

SOIL CONSERVATION TECHNIQUES IN OIL PALM CULTIVATION FOR SUSTAINABLE AGRICULTURE

Teknik Konservasi Tanah pada Budidaya Kelapa Sawit untuk Pertanian Berkelanjutan

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Abstract. *Currently, many have been concerned with the oil palm cultivation since it may also put land resources in danger and bring about environmental damage. Poor practices in managing agricultural land very often occur due to the inadequate knowledge of soil conservation. Application of soil and water conservation is to maintain the productivity of the land and to prevent further damage by considering land capability classes. This research was aimed at obtaining soil and water conservation techniques which are the most appropriate and optimal for oil palm cultivation areas based on land capability classes which can support sustainable oil palm cultivation. Several soil conservation techniques had been treated to each different class III, IV, and VI of the studied area. These treatment had been performed by a standard plot erosion. The results showed for the land capability class III, Cover plants + Manure was able to control runoff, erosion and reduce leaching of N (LSD $P \leq 0,05$), in which soil conservation produced the lowest erosion (3,73t/ha), and N leaching (0,25%). On land capability class IV, Sediment Trap + cover plants+ manure was able to control runoff, erosion and reduce organic C and P leaching (LSD $P \leq 0,05$), in which soil conservation produced the lowest runoff (127,77 m³/ha), erosion (12,38t/ha), organic C leaching (1,14 %), and P leaching (1,28 ppm). On land capability class VI, there isn't significant effect of soil conservation, but Bench Terrace + cover plants +manure has the lowest runoff, erosion and soil nutrient leaching.*

Keywords: *runoff, erosion, oil palm, soil conservation, land capability*

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1. Introduction

Oil palm trees have been widely grown in many parts of Indonesia. In Aceh Province, particularly in Bireuen Regency, these plants have shown rapid development in recent years. In 2012, for example, the land prepared for developing oil palm plantation reached 27.434 ha, spreading across seven subdistricts (IICB, 2014). Of the total land, some 4.372 ha had been planted. The magnitude of the oil palm potential development in Bireuen Regency is undoubtedly crucial to the increase in foreign exchange earnings.

However, many have been concerned with the oil palm cultivation since it may also put land resources in danger and bring about environmental damage. The plantations are generally on the land slope of 15-60%, with land capability classes III - VII (Satriawan and Fuady, 2012). The land classes III and IV are still appropriate for agricultural activities when accompanied by the application of appropriate soil conservation technologies. Needless to say, land capability classes of V - VII are very vulnerable to damage if used for agricultural activities (Saida et al., 2013).

Poor practices in managing agricultural land very often occur due to the inadequate knowledge of soil conservation. What makes matters worse, the land use is based on purely economic considerations. As a result, this land use has triggered diverse rates of soil erosion in the various forms of land cultivation, ranging from 54 to 1.007 tons/ha/year (Satriawan and

Harahap, 2013), which is still higher than the tolerable level of soil erosion in this region, i.e 25-40 tons / ha / year (Fitri, 2010). Without proper application of soil and water conservation, newly-planted oil palm trees can be a source of damage to the soil that can cause land degradation.

The soil and water conservation is carried out to obtain high crop production using the appropriate carrying capacity of the land resources and to assure that the soil erosion rate is lower than or equal to the tolerable level of erosion (Xiang et al., 2012). Application of soil and water conservation is to maintain the productivity of the land that has been degraded and to prevent further damage by considering land capability classes.

The objective of agricultural cultivation to obtain crop production is frequently in conflict with the objective of soil and water conservation (Mansoori and Kohansal, 2009). Likewise, the economic objective of the effort to develop oil palm is in conflict with the objective of maintaining soil quality and environment. These conflicting objectives, therefore, should be compromised to obtain economic value which is feasible without causing greater erosion than the tolerable level of erosion. This research was aimed at obtaining soil and water conservation techniques which are the most appropriate and optimal for oil palm cultivation areas based on land capability classes which can support sustainable oil palm cultivation.

