The effect of legume cover crop *Mucuna bracteata* on soil physical properties, runoff and erosion in three slopes of immature oil palm plantation

**Wawan, I R Dini and Hapsoh**

Department of Agrotechnology, Faculty of Agriculture, Universitas Riau, Kampus Bina Widya KM 12,5 Simpang Baru Panam, Pekanbaru, Indonesia.

E-mail: wakoku62@gmail.com

**Abstract.** This study determined the effect of legume cover crop *Mucuna bracteata* (MB) on soil physical properties, runoff and erosion on three slopes of immature oil palm plantation. This research used split plot design with three slopes as main plot consisted of: S1=slope 0-8%, S2=slope 8-15% and S3=slope 15-25%. The use of MB as subplot consisted of: M0=unovergrown with MB and M1=overgrown with MB. The measuring runoff and erosion used small plot method. The research showed that the oil palm plantation which overgrown by MB had the soil physical properties such as field moisture content, bulk density, total pore space, permeability, infiltration and organic matter better than without MB. The higher slope level decreased the soil physical properties; (2) the use of MB decreased the runoff and erosion compared to the unovergrown MB. The higher level of the slope induced the greater runoff and erosion; (3) the combination of slope with the MB resulted the lower runoff and erosion even at the steeper slope; (4) There is a positive correlation between rainfall intensity and runoff, and runoff with erosion. Thereby, the more rainfall intensity, more runoff as well, and the increase of runoff followed by the increased erosion.

1. Introduction

Oil palm in Riau Province is mostly cultivated on mineral acid soil. These soils have a sandy texture with low content of organic matter on the surface layer, causes the mineral soil become sensitive to erosion. In addition, planting oil palm on mineral soil are often causes a soil compaction. Several studies have shown that the mineral soils which planted with oil palms are compacted [1]. The soil compaction decreases the infiltration [2], resulting the increase of runoff and erosion.

There are five factors affecting runoff and erosion, one of the factors is the topography. Planting of oil palm on mineral soil, especially in Riau Province, is mostly done on the land with wavy up to hilly topography. With such of topographic conditions and supported by high rainfall intensity and erodibility soil, the potential runoff and erosion are large.

Runoff and erosion are the main causes of soil degradation in humid tropics, causing the transport of surface soil layers which are rich in organic matter and nutrient. It has an impact on the decrease in soil fertility and productivity. Therefore, an effort to control the runoff and erosion is needed, for example by using physic-mechanical, chemical and vegetative methods. However, the vegetative methods are mostly chosen because it can control the runoff, erosion, and also increase the soil fertility as well. An example of vegetative methods in controlling runoff and erosion is cover crop.
planting, including legume cover crop (LCC). At this time the type of LCC which is widely used in oil palm plantations is *Mucuna bracteata* (MB).

Planting of legume cover crop MB in immature oil palm plantation is aimed to control the weeds, suppress the runoff and erosion and increase soil fertility. However, the study of its effectiveness in improving the soil physical properties and reducing the runoff and erosion in immature oil palm plantations with the different slopes is still limited. Therefore, this study aimed to find out the effect of MB on soil physical properties, runoff and erosion on three slopes of immature oil palm plantation.

2. Materials and methods

This research was conducted in immature oil palm plantation (3 years old) at PT. Perkebunan Nusantara (PTPN) V Lubuk Dalam Plantation, Siak Regency, Riau Province. This area occupied by dystropepts soil with average annual rainfall 2236 mm.

The materials that were used in this research are *Mucuna bracteata*, oil palm plant 3 years old, black canvas, filter paper, clear plastic. The tools that used in the field are erosion observation plot, ombrometer, 320 ml bottle, clinometer, rolled meter, ring sampler, Belgian auger, hammer, machete, mattock, stationary and camera. The tools that used in the laboratory are analytical scales, measuring cup, permeameter, oven, and the other tools for the soil physical analysis.

This research was conducted with split plot design. The slope (K) as the main plot consisted of 3 levels, namely: K0: slope of 0 - 8%; K1: slope of 8 - 15%; K2: slope of 15 - 25%. The uses of *Mucuna bracteata* (M) as the subplot consist of 2 level which is: M0: the unovergrown LCC *Mucuna bracteata* on oil palm plantation and M1 = the overgrown LCC *Mucuna bracteata* on oil palm plantation. Each treatment repeated 2 times, resulting 12 experimental units. Measurement of runoff and erosion used small plot method by plot size 2m × 3m. Data were analyzed using analysis of variance then continued with *Duncan’s New Multiple Range Test* (DNMRT) at significant level 5%.

