RESEARCH ARTICLE

Water Balance in Oil Palm Plantation with Ridge Terrace and *Nephrolepis biserrata* as Cover Crop

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Abstract

The existence of oil palm plantations as a possible cause of drought of the surrounding areas in Indonesia is a critical issue. Therefore, information related to the effects of oil palm plantations on the surrounding environment in terms of soil water content (SWC) availability is needed. Soil and water conservation techniques in the form of ridge terracing and cover crops, such as Nephrolepis biserrata, can be expected to potentially improve soil water reserves, especially in the dry-season, by accumulating water in the rainy season. This study aimed to study the effects of *N. biserrata* as cover crop, together with the potential effects of ridge terraces, on the water balance in mature oil palm plantations. The research was conducted in mature oil palm plantations, Afdeling III block 375 (planted in 1996) and block 415 (planted in 2005), Rejosari Unit, PT Perkebunan Nusantara (PTPN) VII in Natar District, South Lampung Regency, Indonesia, from August 2014 to January 2015. The research was based on of setting up 15 m x 20 m experimental plots with the following treatments: (i) without ridge terraces and without *N*. biserrata (G_0T_0); (ii) without ridge terraces but with *N. biserrata* (G_0T_1) ; (iii) with ridge terraces but without *N*. biserrata (G_1T_0); (iv) with ridge terraces and with N. biserrata (G_1T_1). Hydrology parameter data were collected for each treatment plot; water balance was calculated using a water balance equation. The results showed that the use of the cover crop N. biserrata in combination with ridge terraces helped improve SWC reserves by approximately 71% and 12%, respectively. The use of N. biserrata as a cover crop reduced the rate of water loss by percolation and run-off, by approximately 36%

and 80%, respectively, in an area where the annual rainfall is above 2,400 mm per year. The presence of *N. biserrata* shortened the period of SWC deficit by extending the period of a water surplus by 70 days when compared with ridge terracing alone (which reduced the period of SWC by 50 days).

Keywords: *Nephrolepis biserrata*, cover crops, ridge terrace, water balance

Introduction

Oil palm (*Elaeis guineensis* Jacq.) is one of plantation crops that is important as a source of foreign exchange for Indonesia. The main product of oil palm is oil, for which the production value of production needs to be further developed in the interest of the national economy of Indonesia. Data from the Direktorat Jenderal Perkebunan (2014) showed that CPO production in 2014 was 27.7 million tons from an area of approximately 10.9 million ha.

The increase in the production of oil palm has been the result of a combination of strategies, particularly the adoption of technology improvements in the field. Soil and water conservation techniques have been adopted in oil palm plantations to improve the carrying capacity of those two factors (soil and water), with resulting improvements in plant growth and development, that have, in turn, improved production. According to Murtilaksono (2007), soil and water conservation technique using siltpit could delay dryness 3.5 months rather than contour ridge which could delay only 2.5 months more than control. Studies of the potential benefits of cover crops in oil palm plantations have received increased emphasis to help in soil and water conservation of oil palm cropping. Cover crops have several potential functions including: a reduction in soil density (Cock, 1985); a place for storage of carbon (Reicosky and Forcella, 1998); a reduction of soil erosion by water and wind, through improvements in soil hydrology (Battany and Grismen, 2000); and an increase in the rate of water infiltration (Archer et al., 2002).

Nephrolepis biserrata (Sw.) Schott is a weed that commonly found in many oil palm plantations especially in mature oil palm plantations (Syahputra et al., 2011), and it is capable of serving as a cover crop (Ariyanti, 2016). N. biserrata is shade tolerant and, as such, can be planted under mature oil palm trees. N. biserrata is characterized as follows: it has flaky soft petioles and is brown in color; it has a rough leaf surface with lush foliage and a tapering leaf shape. The spores are located evenly on the edge of the leaf. The stem is round, slim, elongated and brown. Roots are fibrous roots and black (Romaidi et al., 2012). In oil palm plantations, N. biserrata very useful in maintaining a humid environment. It is also believed to be a host plant for fire caterpillar predators, although this has not yet been supported by scientific research and data.