2. Research Methods

2.1. Research Sites

The research was conducted in community oil palm plantations which already pre-determined of their land capability classes (III, IV and VI). The research site was in Blang Mane Village and Bukit Sudan Village, South Peusangan Subdistrict and Peusangan Siblah Krueng Subdistrict, Bireuen Regency of Aceh Province. The site located at 5°4'30"N and 96°45'18" E with 116 m elevation.

Oil palm which serves as the object of research is immature plant, with ages 1-2 years. Oil palm trees planted with a spacing of 8 x 8 m, by following the directions of slope.

Land capability class III in the study site was an area located on slopes, slightly sloping or bumpy (8-15%), with mild – moderate soil depth (85-125 cm), sensitive to erosion or already experiencing mild – moderate erosion, and the rocks on the surface were light.

Land capability class IV was an area located on sloping or hilly slopes (15-30%), with moderate soil depth (80-90 cm) and moderately eroded (50% upper layer had been lost).

Land capability class VI was an area located on the sloping area (45%), with thin soil depth (< 50 cm) and heavy eroded soil (75% upper layer had been lost).

2.2. Materials

The materials used in the study included community plants, manure of cow, *soybean* (as cover plants), agricultural lime (Dolomite), chemical fertilizers (Urea, ZA, SP-36, KCl), mulch from weeds, fungicides, insecticides, nematicides and herbicides as well as a number of chemicals for soil analysis in the laboratory.

2.3. Tools

The tools used were double ring infiltrometer, digital camera, sediment collector, rainfall-measuring tool (manual), plastic tarp, PVC pipe, bamboo, hoe, stationery, clinometer, and a set of laboratory tools for the analysis of soil samples in the laboratory.

2.4. Methods

The research used an Experimental Method (Standard Erosion Experiment). The testing technique of soil and water conservation for plants was conducted on the basis of land capability classes that have been determined. This test was performed with a standard plot erosion test. Each land capability class had been applied to different technologies according to the recommendation of each class (Arsyad, 2010).

In capability class III, four treatments with three replications had been tested. The four treatments were:

Individual terrace (horseshoe) (P1)
Individual terrace + plant strip (P2)
Cover crops+ manure (P3).

In capability class IV, four treatments with three replications had been tested. The four treatments were:

Farmer system/Control (P0),
Sediment trap (P1),
Sediment trap + vertical mulch (P2),
Sediment trap + cover crops+manure (P3).

In capability class VI, four treatments with three replications had been tested. The four treatments were:

Farmer system/Control (P0),
Bench terrace + plant strip (P1),
Bench terrace + cover crops (P2),
Bench terrace +cover crops + manure (P3).

2.5. Observation and Data Collection

The data collected consisted of: 1) the physical and chemical properties of the soil prior to the treatments; 2) the chemical properties (organic C, total N, available P and exchangeable K) after treatments (one week before harvest of soybean); 3) the infiltration capacity (a week before harvest of soybean); 4) runoff and erosion; 5) concentration of suspended sediment; 6) concentration of organic C, N, P and K in the sediment, and 7) rainfall during the experiment. The soil samples for the determination of the physical properties of soil were taken at a depth of 0-20 cm and 20-40 cm, while for the determination of soil chemical properties using composite soil samples, taken at a depth of 0-40 cm. Runoff and erosion measurements performed during each rainfall event.

a. Measurement of Surface Runoff and Erosion

The measurements of runoff and erosion were performed on each rainfall occurrence during the experiment. The measurements of erosion were done by measuring the volume of runoff and water samples on each drum. The amount of eroded soil was measured by filtering water samples using filter paper, then the soil left on the filter paper was dried in an oven at 60 °C until the weight of the filter paper and sediment was fixed. The amount of sediment that indicated the amount of erosion that occurred was calculated using the following equation:

$$E = \frac{C_{ap} \times V_{ap} \times 10^{-3}}{A}$$

Notes:

- E = Eroded soil (tons / ha)
 Cap = Concentration of sediment load (kg / m³)
 Vap = The volume of runoff (m³)
 A = Eroded area (ha)
 10^{-3} = Conversion from kg to ton

b. Sediment Analysis

Sediment analysis conducted to measure the content of organic C (C_{tot}) (Walkley-Black method), total Nitrogen (N_{tot}) (Kjeldahl method), available P (Bray-1 method) and exchangeable K (extraction with 1 N NH_4OAc pH 7.0). Total organic C, N, P and K carried by erosion were calculated by the equation:

$$X = Y \times E$$

Notes:

- X = the amount of organic C, N, P and K carried by erosion (kg/plot)
 Y = the concentration of organic C, total N, P and K which was available in the sediment
 E = the total amount of eroded soil (kg/plot)

c. Statistic Analysis

The amount of runoff and erosion and the data of nutrient loss measured from erosion sediment were subjected to ANOVA procedure, and means separation test was done by protected Least Significant Difference (LSD) test at 5% level of significance.

3. Results and Discussion

3.1. Group of Land Capability Class III

The soil conservation technologies applied were the individual terrace (the disc around *gawangan* oil), individual terrace + strip plants, and cover crops (soybeans) + manure. Based on the measurement results of runoff and erosion, it was found the soil conservation technique that was capable of suppressing erosion compared to control treatment, in this case the best treatment was using cover plants and organic fertilizers (Table 1).

Soybean as intercropping plant as well as cover plant between rows of oil palm trees was the most effective in controlling runoff and erosion 1) by reducing rain erosiveness through the interception and dissemination of plant canopy that could block the falling rainwater; 2) due to soybean dense root system that could strengthen soil aggregates in the upper layer through granulation; and 3) due to the organic exudates of the root that could increase soil microbial population, soil porosity, and infiltration. On the other hand, combination of plants + individual terrace on oil palm also had a positive effect on erosion control. However, because of the absence of organic material that served as a stable aggregate, the effectiveness was slightly lower.

The result of similar research was found by Mekonena et al. (2016) that is grass barriers can be used as a soil conservation measure, reduce soil loss, and more maintenance demanding physical structures like trenches and ridges.

Table 1. Runoff, soil erosion and nutrient status in sediment on land capability class III

Soil Conservation	Runoff (m ³ /ha)	Erosion (ton/ha)	Organic C (%)	N_{tot} (%)	P_{av} (ppm)	K_{exc} (me/100 gr)
Control (P0)	15,80b	5,13b	3,40	0,41ab	1,78	0,42
Individual Terrace/IT (P1)	14,47ab	4,07a	2,70	0,29ab	1,89	0,36
IT + Plant strip (P2)	12,05a	3,86a	2,29	0,13a	1,80	0,32
CC+Manure (P3)	12,80a	3,73a	2,55	0,25ab	1,37	0,23
LSD 0,05	2,86	0,38		0,22		

Note: In the same column, values with different indices are significantly different from one another at the LSD ($p \leq 0,05$) test.

In conjunction with the physical properties of soil, organic materials such as manure and compost can play a role in the formation of stable aggregates (Sutono et al., 1996) as it can bind the primary granules into secondary granules. This occurs because the application of organic matters trigger the presence of polysaccharide gum produced by soil bacteria and the growth of the hyphae and fungi from actinomycetes around soil particles. The improvement of soil aggregate stability increases soil porosity and facilitates the absorption of water into the soil, increasing the retaining capacity of ground water. According to Juarsah et al. (2008), the roles of organic matters to the physical and chemical soil properties are among others to increase aggregation, protect aggregate from destruction by water, make the soil more easily processed, im-

prove porosity and aeration, and increase the capacity of infiltration and percolation.