3. Result and discussion

3.1. Soil physical properties

The selected soil physical properties on three slopes land which overgrown MB and unovergrown MB are presented in Table 1, where the soil physical properties on oil palm plantation which overgrown with LCC *Mucuna bracteata* are better. These were indicated by field moisture content, total pore space, permeability, infiltration, and the organic matter are higher, and the bulk density which were lower compared with unovergrown MB. The steeper of the slope causes the worse in soil physical properties. Increasing in slope lowered the field water content, total pore space, permeability, infiltration, organic matter, and also increased bulk density.

| Slopes Level | Water Content (%) | Bulk Density (g cm⁻³) | Total Pore Space (%) |
|--------------|-------------------|------------------------|----------------------|
|              | M0                | M1                     | M0                  | M1                  | M0            | M1            |
| 0%-3%        | 25.50b            | 33.43a                 | 0.94ab              | 0.82b              | 56.91ab       | 66.15a        |
| >3%-8%       | 20.25c            | 29.27ab                | 1.10ab              | 0.85b              | 52.82ab       | 62.25ab       |
| >8%-15%      | 19.08c            | 26.99b                 | 1.17a               | 0.99ab             | 49.28b        | 58.43ab       |
| Average      | 21.61b            | 29.90a                 | 1.07a               | 0.88b              | 53.00b        | 62.27a        |

|                     | Permeability (cm/h) | Infiltration (cm/h) | Organic matter (%) |
|---------------------|---------------------|---------------------|--------------------|
|                     | M0                  | M1                  | M0                | M1                |
| 0%-3%               | 19.80c              | 42.07a              | 22.19b             | 33.13a            | 6.98c         | 10.24c        |
| >3%-8%              | 17.20c              | 39.08bc             | 14.08d             | 25.48b            | 6.61c         | 8.32b         |
| >8%-15%             | 13.77c              | 26.19bc             | 6.29d              | 10.43k            | 5.99c         | 7.54c         |
| Average             | 16.92b              | 35.78a              | 14.18b             | 23.01a            | 6.53b         | 8.70b         |

Number which followed by the same small letter in the same column shows the not significantly different based on DMRT on significant level 5%.

Increasing in field water content on the land overgrown with LCC MB oil palm plantation because the soil surface is covered MB, thus water loss caused by the evaporation can be lowered. Other
physical soil improvement was due to addition of litter into the soil which increased organic matters in the soil (Table 1). In a good moisture condition, organic matter is decomposed by the soil biota and releases organic acids that play a role in aggregate formation.

3.2. Runoff
Slope, MB and the combination between slope and MB affected the runoff in February, March and April (Table 2). The higher slope increased runoff in each observation, except in February, where the 0-8 % slope was not different with the 8-15% slope. Generally, different slope had different gravity.

### Table 2. The average of runoff (mm) in February to April on 3 slopes overgrown and unovergrown MB

| Mucuna bracteate | Slope (%) | Average |
|------------------|-----------|---------|
|                  | 0 - 8%    | 8 - 15% | 15 - 25% |
| Unovergrown MB   | 1.92<sup>a</sup> | 2.93<sup>b</sup> | 5.24<sup>a</sup> | 3.36<sup>a</sup> |
| Overgrown MB     | 1.43<sup>a</sup> | 1.78<sup>a</sup> | 2.76<sup>b</sup> | 1.99<sup>b</sup> |
| Average          | 1.67<sup>b</sup> | 2.36<sup>b</sup> | 4.00<sup>a</sup> |
|                  | February  |         |         |
| Unovergrown MB   | 8.21<sup>c</sup> | 13.51<sup>b</sup> | 22.60<sup>a</sup> | 10.86<sup>a</sup> |
| Overgrown MB     | 4.84<sup>d</sup> | 5.42<sup>d</sup> | 8.76<sup>c</sup> | 6.34<sup>b</sup> |
| Average          | 6.52<sup>c</sup> | 9.46<sup>b</sup> | 15.68<sup>a</sup> |
|                  | March     |         |         |
| Unovergrown MB   | 17.43<sup>c</sup> | 29.84<sup>b</sup> | 51.91<sup>a</sup> | 33.06<sup>a</sup> |
| Overgrown MB     | 9.15<sup>c</sup> | 11.33<sup>d</sup> | 16.80<sup>d</sup> | 12.43<sup>b</sup> |
| Average          | 13.29<sup>c</sup> | 20.59<sup>b</sup> | 34.35<sup>a</sup> |

<sup>a, b, c, d</sup> Number which followed by the same small letter in the same column shows the not significantly different based on DMRT on significant level 5%.