The adoption of cover crop cultivation is acknowledged to be one vegetative method for soil and water conservation. Other techniques are mechanically based and include soil tillage, ridges, terracing, reservoirs, and drainage and irrigation improvement (Arsyad, 2010). Ridge terracing is a mechanical conservation method for retaining water, so that water can be absorbed by the soil. Cover crops serve to improve the capability of soils in retaining water through the root system and plant debris, which also improve soil organic matter content after decay. Ridge terraces are based on the construction of is a soil mound along the contour or across the slope, with channels being created in the upper slopes that follow the direction of the soil mounds. Murtilaksono et al. (2007) stated that the application of mounds and silt pilt completely with vertical mulching has positive effects on the number of midrib leaf, the number of oil palm bunches, the average weight of bunches, and the production of fresh fruit bunches (FFB) of oil palm. This conservation technique is useful in improving SWC reserves to meet water needs during the dry-season, so that palm oil production may be maintained.

The state of hydrology in a landscape can be described through the water balance. Broadly speaking, the water balance reflects the relationship between the water in-flow and outflow in an area.

The water balance can also be defined as the difference between the amount of water received by plants and water loss from the plant and soil through evapotranspiration process (Mayong, 2006). Rainfall is the input variable in the water balance, while runoff, interception, evapotranspiration and percolation are output variables, all of which play important roles in determining the soil water content reserves of oil palm plantations.

Material and Methods

Research Method

This research was conducted in Afdelling III block 375 and block 415 Rejosari Unit, PT Perkebunan Nusantara (PTPN) VII, District of Natar, South Lampung Regency. Soil analysis was conducted in Soil Laboratory, Bogor Agricultural University. The research was conducted from August 2014 to April 2015.

The research was conducted on 9 and 18-yearold mature oil palm with *N. biserrata* as cover crop. Scoring of soil water content was conducted using measuring device DFRobot SEN0114 soil moisture sensors/probes and a custom-built multimeter to read the sensors (Yogaswara, 2015).

The research was implemented by designing of experimental plots measuring 15 m x 20 m with treatments combination: without ridge terrace, without *N. biserrata* (G_0T_0), without ridge terrace with *N. biserrata* (G_0T_1), with ridge terrace without *N. biserrata* (G_1T_0), with ridge terrace and *N. biserrata* (G_1T_1). The experimental plots with cover crops treatment were fully covered by *N. biserrata* (100%).

The observed hydrological variables were precipitation, oil palm interception, *N. biserrata* interception, evapotranspiration of *N. biserrata*, initial SWC, SWC during the experiment at specified soil depth, and percolation. Data of hydrological variables were daily observed in each plot and lasts for nine months, starting from August 2014 to April 2015. The hydrological variables used in the water balance equation were as follow:

 Δ SWC = P – ETP(Nb) – INTP(Nb) – INTP(KS) – PERK where:

 Δ SWC = water soil content variableP = precipitationETP = evapotranspirationINTP = interception, Nb = Nephrolepis biserrata,KS = palm oil



300 200 100 (IIII) -100 -100 -200 0 -300 -400 Date -500 10/11/14 01/10/14 31/10/14 20/12/14 30/11/10 10/12/10 11/10/1 20/11/1 30/12/12 21/10 IIII Percolation Interception of oil palm Runoff Evapotranspiration SWC Precipitation **S**R. Interception of N.biserrata

G₀T₁ (October 2014-December 2014)

G1T1 (October 2014-December 2014)



Figure 1. Daily cumulative water balance in plots (G1) and without ridge terrace (G0), with ridge terrace (T1) and without cover crop (T0) from October to December 2014 in Oil Palm Plantation PTPN VII Rejosari, South Lampung.



Figure 2. Daily cumulative water balance in plots (G1) and without gulud terrace (G0), with gulud terrace (T1) and without cover crop (T0) from January 2015 to April 2015 in Palm Oil Plantation PTPN VII Rejosari, South Lampung.

