

DOI: 10.17951/pjss/2016.49.2.223

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SOIL CONSERVATION BY VEGETATIVE SYSTEMS IN OIL PALM CULTIVATION

Received: 2016.03.17

Accepted: 2017.02.02

Abstract. In Indonesia, agricultural land for oil palm plantation is mostly placed on slope areas. Erosion carries down surface soil layers which are generally fertile and rich in organic matter and nutrients, causing the loss of plant nutrients. Cover crops provide protection against the destruction of soil aggregates by rain and runoff. This research aims to study the effectiveness of vegetation as soil conservation in controlling erosion and runoff. This study was a field experiment on erosion plots of 10 m × 5 m with 1–2-year-old oil palm trees planted on a 15–40% slope, which were arranged in a Split Plot Design with replications as blocks, consisting of a combination of two factors: the age of the oil palm and slope as the first factor, and conservation techniques as a second factor. The results showed that the soil conservation techniques in oil palm cultivation could reduce the rate of surface runoff, soil erosion and nutrient loss. Soil conservation with upland rice – soybean – *Mucuna bracteata*, in sequence (T3) in oil palm 7–25 months old and 15–25% slopes (P1) were most effective reduced runoff, increase the infiltration and preventing soil erosion and nutrient loss in all age of oil palm and slope of land.

Keywords: runoff, erosion, sediment, nutrients, soil conservation

INTRODUCTION

Soil erosion is a highly dynamic and complex process. The spatial variability and the temporal changes of soil erosion are very high on a sloping area. In addition, vegetation, slope and soil type play an important role in soil

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erosion (Cerda 2015; Mohammadi and Kavian 2015). Soil erosion on agricultural land mostly occurs due to the loss of soil organic matter. In Indonesia, agricultural land for oil palm plantation is mostly placed on slope areas. As an example, in Aceh province, agricultural land is located on ramps area up to steep slope area. Specifically, 36.58% of agricultural land is located on a slope of 5–40%. This condition is important to investigate, since approximately 13% of the earth's surface is affected by agriculture-related human activities (Chen *et al.* 2011).

Erosion carries down surface soil layers which are generally fertile and rich in organic matter and nutrients, causing the loss of plant nutrients. In the process of erosion, fine soil fraction is taken away first, than more coarse fraction, so that clay content in sediment is higher than in the soils. This is related to carrying capacity of surface runoff to soil grains with different weights. The removal of fine particles by erosion leads to an increased percentage of sand and gravel on the ground, and, at the same time, reduced percentage of silt and clay (Blanco and Lal 2008). Thus, the soil that has been eroded has coarser texture compared to the one that has not been eroded. Furthermore, erosion causes a decline in soil fertility owing to the loss of essential nutrients and soil organic matter.

Oil palms are plantation crops that develop rapidly in the province of Aceh, including Bireuën. The oil palm planting area in Bireuën Regency, which in the period 2008–2012 reached 4,644 ha (BPS Aceh, 2013), were generally young plants that had the potential to cause land degradation due to increased erosion and reduced infiltration rate, especially if not managed properly. This condition often occurs not only when oil palm trees are still young and the land cover is still low, but also when the soil surface is disturbed due to the land preparation. The prediction studies of soil erosion rate in the region showed that the erosion ranged from 54.6 to 344.01 ton/ha/year (Satriawan and Azizah 2011), which was still higher than those allowed for soil erosion in the region, i.e. 5.1–40 ton/ha/year (Fitri 2010).

Cover crops play an important role in influencing erosion intensity. In this case, the cover crops provide protection for soil against the process of destroying aggregates of rain and surface runoff, thereby limiting the destructive power of the rain and surface runoff (Morgan 2005). Besides, cover crops can also improve soil physical and chemical properties through their contribution to increased levels of soil organic matter (Zuazo *et al.* 2004).