The gravity is bigger in line with the steeper soil surface from the horizontal field. This gravity is an absolute requirement in the occurrence of scrape, transport and deposition processes. The higher slope had the higher gravity rather than the lower one, thus lowering ability of the soil to hold water. As the results, the runoff on the 0 - 8% slope become lower rather than 8 - 15% and 15 - 25% slope.

It is well documented that the slope affects the amount of runoff. In the steeper slope, soil particles splashed down by the raindrops, thus the soil surface rich in organic matters is erosived [3]. The unovergrown MB land has the higher runoff rather than the overgrown MB land (Table 2) due to shadding of the rainfall, so that the rainfall kinetic energy can be restrained. The function of vegetation are to block the rainfall and prevent the crash on soil surface. Density and type of vegetation determine the effectivity in preventing runoff and erosion [4].

The use of MB also resulting litters as organic mulch which can minimize the occurrence of runoff and erosion. The use of straw mulch can reduce the amount of runoff at 5 and 10 % in the different rain duration [5]. The MB litters become the source of C and energy for the soil biota, leads to increase soil biodiversity [6, 7]. Increasing soil biodiversity has an effect on the improvement of soil physical properties (Table 1). The MB litters which decomposed by the soil biota resulting organic acids and humic compounds as cementing agent in the aggregate formation. Improvement in soil structure have an effect on the improvement of the others soil physical properties (Table 1).

Tabel 2 shows an interaction between slopes and the use of MB on runoff. The runoff on higher slope planted with MB did not differ with unovergrown MB treatment on the lower slope. The use of MB on the 8-15% slope results the runoff which is not significantly different compared to the 0-8%
slope, either overgrown or unovergrown MB. The uses of MB on the 15 - 25% slope result the runoff which is not significantly different than on the 8-15% slope of unovergrown MB.

In March, the runoff on the 15 - 25% slope and use of MB was different with the unovergrown MB in the 0 - 8% slope. In April the use of MB on the 15 - 25% slope resulting the runoff that is not significantly different with the unovergrown MB on 0 - 8% slope and also not significantly different on the use of MB on 15 - 25% slope. An interaction between the slope and MB is probably because both factors influence the runoff and erosion directly. The increase of slope increases the runoff and erosion, while the MB planting decreases the runoff and erosion.

3.3. Soil erosion

The results of the analysis of variance show that the level of slope and the use of MB also the interaction between the slopes with the use of MB have a significant effect on the soil erosion. The average of the erosion after testing by DNMRT is presented on Table 3.

Table 3. Average of erosion (ton ha⁻¹) in February to April on three slopes with overgrown and unovergrown MB.

| Sub Plot Mucuna bracteata | Main Plot of Slope (%) | Average |
|--------------------------|------------------------|---------|
|                          | 0 - 8%                 | 8 - 15% | 15 - 25% |
|                          | Febuary                |         |         |         |
| Unovergrown MB           | 2.59c                  | 5.15b   | 9.31a   | 5.68a   |
| Overgrown MB             | 1.89c                  | 2.91c   | 4.85b   | 3.22b   |
| Average                  | 2.24c                  | 4.03b   | 7.08a   |         |
|                          | March                  |         |         |         |
| Unovergrown MB           | 5.00c                  | 9.67b   | 19.23a  | 11.30a  |
| Overgrown MB             | 3.50c                  | 5.14c   | 8.86b   | 5.83b   |
| Average                  | 4.25c                  | 7.40    | 14.04a  |         |
|                          | April                  |         |         |         |
| Unovergrown MB           | 12.41c                 | 23.07b  | 43.83a  | 26.44a  |
| Overgrown MB             | 5.99c                  | 9.76d   | 12.01cd | 9.25b   |
| Average                  | 9.20c                  | 16.42b  | 27.92a  |         |

a,b,c,d,e Number which followed by the same small letter in the same column shows the not significantly different based on DMRT on significant level 5%.