G0T1 (January 2015-April 2015)

PERK = percolation

Daily change of SWC (Δ SWC) was calculated by the average value of SWC differences between SWC at measurement with the previous day. Oil palm interception was calculated by equation : Int(KS) = (0.1513 x rainfall) + 0.8885 (Purba, 2007). Interception of N. biserrata was calculated based on the equation : if $0 \le \text{Lai} \le 3$ then Int (Nb) = (1.27/3) x Lai (Nb), if Lai > 3 then Int (Nb) = 1.27 mm (Zinke, 1967). N. biserrata evapotranspiration is calculated based on changes in daily SWC average at soil depth of 30 cm in the dry months (no rain at all). SWC was measured using a sensor that connected with multimeter (Yogaswara, 2015). Percolation and runoff occur when SWC value higher than total soil porosity. All hydrological variables were based on ten days data and calculated at 30 cm of soil depth. The observed physical property was bulk density required for calculation of SWC with the equation:

SWC= bulk density x SWC read on multimeter

Result and Discussion

The water balance in conditions ridge terraces and N. biserrata as a cover crop in oil palm plantation PTPN VII, South Lampung, is presented in Figure 1 (October to December 2014) and Figure 2 (January to April 2015). The hydrological variables of plots without ridge terraces (G_0) and with ridge terraces (G_1) , and planting with *N. biserrata* (T_1) , includes precipitation, N. biserrata evapotranspiration, N. biserrata and palm oil interception, daily average of Δ SWC and percolation. The hydrological variable of plots without ridge terraces (G_0) and with ridge terrace (G_1) , but not planted with N. biserrata (T_0) , include precipitation, oil palm interception, daily average of \triangle SWC and percolation. The water balance was calculated based on the data of hydrological variables over 10 day periods.

During the period October to December 2014, the average monthly rainfall was 183.5 mm per month, while the SWC in treatments G_0T_0 , G_0T_1 , G_1T_0 , and G_1T_1 were -48.21 mm, -13.99 mm, -42.42 mm and -57.11 mm. respectively (Figure 1). This indicates that planting of *N. biserrata* as a cover crop was able to increase the water holding capacity, so that water soil content reserves increased by an average of 71%. This was largely achieved by the root systems of *N. biserrata* in creating soil pore space that can be filled with water, so that the water reserves increased. Ridge terraces also improved the SWC reserves but only by an average of 12.0% The combination of treatments (ridge terrace with *N. biserrata*) decreased runoff by

91.5% in the period when the rainfall was less than 200 mm/month. In the dry months, *N. biserrata* planting increased the daily average of SWC in ridge terrace plots at a depth of 30 cm, 60 cm, 90 cm by 47.9%, 27% and 38.9%, respectively (Ariyanti, 2016). In the wet months, *N. biserrata* planting increased SWC daily average in the non ridge terrace plots at a depth of 30 cm, 60 cm, 90 cm by 11.6%, 11.5%, 11.8%, respectively (Ariyanti, 2016).

During the period of highest rainfall, January to April 2015 (225.62 mm per month), the SWC of treatments G_0T_0 , G_0T_1 , G_1T_0 , and G_1T_1 were -14.14 mm, 1.08 mm, 10.08 mm, and -17.63 mm, respectively (Figure 2). Ridge terrace was able to increase the SWC reserves higher than N. biserrata planting alone. In this period, the planting of N. biserrata was able to shorten the period of SWC deficit, with a longer period of water surplus period (70 days) compared to ridge terrace alone (50 days). In addition, N. biserrata reduced the percolation loss to 36.15% and run-off by 80.4%. Land with ridge terraces and planted with N. biserrata, land without ridge terraces but planted with N. biserrata, and land ridge terraces but without N. biserrata, reduced surface water run-off by 95.7%, 80.0% and 63.4%, respectively (Ariyanti, 2016).