Loss of soil element through sediment on oil palm trees in land capability class III occurred in the element of organic C, which serves as a soil ameliorant-where. The largest loss was in the control treatment. Applying the soil conservation technique, in general, could reduce the loss of organic C. Similarly, with the loss of N, the amount of loss resembled the loss of organic C. This can be understood as the element of N was correlated with soil Carbon (Table 2). In general, the application of soil conservation which modifies the surface roughness of the land by making individual terraces and maximizing land cover could prevent the loss of nutrients through erosion.

Table 2. Weight of sediment nutrient in land capability class III

Soil Conservation	Weight (kg)			
	Organic C	N _{tot}	P _{av}	K _{exc}
Control (P0)	174,26b	20,84c	0,009a	0,022a
Individual Terrace/IT (P1)	109,84a	11,93ab	0,008a	0,015a
IT + Plant strip (P2)	95,02a	9,45a	0,007a	0,012a
Cover Crops + Manure (P3)	88,41a	4,88a	0,005a	0,009a
LSD 0.05	42,51	6,23	0,01	0,02

Note: In the same column, values with different indices are significantly different from one another at the LSD ($p \leq 0,05$) test.

Nutrient weight was positively correlated with the amount of eroded soil and sediment nutrient content. The more the eroded soil, the greater the weight of lost nutrients. Table 1 shows the amount of the largest loss of nutrients found in the control treatment, which was followed the Individual terrace treatment, IT + plant strip and cover crops + manure, respectively.

3.2. Group of Land capability class IV

Likewise, on the group of land capability class IV, with the adoption of soil conservation technology called sediment trap, sediment trap + vertical mulch and sediment trap + cover crops and manure significantly reduced runoff and erosion (Table 3).

Table 3. Runoff, soil erosion and nutrient status in sediment on land capability class IV

Soil Conservation	Runoff (m ³ /ha)	Erosion (ton/ha)	Organic C (%)	N _{tot} (%)	P _{av} (ppm)	K _{exc} (me/100 gr)
Control (P0)	235,81d	30,80d	2,62a	0,17	2,40ab	0,34
Sediment Trap/ST (P1)	187,31c	20,40c	1,55a	0,19	3,86b	0,35
ST+Vertical Mulch (P2)	160,55b	16,26b	1,80a	0,24	0,86a	0,50
ST+Cover Crops+Manure (P3)	127,77a	12,38a	1,14a	0,19	1,28a	0,38
LSD 0.05	11,26	2,41	2,09		1,83	

In the same column, values with different indices are significantly different from one another at the LSD ($p \leq 0,05$) test.

On land capability class IV, the runoff and erosion occurred at the lowest in the treatment of sediment trap + cover crops + manure, and the highest in the treatment of control. The treatment of sediment trap + cover crops + manure was capable of suppressing the amount of runoff and erosion by 54% compared to the control treatment. The ability of conservation techniques was closely related to the function of sediment trap as water collector and sediment control carried by surface runoff. In addition to land cover with cover plants, the soil was also very helpful in controlling the rate of runoff. This is consistent with results of the previous studies that the effectiveness of the application was relatively high to suppress the occurrence of erosion which reached 71%, depending on the soil structure and the condition of land cover. The shorter the distance between the sediment trap on the same slope, the more effectively it reduced erosion and runoff, increasing the groundwater content (Monde, 2010; Brata, 1998; Murtalaksono et al., 2008).

Effectiveness of soil loss controlled by sediment trap/micro basin tillage was reported by Sui et al. (2016), where the attributed to the fact that sediment trap built forming a relatively large surface roughness, increasing duration of time for lateral and vertical infiltration, can reduce the kinetic energy responsible for detachment and transport of soil erosion.

Sediment trap + cover plant planting (soybean) and manure treatment could prevent the loss of organic C, N, P and K. Based on Table 3, the lowest level of organic C and N in the erosion sediment was found in the treatment of sediment trap + cover crops + manure, whereas the loss of P and K through sediment was in the treatment of sediment trap + vertical mulch. The low loss of C and N in the treatment of sediment trap + cover crops + manure was possible due to the role of cover plants that were able to use C and N appropriately as a source of nutrients in their growth process.