Table 3 showed that the magnitude of erosion is affected by the interaction between the slope and the use of MB. The erosion on the higher slope and overgrown MB was not significantly different compared to unovergrown MB on the lower slope. The observation in April shows that the higher slope overgrown MB has the lower erosion compared to unovergrown MB.

The increasing of slope increased of erosion in every observation (Table 3). Erosion in February was smaller compared with the erosion on March and April for every slope. The increase of erosion in the level of slope is caused by the relation between the gravity and runoff. The slope has an effect on runoff (Table 2). Increasing amount and rate of runoff will amplify the kinetic energy, so that the ability to transport the soil particle increases as well. Generally, the erosion increases when the slope increases and effect of slope towards erosion vary greatly depend on the type of soil [8]

The use of MB resulted the lower erosion on every observation. The lower of erosion on the planting of MB treatment because the MB can restrain the kinetic energy of raindrops and the runoff, thus the potential of erosion become smaller. The MB produces a wet weight of 1,380.7 g per plant and dry weight of 246.3 g per plant [9]. The organic matter from litter can increase the soil aggregate formation. The improvement of soil structure has an effect to the infiltration which and lower the runoff.

Soil erosion is very closely related with the runoff, so that the factor which affected runoff also affected the soil erosion. Regarding to measurements results of runoff, other factors also have an effect suc as rain characteristic, soil properties and surrounding environment around the observation
plot which interacting each other. The amount of rainfall in one period may not cause the erosion if its intensity was low. Also, the short time rain may not cause erosion [10].

The kinetic energy of rainfall causes the dispersion of soil particles, so that the clay particles are transported and washed away by runoff, and cover the pores of soil so that the infiltration of water into the soil becomes obstructed and the runoff increases. The amount of soil flashed every single raindrop is directly proportional to the magnitude and velocity of the raindrop and rainfall intensity [11].

3.4. The Correlation between amount and intensity of the rainfall with the runoff and erosion

Correlation between rainfall amount and intensity as well as runoff and erosion in the observation plots is presented in Table 4. High correlation occurs between the amount of rainfall and rainfall intensity on the runoff. Correlation also occurs between the amount of rainfall and the its intensity toward the erosion.

| Table 4. The correlation between the amount of rainfall and the its intensity and the runoff and erosion. |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Amount of Rainfall                             | Rain Intensity                                 | Runoff                                          |
| Rain intensity                                 | 0.947**                                        |                                                  |
| Runoff                                         | 0.645**                                        | 0.667**                                         |
| Erosion                                        | 0.553**                                        | 0.593**                                         | 0.983**                                         |

**. Significant correlation at the level of 1%

The most important climatic factors that affect runoff and erosion is characteristics of rain, including the amount of rainfall, rainfall intensity and rain distribution [4]. The effect of rain intensity on runoff and erosion are more important rather than the amount, duration and distribution of rain [9]. Even though in moderate rain, if it occurs on successive days it will cause large runoff, because the soil pores still filled with water and water loss due to evaporation can be retained. When viewed from the research data, the amount of rainfall in this study has an average of monthly rainfall between 9.70 - 22.66 mm with moderate to high rainfall intensity.

Runoff is closely related to soil erosion. The increased erosion occurs due to increased runoff and decrease in soil infiltration [11]. Rainfall and runoff and erosion has a high correlation more than 67%, which proves that runoff and erosion is closely related [12].

4. Conclusion

From the research that has been done it can be concluded that the oil palm plantation which overgrown MB has the soil physical properties better such as field moisture content, total pore space, permeability, infiltration, and organic matter, and lower bulk density compared to unovergrown MB. The higher the slope level decreases the quality of selected soil physical properties. The use of MB decreases the runoff and erosion compared to unovergrown MB. The higher level of slope, the greater the runoff and erosion. The combination of slope with MB produced a lower runoff and erosion, including on the higher slope. There is a positive correlation between rainfall intensity and runoff, and runoff with erosion. Increasing rainfall intensity increases the runoff, followed by increases of erosion.

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