During the period October 2014 to April 2015 there was one dry month, this being October 2014 (47.6 mm), while the wettest month was December 2014 (278.9 mm). The water balance in the dry month for treatments G_0T_0 , G_0T_1 , G_1T_0 , G_1T_1 was -9.08 mm, 103.3 mm, 17.9 mm and 31.1 mm, respectively, for SWC, and 0 mm, 0 mm, 41.52 mm and 34.98 mm, respectively, for percolation (Figure 1). This shows that in the dry months, N. biserrrata was able to maintain the SWC. N. biserrata affected the water balance in mature oil palm by reducing the SWC deficit during the dry months, with an average of SWC deficit amounting to 36.71% (Ariyanti et al., 2015a). There was an increase in SWC on average in plots planted with N. biserrata compared to without N. biserrata (Ariyanti et al., 2015b). SWC is affected by land cover, in this case by N. biserrata. In order to maintain SWC during dry-season, it is suggested to improve the condition of vegetation growing above the soil, so that shading reach above 80% and 100% litter coverage of the soil (Suhardi et al., 2012). Land cover with Asystasia gangetica is able to increase SWC in the range 33% - 66% (Junaedi, 2014). Water balance in the wet month December 2014

for treatments G_0T_0 , G_0T_1 , G_1T_0 , G_1T_1 were -8.77 mm, 8.69 mm, 33.45 mm and 19.95 mm for SWC, respectively, and 27.58 mm, 8.69 mm, -28.25 mm ; 147.51 mm for percolation, respectively. In the wet month, SWC was more determined by precipitation than *N. biserrata* as a cover crop or ridge terraces as

a soil water conservation measure.

Conclusion

Planting cover crop *N. biserrata* and ridge terraces were able to improve SWC reserves by an average of 70.98% and 12.01%, respectively. *N. biserrata* reduced the rate of percolation and run-off by 36.15% and 80.42%, respectively, during periods when the level of precipitation above 2400 mm/year. *N. biserrata* shortened the period of SWC deficit and gave longer water surplus (70 days) compared to the use of ridge terraces alone (50 days). However, the optimum treatment for sustainable production is the combination of the use of ridge terraces and *N. biserrata* as a cover crop.

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The Roles of *Asystasia gangetica* (L.) T. Anderson and Ridge Terrace in Reducing Soil Erosion and Nutrient Losses in Oil Palm Plantation in South Lampung, Indonesia

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Abstract

Asystasia gangetica (L.) T. Anderson is a weed commonly found on oil palm plantations and can be used as cover crop for mature oil palm plantations due to its tolerance to shading. The use of cover crop is a soil conservation technique to support sustainable availability of soil nutrients by reducing erosion and nutrients loss, particularly during the rainy seasons. This research aims to determine the roles of A. gangetica as cover crop for measures against erosion and nutrients loss in mature oil palm plantation. This research was conducted in oil palm plantation, Unit Rejosari, PT Perkebunan Nusantara (PTPN) VII, District of Natar, South Lampung Regency from August 2014 to April 2015. The research used split block design in randomized complete block design with two factors and six replications. The main plots were ridge terrace, namely with and without ridge terrace. The sub plots were cover crops, namely with and without cover crops A. gangetica. The results show that using A. gangetica as cover crops in mature oil palm plantations effectively minimized erosion and loss of organic C, N, P, and K by 95.7%, 93.4%, 96.0%, and 90.0 %, respectively. The use of cover crop became more effective when combined with ridge terrace and reduced erosion by 94.1%, and loss of organic C, N, P and K by 99.1%, 99.2%, 90.0% and 98.5%, respectively.

Keywords: carbon-organic, cover crops, kalium, natrium, phosphat

Introduction

Soil erosion on agricultural land results in the loss of soil organic matter (Chen et al., 2011). Erosion caused reduction in fertile surface soil layer which are rich in organic matter and nutrients (Blanco and Lal, 2008), and reduce land and plant productivity. According to Abdurachman et al. (2003) loss of 10 cm top soil on oil palm plantation can decrease production by more than 50% despite complete fertilization was applied, because top soil as the source of nutrients will be eroded. Erosion does not only affect soil organic matter content but also the soil major nutrients N, P, and K. The amount of nutrients lost to erosion was usually greater than the predicted values, because fine and fertile soil particles will be leached, resulting in an accelerated decrease in soil fertility (Arsyad, 2010).