An understanding of the effectiveness of the vegetation in protecting the soil surface to resist the erosion can be an alternative technology of good and effective land resource management. Fuady and Satriawan (2011) reported on degraded land with a slope of 15%, with the application of vegetation (maize and peanuts) and ridges could control runoff and erosion. Plantation crops and reforestation crops grown in an agroforestry manner are also known to be able to control soil erosion. Sengon (*P. falcataria*) aged 3 years and cocoa aged 5 years

are more effective to control erosion compared with reeds and *pinang* (betel nut) aged 5 years (Satriawan *et al.* 2012; Satriawan *et al.* 2011).

This study aimed to choose a vegetative soil conservation technique which is the most effective for controlling erosion and preventing the loss of nutrients in young oil palm trees.

MATERIALS AND METHODS

Study Area

The study experimental plot used to measure the overland flow, sediment and nutrient loss was located in the village of Blang Mane, the district of South Peusangan, Bireuën Regency, Aceh, Indonesia (5°4'36"N and 96°45'18"E). The experiment lasted for 7 months (March–September 2015). The area was cultivated with 1–2-year-old oil palm trees planted on a 15–40% slope. Average annual rainfall in this area was 1,818 mm, and the daily mean air temperature was 27.6°C. The soil of the experimental area is classified as Typic Paleudults (USDA Soil Taxonomy), which has sandy clay in the topsoil (0–0.15 m depth).

Experimental Design

This study was a field experiment on erosion plots measuring 10 m × 5 m arranged in Split Plot Design with replications as a block consisting of two factors, namely the combination of the ages of oil palm and the slopes as the first factor, and conservation techniques as the second factor.

1. Ages of oil palm crops / slopes consisted of 4 levels, namely: a) The ages of oil palm crops were 5–7 months and the slopes were 15–25% (P1); b) The ages of oil palm crops were 7–24 months and the slopes were 15–25% (P2); c) The ages of oil palm crops were 5–7 months and the slopes were 30–40% (P3); d) The ages of oil palm crops were 7–24 months and the slopes were 30–40% (P4)

2. Conservation technique with 3 levels, namely: a) land clearing and weeds were allowed to grow on the oil palm spacing areas (T1); b) Upland rice was planted in sequence with soybeans (T2); c) Upland rice was planted in sequence with soybeans + strip *M. bracteata* (T3).

There were 12 combinations of experimental plots with each combination repeated three times to obtain a total of about 36 plots.

The erosion plots were located on the hill slopes of 15–45% inclination (Land capability class of III, IV and VI). Each erosion plot consisted of a galvanised enclosure, drawer collector, sediment and runoff collector (Θ 0.8 m, 1.2 m high), sediment and runoff collectors are designed to be assembled during the measurement. The application rate of chemical fertiliser during the study was

(150 kg N/ha, 100 kg P/ha, and 75 kg K/ha) for crops in each treatment. Moreover, the dose of fertiliser for an oil palm was 1 kg/tree.

Measurements

Infiltration

During the measurement of infiltration in experimental plots, the double ring infiltrometer method was used. Data infiltration was obtained from measurements formulated into the infiltration equation model developed by Horton (1940).

Runoff

Runoff ($\text{m}^3 \text{ ha}^{-1}$) was observed using sediment collector after each rainfall event by measuring the water level in the container. Total volume of runoff which accommodated in container, was calculated by equation of tube volume.

Sediment

Observations and sampling of sediments on soil collector were performed in conjunction with observations on the runoff surface flow collector. All the sediments that exist in the soil collector was taken out at each observation, having previously prepared a 100 g sample for the analysis of nutrient levels and C organic of sediment. Sediments that was removed out from collector were dried and then weighed to determine the wet weight. To determine the dry weight of sediment, there was taken the 250 g sediment sample to be dried in an oven at a temperature of 105°C for 24 hours. Sediment amount was calculated using the formula:

$$E' = \frac{\text{Wet weight of sediment (gr)}}{0,25\text{kg}} \times \text{Dry weight of soil sample (gr)} \quad (1)$$

Total soil eroded was calculated using the formula:

$$A = E + E' \quad (2)$$

Where: A = total soil erosion (ton ha^{-1}); E = the amount of suspended sediment in the surface runoff (ton ha^{-1}); E' = the amount of sediment in the sediment collector (ton ha^{-1}).

