \quad R^2 = 0.946 \qquad (14)$$

Where, $ER_{WOSP\text{-}USLE}$–erosion rates prediction using USLE method without silt pit (kg/ha), $ER_{WSP\text{-}USLE}$–erosion rates prediction using USLE method with silt pit (kg/ha).

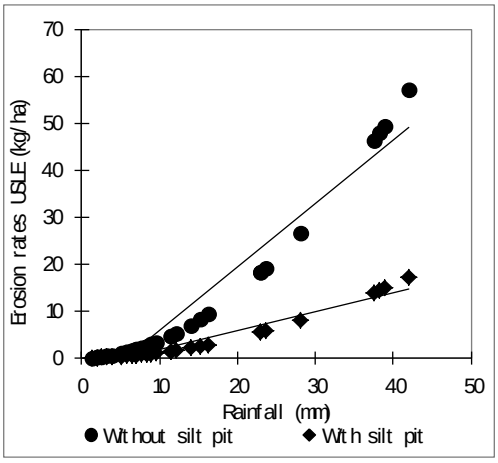


***Fig. 8**. Relationship between rainfall vs erosion rate through the USLE approach*

The relationship between experimental erosion rates and estimated erosion of the USLE method is presented in Figure 9. From these results, Equation 15 and Equation 16 are obtained which can improve the accuracy of the erosion estimation of the USLE method to have a coefficient of determination respectively with and without silt pit is 94.23%, 94.98 %. These equations can be a reference in estimating erosion in date palm plantations that use the mechanical conservation method of silt pit, especially for the tropics. Some parameters needed by the USLE erosion estimation method include erosivity, erodability, slope length and slope, coefficient of plant type and coefficient of kind of method conservation of land used on land [24-26].

$$ER_{WOSP-USLE} = 0.22ER_{WOSP} - 4.89 \quad R^2 = 0.9498 \qquad (15)$$

$$ER_{WSP-USLE} = 0.51ER_{WSP} - 1.38 \quad R^2 = 0.9423 \qquad (16)$$

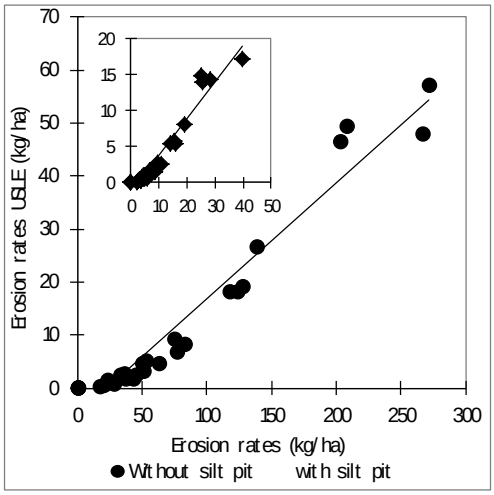


***Fig. 9**. The erosion relationship model of experimental results with the USLE estimation method*

CONCLUSION

An in-depth study of the effect of silt pit application on tropical date palm plantations, especially in Aceh Province. The parameters of natural rainfall, surface runoff and erosion rates have been measured with a maximum magnitude of 42.04 mm, 1.46 mm/ha, 271.92 kg/ha, respectively. Application of

tropical palm plantation silt pit has been able to reduce surface runoff by 88.55%. The reduction in erosion rates on the use of silt pit was 85.42%. A model for estimating erosion rates on date palm plantations has also been developed with an average coefficient of determination above 90%. This shows that the erosion prediction model that was built can be used to make decisions in efforts to conserve silt-based land.

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