Oil palm plantations in PTPN VII Rejosari, Regency of Natar, South Lampung is generally dominated by S-2 (moderately suitable) and S-3 (marginally suitable) Ultisol, which indicates that the production potential of oil palm is relatively low. One of the constraining factors in oil palm production is the sloping contour of the land (3%-8%), shallow solum (\pm 1 m), and limited rainfall throughout the year in the area of oil palm production. Murtilaksono et al. (2009) reported pronounced dry seasons and excessive rainy season in South Lampung, which results in drought during the dry season and high rate of erosion during the rainy season.

Erosion in oil palm plantations can be reduced by creating ridge terraces and planting cover crops, a

soil conservation technique to support a sustainable nutrient availability in agricultural land. Terracing is a combination of contouring and land shaping in which earth embankments, or ridges, are designed to intercept run off water and channel it to a specific outlet. Terraces reduce erosion by decreasing the steepness and length of the hillside slope and by preventing damage done by soil surface run off. Cover crops provide protective covering which is in direct contact with the ground provides more protection than canopy cover. By absorbing the destructive forces of raindrops and wind, cover crops reduce erosion, conserve water in the soil solum, and add organic matter and soil nutrients (Bunch, 2012).

Recently mature oil palm plantations no longer use legumes as cover crops due to their intolerance to shade, and because planted legumes were naturally overgrown by different types of shade-tolerant weeds, including *A. gangetica*.

A. gangetica is known as weeds to be controlled in oil palm plantations, because it produce seeds in large quantities (Adetula, 2004). However, *A. gangetica*, mainly subspecies *gangetica*, can be used as cover crop as it has no tendrils or spines (Ismail and Shukor, 1998), easy to grow and grow quickly (Yenni et al., 2015a), adaptable to different environmental conditions (Sandoval and Rodriguez, 2012), shade-tolerant (Yenni et al., 2015a), they can even grow well under 90% shaded (Adetula, 2004). *A. gangetica* was reported to increase water availability in ultisol (Junedi, 2014), and increase the availability of N, P, K through the creating nutrient balance (Yenni et al., 2015b).

A. gangetica is able to grow well in full of light and low soil fertility (Samedani et al., 2013; Kiew and Vollesen, 1997), to restrain or reduce erosion due to raindrops and surface run off (Adetula, 2004), has high nutritional value (antioxidants) for animal feed and drugs (Adetula, 2004; Gopal et al., 2013; Mugabo and Raji, 2013), and can serve as bio-monitor for the presence of heavy metals such as mercury (Hg) (Chew et al., 2012). In addition *A. gangetica* contributed N, P, and K to the soil (Yenni et al., 2015b), rapidly decomposed (Yenni et al., 2014), and can serve as soil carbon stock (Yenni et al., 2015b).

Results of Fuady and Satriawan (2011) showed that planting cover crops such as corn and peanuts as well as ridge terracing was able to control run off and erosion to 63.5% and 90.3%, respectively, compared to the absence of cover crops and ridge terrace. Planting cover crops on palm oil plantations were effectively reduced run off and soil erosion, and prevent loss of nutrients (Fuady et al., 2014;

Satriawan et al., 2011; Satriawan et al., 2012). This study aims at examining the roles of *A. gangetica* as cover crop to minimize soil erosion and loss of nutrients in mature oil palm plantation in South Lampung, Indonesia.

Materials and Methods

This research was conducted in the field using split block design in a randomized block design with two factors and six replications. The main plots were: ridge terrace consists of with and without ridge terrace. The subplots were cover crop, consists of with and without cover crops *A. gangetica*.