Water samples taken were used to calculate the suspended sediment and analyze the amount of C organic, N, P and K carried away. Then from the sediment sample an analysis was conducted to find out the content of organic C (the Walkley-Blake method), total N (the Kjeldahl method), P_2O_5 (Bray-1 method) and K_2O (extraction with 1 N NH_4OAc pH 7.0).

The amounts of C organic, N, P and K carried away by erosion were calculated by the equation:

$$X = Y \times E \quad (3)$$

Where: X = the amounts of organic C, N, P and K carried by erosion (ton ha^{-1}); Y = the concentration of organic C, total N, P and K available in sediments ($\text{mg} / 100\text{g, \%}$); E = the total amount of eroded soil (ton ha^{-1}).

Data were analyzed using the analysis of variance at 95% confidence level, if there is a significant effect on conservation technique treatment, carried out a further test LSD at 5%.

RESULTS AND DISCUSSION

Rainfall during study

During the experiment period, total of rainfall recorded at 1,139 mm, with the highest rainfall occurred in March. March was the peak of the rainy season in 2015.

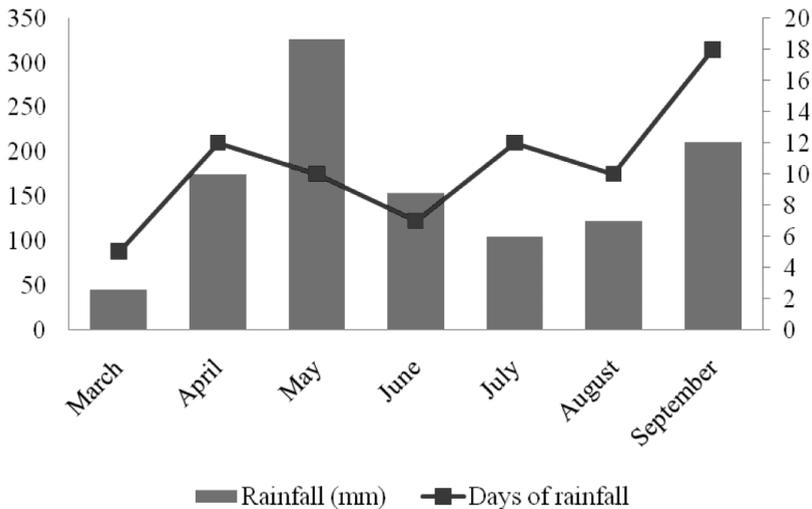


Fig. 1. Rainfall and days of rainfall during study

Infiltration

The maximum rate of infiltration of the soil at a time (infiltration capacity) shows the amount of water that can be infiltrated into the ground per unit time. Results of analysis of variance showed that the age of oil palm crops / slopes (P)

and soil conservation technique (T) have significantly affected the volume of infiltration (Vol), but did not significantly affected infiltration capacity (fc) and interaction effect between both.

TABLE 1. THE VOLUME OF WATER THAT CAN INFILTRATE INTO THE GROUND UNTIL REACHED CONSTANT INFILTRATION (VOL), AND INFILTRATION CAPACITY (FC) ON VARIOUS TREATMENT OF P AND T

Treatment	Vol (mm)	fc (mm hour ⁻¹)
Ages of oil palm / slopes		
5–7 months / slopes 15–25% (P1)	14.68 ^{bc}	1.46
7–25 months / slopes 15–25% (P2)	17.35 ^c	1.90
5–7 months / slopes 30–40% (P3)	10.15 ^a	1.16
7–25 months / slopes 30–40% (P4)	12.34 ^b	1.25
Soil conservation technique		
LC weeds allowed (T1)	11.69	1.20
Rice + soybeans (T2)	14.88	1.51
Rice + soybeans + strip <i>M. bracteata</i> (T3)	18.34	1.62
Interaction	tn	tn

In the same column, values with different indices of superscript are significantly different from one another at the LSD test at $P \leq 0.05$.

Effect of P and T treatment significantly affected constant infiltration reached (Vol), but did not significantly affected infiltration capacity (fc) (Table 1). This is due to new treatments which were able to improve the physical properties of the soil in the topsoil and have not been able to change the physical properties of the subsoil, especially, aggregate stability. This is evidenced by the treatment P2 and T3 whose the top soil aggregate stability is significantly higher (101.2), also infiltration volumes (Vol) are significantly higher (17.35 mm and 18.34 mm, respectively), but fc value did not significantly different from other treatments. Higher value of infiltration (Vol) at P2 and T3, also caused by soil pores could be maintained at a high soil moisture due to high aggregate stability.

Infiltration (Vol) that is significantly higher on P2 also contributed to improvements in the physical properties of soil caused by the wider closure of the oil palm canopy with a lower slope (15–25%). Higher percentage of ground cover by canopy of palm oil causes that soil aggregates are protected from damage due to the direct impact of raindrops, so that the pores infiltration are maintained during rainfall. Furthermore, the lower slope provides an opportunity for rain to infiltrate into the soil surface due to low flow rate.

The high value of aggregate stability, as well as a good aggregation process in the root zone of the plant, favor for higher infiltration, which occurs in T3 treatment. Aggregation process in rhizosfer can occur directly through binding soil particles by the fine roots, and through binding soil particles by root exudates. In this case

the root exudates are produced and plant roots will increase the microbial activity which will produce an adhesive humic acid to aggregate of soil particles (Gregory 2006). Furthermore, the secondary larger granules are united by threads of fungi or fine roots to form a crumb and stable soil structure (Bruns and Byrne 2004).

Fc value which is not significantly different in each treatment showed that the improvement of the physical properties of topsoil is not sufficient to significantly increase the constant infiltration capacity, if it is not supported by the improvement of soil physical properties in the deeper layers. The fact that fc values were not significantly different showed that on sloping lands, the ability of soil to infiltrate water at a constant infiltration affected the amount of runoff, because, rainfall on the sloping land have enough time to be infiltrated into the ground until reached constant infiltration. This is evident from the results of measurements of the runoff (Table 2) which showed significant differences in almost treatment, although did not make the difference for constant infiltration capacity. Therefore, in the sloping lands, influence of the slope is more dominant in causing runoff compared with the effect of soil physical properties, wherein volume of runoff will increase on land with a higher slope despite having the same infiltration capacity.

Runoff

Runoff measurement was conducted over 5 months (beginning of April to September 2015). Results of analysis of variance showed that the treatment of tree ages and slopes combined with soil conservation measures has significantly affected surface runoff, and there is interaction effect between both (Table 2).

Combination of oil palm treatment aged 7–24 months with a slope of 15–25% (P2) with soil conservation measures of oil palm + upland rice planted sequentially with soybean + strip *Mucuna bracteata* (T3) resulted in the lowest surface runoff ($249.37 \text{ m}^3 \cdot \text{h}^{-1}$) compared to other treatments. Meanwhile, oil palm treatment aged 5–7 months with a slope of 30–40% (P3) with palm oil conservation measure + land clearing and weeds (T1) significantly resulted in higher runoff than other treatments ($403.84 \text{ m}^3 \cdot \text{h}^{-1}$).

TABLE 2. AVERAGE RUNOFF AT THE TREATMENT OF VARIOUS AGE / SLOPE AND CONSERVATION TECHNIQUES ($\text{M}^3 \cdot \text{H}^{-1}$)

Soil conservation technique	Ages of oil palm / slopes				LSD
	P1	P2	P3	P4	
LC weeds allowed (T1)	289.72 ^{bc}	271.51 ^{ac}	403.84 ^{ca}	402.98 ^{ca}	13.89
Rice + soybeans (T2)	271.95 ^{ab}	259.42 ^{ab}	400.84 ^{ba}	400.31 ^{ba}	
Rice + soybeans + <i>M. bracteata</i> (T3)	262.83 ^{aA}	249.37 ^{aA}	399.84 ^{ba}	398.64 ^{ba}	
LSD	4.93				

In the same column and row, values with different indices of superscript are significantly different from one another at the LSD test at $P \leq 0.05$; lowercase letters read horizontally, uppercase letters read vertically.