Before the erosion plots were constructed ridge terraces were arranged in the same directions to contour on each vertical interval 80 cm. Height, width and depth of mounds channel was 30 cm (Figure 1). Erosion plots were made on each block experiment with an area \pm 300 m² using ebonite tarpaulin material. Erosion materials from the erosion plots were collected using Tub A measuring 5 m x 1 m x 1 m, and on outwards facing side created 7 sinkholes, 6 cm in diameter. The center hole was connected by pipes Ø 6 cm into Tub B (Figure 1). Gauze was placed above the Tub A which serves to accumulate soil erosion by run off. *A. gangetica* for cover crop was planted after erosion plot has been constructed, with a spacing of 10 cm x 10 cm.

Erosion measurements were performed following every rainfall event during the study. The erosion measurement includes soil filtered on gauze and sediments that were dissolved in the tub A and B. Soil particles that were collected in gauze was weighed by draining in oven at 105 °C until reaching a constant weight. The weight of soil sediment samples were weighed by filtering the water using filter paper. Sediments that were left on the filter paper were dried in the oven at 105°C until reaching a constant weight. The amount of soil and sediment (E) was calculated using the following equation :

$$E = \frac{(S + (C_{apA} \times V_A) + (C_{apB} \times V_B \times 7)) \times 10^{-3}}{A}$$

Where

E	: soil erosion (t.ha ⁻¹)
C_{anA} and C_{anB}	: concentration of sediment load in
april app	Tub A and B (kg.m ⁻³⁾
V_{A} and V_{B}	: run off volume (m ³⁾
A	: area (ha)
10 ⁻³	: conversion unit from kg to ton.

Soils and sediments analysis were performed to measure the concentration of organic C using Walkley & Black Method, Total N using Kjeldhal Method, P_2O_5 available using Bray Method with spectro-photometer, and K_2O available using Bray Method with flame photometer. The analysis results of organic C, Total N, P_2O_5 and available K_2O through erosion (soil and sediment) were calculated by the following equation:

Where:

- X = Amount of organic C, N, P and K lost through erosion (kg.ha⁻¹)
- Y = Concentration of Organic C, total N, P and K available in sediment
- E = Amount of total soil erosion (t.ha⁻¹).

Data obtained from the amount of erosion and nutrients loss through erosion were analyzed using ANOVA; further testing used Least Significant Difference (LSD) at 5% significant level. Data were analysed using the Statistical Analysis System (SAS) Software 9.1. (SAS, 2004).

Results and Discussion

Soil Erosion

Effect of ridge terrace and cover crops A. gangetica on erosion in oil palm plantation PTPN VII Rejosari, South Lampung is presented in Figure 2. Erosion is the loss of soil surface top layer along with run off caused by rain (Arsyad, 2010). Run off as the cause of soil erosion occurred due to heavy rainfalls, demonstrated in Figure 2. Erosion did not occur in August and September 2014 where there was no rain whereas erosion occurred in October 2014 when rainfall was 21.8-251.3 mm. In December 2014 with rainfall of around 220.9 mm, erosion in plots with ridge terrace with A. gangetica as cover crop (G_1T_1) was smaller than without ridge terrace and cover crop $(G_{0}T_{0})$, i.e. 0.03 t.ha⁻¹ and 3.3 t.ha⁻¹, respectively. This is because in the G₀T₀ treatment rain droplets directly falling onto the unprotected soil surface, accelerating run off and caused soil erosion. Sinukaban (1989) stated that erosion will increase drastically with increased rainfall when the soil surface is not covered by vegetation, or contoured with ridge terrace due to limited opportunity for water infiltration.

Treatment with ridge terrace and planting cover crop *A. gangetica* was able to reduce soil erosion despite the high rainfall; the plant canopy of the cover crops protected the soil surface from the kinetic energy

of rain droplets. In addition, more rain water was intercepted by plants, and the ridge terrace improved water infiltration to the soil through trenches and holes in the ridge terrace. Other studies show that oil palm planting + upland rice followed with soybean + *Mucuna bracteata* strips were able to minimize erosion in the five to seven-year-old oil palm plantation (Fuady et al., 2014). Similarly, ridge terrace and cover crops significantly supress erosion in coffee plantation compared to coffee without cover crops (Dariah et al, 2004).