The low runoff of P2T3 was caused by two main factors: the closure of the plant canopy and slopes. In P2T3 the presence of intercropping in the oil palm crops which were planted soybeans + strip *Mucuna bracteata* generated a sizeable land cover where approximately 75% of the land surface was evenly covered, as well as the more varied surface roughness condition of the soil by plant roots. In P2T3 treatment, the presence of *Mucuna bracteata* became a differentiator compared to the other treatments. *Mucuna bracteata* with a high growth rate becomes an additional filter besides soybean so that the energy of the rain drops reaching the land surface can be suppressed and reduce the runoff.

The influence of cover crops on the runoff is also shown by the results of Zuzel and Pikul (1993), higher closure of the land surface by plant cover, lower surface runoff. Closure of the land 25, 50, 75, and 100% has a runoff of 48, 37, 27, and 39 mm, respectively. Similarly, Nurmi *et al.* (2012) reported on the cocoa crop with 36% closure of plant canopy able to suppress runoff by 51%, compared to the cocoa fields that have canopy of plant 6%. In this context, the plant cover offers important soil protection by scattering the runoff and thereby diminishing its erosive power.

Soil Erosion

Further LSD test to treatment showed that age of oil palm plant and land slope combined with soil conservation measures had a significant effect on soil erosion. The treatment on oil palm aged 5–7 months with a slope of 15–25% (P2) with upland rice + soybeans + *M. bracteata* (T3) produced the lowest soil erosion (52.74 tons / ha) compared to other treatments. Meanwhile, the treatment on oil palm aged 5–7 months with a slope of 30–40% (P3) with land clearing and weeds allowed to grow on the oil palm spacing area (T1) really resulted in soil erosion higher than other treatments (90.84 tons / ha) (Table 3). Furthermore, as compared with treatments which have highest erosion, the erosion under P2 and T3 decreased by 41.94%.

The influence of the use of plants for erosion control in oil palm plantations in tropical area is also demonstrated by Satriawan *et al.* (2015), where the use of *Mucuna bracteata* as cover crop plants enables to minimize erosion up to 34.61% compared with no soil conservation. Moreover, using plants for erosion control indicated benefits in controlling soil erosion in other climatic regions, similar to other previous studies by Gomez *et al.* (2009) who reported that using cover crop with barley reduced the soil losses to 0.8 t/ha/year and the average annual runoff coefficient to 1.2%, that indicated the use of a cover crop can be a simple, feasible soil and water conservation practice. Zuazo *et al.* (2006) claimed that in sub tropic areas, there was reported the reduction of soil erosion by the effect of the plant covers. It was reduced by 90 up to 98% in comparison with a bare soil.

TABLE 3. SOIL EROSION ON OIL PALM AT THE TREATMENT OF VARIOUS AGE / SLOPE AND CONSERVATION TECHNIQUES (T.H⁻¹)

Soil conservation technique	Ages of oil palm / slopes				LSD
	P1	P2	P3	P4	
LC weeds allowed (T1)	68.17 ^{bb}	53.57 ^{aA}	90.84 ^{dB}	79.77 ^{cA}	8.67
Rice + soybeans (T2)	68.93 ^{bb}	53.45 ^{aA}	85.42 ^{cA}	82.05 ^{cA}	
Rice + soybeans + <i>M. bracteata</i> (T3)	64.73 ^{ba}	52.74 ^{aA}	84.61 ^{cA}	80.29 ^{cA}	
LSD	2.7				

In the same column and row, values with different indices of superscript significantly different from one another at the LSD test at $P \leq 0.05$; lowercase letters read horizontally, uppercase letters read vertically.

The amount of soil erosion is closely related to surface runoff generated from each treatment. The erosion was significantly lower in the combination treatment of P2 and T3 compared to the combination of other treatments caused by the planting of seasonal crops and legumes group that served as land cover, which could have a positive impact on the improvement of soil properties, especially on physical and biological properties of the soil. The existence of seasonal crops and legumes could improve soil aggregate stability by 12.5% of the initial condition, which is extremely important in reducing soil erodibility. Meanwhile, other soil conservation treatments could only increase soil aggregate stability by 8%–10.7%.

NUTRIENT LOSS

Nitrogen

Leaching of N that was measured in the sediment was in the form of total N. Test of variance showed that soil conservation techniques and ages and slope did not significantly affect the amount of the total soil N in sediments (Table 4).

TABLE 4. TOTAL N SEDIMENT AT THE TREATMENT OF VARIOUS AGE / SLOPE AND CONSERVATION TECHNIQUES (%)

Soil Conservation technique	Ages of oil palm / slopes				LSD
	P1	P2	P3	P4	
LC weeds allowed (T1)	0.33 ^{aA}	0.29 ^{aA}	0.31 ^{aA}	0.25 ^{aA}	0.43
Rice + soybeans (T2)	0.31 ^{aA}	0.29 ^{aA}	0.20 ^{aA}	0.19 ^{aA}	
Rice + soybeans + <i>M. bracteata</i> (T3)	0.25 ^{aA}	0.20 ^{aA}	0.17 ^{aA}	0.16 ^{aA}	
LSD	0.15				

In the same column and row, values with different indices of superscript significantly different from one another at the LSD test at $P \leq 0.05$; lowercase letters read horizontally, uppercase letters read vertically.

The combination of soil conservation techniques most effectively prevent the loss of N is strip cropping system between rice + soybean + *M. bracteata* (T3), it was found in all treatment of age oil palm + slope. Total leaching of nitrogen which was lower in T3 not only caused lowest soil erosion in it (Table 4) but also caused lower loss of C organic in T3 treatment (Table 7). C organic is a major source of N soil in addition to coming from the air fixation, and the high leaching will cause a great loss of N.

Phosphorus

Analysis of variance for total P showed that the soil conservation treatment had a significant effect on total amount of P transported along sediment, but on age of tree and slope did not have a significant effect. Table 5 shows that T3 treatment produced the lowest weight of P contained in the oil palm aged 7–24 months at slope 30–40% (P4). Meanwhile, the highest weight of P was found in T2 treatment in oil palm plantations aged 7–24 months at slope 30–40% (P4).

TABLE 5. TOTAL P SEDIMENT AT THE TREATMENT OF VARIOUS AGE / SLOPE AND CONSERVATION TECHNIQUES (PPM)

Soil Conservation technique	Ages of oil palm / slopes				LSD
	P1	P2	P3	P4	
LC weeds allowed (T1)	3.3 ^{aA}	6.0 ^{aA}	5.3 ^{aA}	6.8 ^{aAB}	25.03
Rice + soybeans (T2)	4.0 ^{aA}	4.3 ^{aA}	6.3 ^{aA}	11.1 ^{aB}	
Rice + soybeans + <i>M. bracteata</i> (T3)	2.9 ^{aA}	2.4 ^{aA}	2.4 ^{aA}	2.0 ^{aA}	
LSD	6.96				

In the same column and row, values with different indices of superscript significantly different from one another at the LSD test at $P \leq 0.05$; lowercase letters read horizontally, uppercase letters read vertically.

Table 5 also shows that T3 treatment was very effective in preventing the leaching of P in all ages and slopes, but, in general, the high leaching of P nutrient occurred in the soil conservation of T1 treatment. The high leaching of P in T1 treatment was related to the great amount of erosion in the treatment, in which the soil transported through erosion was topsoil that had a higher nutrient content than subsoil.

Potassium

Analysis of variance on potassium (K) in the sediments showed that soil conservation treatment and the age of the slopes of the plant have significantly affected the potassium (K) in the sediment. Table 6 shows that T3 treatment resulted in the lowest leaching of K-exchangable in age of oil palm 7–24 months at slope 15–25% (P1). Meanwhile, the highest leaching of K-exchang-

able was found in T1 treatment in oil palm plants aged 5–7 months at slope 30–40% (P3).