Table 1 shows that interaction between ridge terrace and cover crops had significant effects on erosion. Ridge terrace with cover crop *A. gangetica* (G_1T_1) had the lowest soil erosion of 3.3 t.ha⁻¹ per year, whereas those without ridge terrace and cover crops (G_0T_0) had the highest soil erosion of 56.4 t.ha⁻¹ per year.

Growing *A. gangetica* in the oil palm plantation improved the effectiveness of ridge terrace on reducing erosion from 47.1 % (G_1T_0) to 94.1 % (G_1T_1) (Table 1). Idjudin (2011) reported that the effectiveness of ridge terrace in reducing erosion will increase if this practice is combined with planting cover crops. Satriawan et al. (2015) also showed that combination of ridge terrace and cover crop reduced erosion 1.8 times more effective than without ridge terrace and cover crops, whereas Nursa'ban (2009) reported 100% soil protection from erosion by ridge terrace and cover crop.

Loss of Organic C, N, P, and K

Table 2 shows that soil erosion caused the loss of organic C, N, P and K in the soil, and that ridge terrace and cover crops has significantly reduced the losses of organic C and total N, P_2O_5 and K_2O . Loss of organic C, total-N, P_2O_5 and K_2O by erosion were lower on ridge terrace (G₁) treatment compared to without ridge terrace (G₀). This is because ridge terrace will delay run off and provide channels for the run off, thereby increasing the rate of water infiltration into the soil, reduce loss of organic C and soil nutrients through erosion.

Loss of organic C, total-N, P_2O_5 and K_2O through erosion in the plots with cover crops *A. gangetica* (T₁) were also less than without the cover crop (T₀), likely because the presence of canopy and root system from the cover crop were able to improve soil carrying capacity and facilitated water infiltration into soil, in turn reduce loss of organic C and soil nutrients.

Combination of ridge terraces and cover crops also significantly reduced the loss of organic C, total-N, P_2O_5 and K_2O through erosion. Cultivation of *A*.



Figure 1. The ridge terrace and sediment collector system at the experimental plots.

 Table 1. Effectiveness of ridge terrace and cover crop A. gangetica in reducing erosion in palm oil plantation

 PTPN VII Rejosari, South Lampung, from August 2014 to April 2015

Treatments	Erosion (t.ha⁻¹ per year)	Effectiveness to minimize erosion (%)	Total rainfall (mm per year)	Rainfall day (day)
G ₀ T ₀	56.4a	-	1208.1	44
G ₀ T ₁	25.5b	54.7	1208.1	44
G ₁ T ₀	29.8b	47.1	1120.0	43
G ₁ T ₁	3.3c	94.1	1120.0	43

Note : Different letters in the same column show significant differences at 5% LSD. G_0 = without ridge terrace, G_1 = ridge terrace, T_0 = without cover crop; T_1 = with cover crop *A. gangetica*. The effectiveness to minimize erosion is calculated by comparing the erosion of $G_0 T_0$ treatment (control) with other treatment.



Figure 2. Average erosion and monthly rainfall during the period of August 2014 to April 2015. A: without ridge terrace + without cover crop A. gangetica (G0T0), and without ridge terrace + cover crop A. *gangetica* (G0T1); B: with ridge terrace and without cover crops (G1T0) and with ridge terrace and cover crop A. *gangetica* (G1T1).

Table 2.	Effect of cover	crops and ridge	e terraces to	the loss o	f total	organic C,	total-N, I	P_2O_5 and k	< _₂ O throug
	erosion in oil p	alm plantation P	'TPN VII Rejo	osari, Sout	th Lam	pung from	August 2	014 to Apr	ʻil 2015.

The stars and a	Cover crop	Maaa		
Treatments	T _o	T ₁	mean	
Ridge Terraces	Organic C (kg.ha ⁻¹)			
G ₀	97.4a	5.1c	34.4a	
G ₁	40.8b	0.9c	13.9b	
Mean cover crop ¹⁾	69.1a	3.0b		
	Total N (kg.ha-1)			
G ₀	8.70a	0.80c	3.2a	
G ₁	3.50b	0.07c	1.2b	
Mean cover crop ¹⁾	6.10a	0.44b		
	P ₂ O ₅ (kg.ha ⁻¹)			
G ₀	0.020a	0.002c	0.009a	
G ₁	0.007b	0.002c	0.003b	
Mean cover crop ¹⁾	0.050a	0.002b		
	K₂O (kg.ha⁻¹)			
G ₀	1.4a	0.20c	0.5a	
G ₁	0.5b	0.02c	0.2b	
Mean cover crop ¹⁾	1.0a	0.11b		

Note : G0 = without ridge terrace, G1 = ridge terrace, T0 = without cover crop A. gangetica; T1 = with cover crop *A. gangetica*

Values in the column and row followed by the same letter are not significantly different at 5% LSD 1) The mean values in the same column and row followed by different letters show significant differences at 5% LSD.

gangetica improved the effectiveness of ridge terrace in reducing the loss of organic C, total-N, P_2O_5 and K_2O from 58.1% (G_1T_0) to 99.1% (G_1T_1), 59.8% (G_1T_0) to 99.2% (G_1T_1), 65.0% (G_1T_0) to 98.9% (G_1T_1) and 64.3% (G_1T_0) to 98.5% (G_1T_1), respectively.

Loss of soil organic C also means losing of soil organic matter, because Organic C is the main constituent of soil organic matter. The loss of Organic C by erosion is a serious problem as it will accelerate soil degradation and declining soil fertility. Content of soil organic matter is one indicator of land resources sustainability (Wolf and Snyder, 2003). Organic materials serve to recycle nutrients back into the soil, and improve water holding capacity. The organic matter content of agricultural top soil is usually in the range of 1 to 6%. A study at Michigan demonstrated potential crop yield increases of about 12% for every 1% organic matter. In a Maryland experiment, researchers saw an increase of approximately 2 tons of maize per acre when organic matter increased from 0.8% to 2% (Magdoff, 2012). Soil organic matter affects soil biological, chemical and physical properties,

and makes it of critical importance to healthy soils (Magdoff, 2012; Bunch 2012).

The loss of total N through erosion was higher than the loss of P and K. This might be because one of N sources is soil organic matter (Hardjowigeno, 2010), so the increased loss of organic C through erosion resulted in the higher leach of N. Loss of K by erosion is usually higher than P because by K is more susceptible to leaching compared to P (Havlin et al., 2005).

Information from this study shows that oil palm plantations may have experienced accelerated land degradation due to erosion, which resulted in decreased soil organic matter content and soil nutrients (Arsyad, 2010). However, with ridge terrace and cover crops *A. gangetica* erosion and loss of organic matter and nutrients can be controlled, as the loss of nutrients was directly related to the amount of erosion, and it is a function of organic C and nutrients concentration in the sediment (Sinukaban, 2007; Arsyad, 2010).

Similar results were reported in teak (Didjajani, 2012) and coffee plantation (Dariah et al., 2004) that higher soil erosion resulted in a higher loss of organic C, N, P, and K. Similarly, Henny et al. (2011) show that planting potato on ridges across the slope land decreased loss of organic C, N, P, and K due to reduced erosion. Other studies show that ridge terrace and intercropped areca nut with maize, and ridge terrace and intercropped cocoa with peanut reduced the loss of organic C, N, P, and K due to lower incidence of erosion (Satriawan, 2015).

Conclusion

A. gangetica as cover crops in mature oil palm plantations can effectively minimize erosion and reduce the loss of organic C, N, P, and K by 95.7%, 93.4%, 96.0% and 90.0%, respectively. Combination of ridge terrace with cover crop *A. gangetica* in mature oil palm plantations was more effective to reduce erosion and loss of organic C, N, P, and K, i.e. by 94.1%, 99.1%, 99.2%, 90.0% and 98.5%, respectively.

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