TABLE 6. POTASSIUM (K) SEDIMENTS AT THE TREATMENT OF VARIOUS AGE / SLOPE AND CONSERVATION TECHNIQUES (ME/100 GR)

Soil Conservation technique	Ages of oil palm / slopes				LSD
	P1	P2	P3	P4	
LC weeds allowed (T1)	0.89 ^{aC}	0.89 ^{aB}	1.21 ^{aB}	0.93 ^{aB}	0.61
Rice + soybeans (T2)	0.67 ^{aB}	0.80 ^{aB}	1.01 ^{aB}	0.83 ^{aAB}	
Rice + soybeans + <i>M. bracteata</i> (T3)	0.36 ^{aA}	0.52 ^{aA}	0.71 ^{aA}	0.68 ^{aA}	
LSD	0.22				

In the same column and row, values with different indices of superscript significantly different from one another at the LSD test at $P \leq 0.05$; lowercase letters read horizontally, uppercase letters read vertically.

The high leaching of K nutrient in T1 treatment in oil palm plants aged 5–7 months at 30–40% slope (P3) was caused by the element of potassium that is very susceptible to leaching / washing compared to N and P. Furthermore, an increasing number of eroded soil is not followed by the increased loss of potassium, because potassium concentration decreases with increasing number of eroded soil.

C organic

Further test analysis of amount of C organic leached showed that soil conservation treatment and age of oil palm and slope had an effect on amount of C organic which transported along with sediments. The lowest leaching of C organic was found in strip cropping rice + soybeans + *M. bracteata* (T3) in age of oil palm 7–24 months at slope 30–40% (P4). Meanwhile, the highest leaching of C organic was found in LC weeds allowed (T1) in age of oil palm 5–7 months at slope 30–40% (P3) (Table 7).

TABLE 7. TOTAL C ORGANIC SEDIMENTS AT THE TREATMENT OF VARIOUS AGE / SLOPE AND CONSERVATION TECHNIQUES (%)

Soil Conservation technique	Ages of oil palm / slopes				LSD
	P1	P2	P3	P4	
LC weeds allowed (T1)	1.80 ^{aA}	2.27 ^{aB}	2.51 ^{aB}	1.64 ^{aA}	2.92
Rice + soybeans (T2)	0.91 ^{aA}	1.46 ^{aAB}	1.40 ^{aAB}	1.10 ^{aA}	
Rice + soybeans + <i>M. bracteata</i> (T3)	0.82 ^{aA}	1.16 ^{aA}	1.32 ^{aA}	0.73 ^{aA}	
LSD	0.99				

In the same column and row, values with different indices of superscript significantly different from one another at the LSD test at $P \leq 0.05$; lowercase letters read horizontally, uppercase letters read vertically.

The high leaching of C organic in T1 treatment was related to the high amount of erosion in the treatment, in which the soil transported through the erosion of topsoil was the top layers of soil that contain carbon in the form of C organic. The low leaching of C organic in T3 was probably because of the effectiveness of strip *Mucuna bracteata* plant and upland rice in filtering soil particles transported by erosion so that the sediment C organic levels became low.

CONCLUSIONS

Soil conservation techniques in the cultivation of oil palm can reduce the surface runoff, soil erosion and nutrient leaching. The soil conservation treatment of upland rice planted sequentially with soybean + strip *Mucuna bracteata* (T3) in oil palm crops were 7–25 months and the slopes were 15–25% most effectively reduced runoff, increase the infiltration and prevented soil erosion. Similarly, treatment of upland rice planted sequentially with soybean + strip *Mucuna bracteata* (T3) also most effectively prevented nutrient leaching in all age of oil palm and slope of land.

ACKNOWLEDGMENT

The authors would like to thank the Directorate of Research and Community Services of KEMENRISTEK DIKTI for funding this research through Fundamental Grants in 2015.

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