In addition, the sediment trap made the water stored which contained nutrients was close to the plant roots. Meanwhile, the elements of P and K that are mobile and easily soluble in the water were mostly found in the treatment of control and sediment trap. Nutrient weight was positively correlated with the amount of eroded soil and sediment nutrient content. The more the eroded soil, the greater the weight of lost nutrients. Table 4 shows the amount of the largest loss of nutrients found in the control treatment, which was followed the sediment trap treatment and vertical mulch, and sediment trap+cover crops+manure.

Table 4. Weight of sediment nutrient in land capability class IV

Soil Conservation	Weight (kg)			
	Organic C	N _{tot}	P _{av}	K _{exc}
Control (P0)	810,41b	52,62	0,07a	0,28b
Individual Terrace/IT (P1)	321,64a	39,87	0,08a	0,20a
IT + Plant strip (P2)	291,60a	39,53	0,01a	0,15a
Cover Crops + Manure (P3)	141,64a	23,29	0,02a	0,12a
LSD 0.05	341,98		0,04	0,05

In the same column, values with different indices are significantly different from one another at the LSD ($p \leq 0,05$) test.

3.3. Group of Land Capability Class VI

The different results found in the application of soil and water conservation technology on land capability class VI, where the treatment hasn't significant effect on runoff, erosion and loss of nutrients (Table 3). Nevertheless, the general adoption of soil conservation technologies can reduce runoff and erosion and nutrient leaching compared to treatment without application of soil and water conservation technology, although not yet reached < tolerable erosion.

In the group of land capability class VI, the role of soil and water conservation technology was high role in reducing erosion and runoff. The results showed that cover plants were best in reducing surface runoff by 40,51%, followed by cover crops+manure and sediment trap, respectively, compared to the control runoff. In terms of the soil loss (erosion), cover crops + manure could reduce the erosion at the highest compared to other soil conservation treatments, which was 65,9% lower than the erosion in the control.

Table 5. Runoff, soil erosion and nutrient status in sediment on land capability class VI

Soil Conservation	Runoff (m ³ /ha)	Erosion (ton/ha)	Organic C (%)	N _{tot} (%)	P _{av} (ppm)	K _{exc} (me/100 gr)
Control (P0)	106,64	54,38	1,69	0,19	2,49	0,71
Bench Terrace + Sediment Trap (P1)	73,32	20,42	0,98	0,14	1,70	0,54
Bench Terrace + Cover Crops (P2)	63,44	27,71	2,08	0,25	2,33	0,56
Bench Terrace + Cover Crops + Manure (P3)	72,53	18,54	2,32	0,23	1,67	0,67
LSD 0,05	38,78	1,5	1,45	0,09		

In the same column, values with different indices are significantly different from one another at the LSD ($p \leq 0,05$) test.

Cover crops are very useful for plantation trees because they can 1) hold or reduce the destructive power of falling rain drops and surface runoff, 2) add to soil organic matter through the stems, twigs and fallen dead leaves, 3) carry out transpiration which reduces

soil water content. The role of the cover crops leads to reduced strength dispersion of the rainwater, reducing the amount and speed of runoff and increasing water infiltration into the soil, and therefore it can reduce erosion.

Table 6. Weight of sediment nutrient in land capability class VI

Soil Conservation	Weight (kg)			
	Organic C	N _{tot}	P _{av}	K _{exc}
Control (P0)	908,90	102,44	0,14	0,38
Bench Terrace + Sediment Trap (P1)	197,96	27,46	0,03	0,11
Bench Terrace + Cover Crops (P2)	580,67	69,40	0,06	0,15
Bench Terrace + Cover Crops + Manure (P3)	448,56	44,33	0,03	0,13
LSD 0,05	707,31	72,63	0,07	0,25

In the same column, values with different indices are significantly different from one another at the LSD ($p \leq 0,05$) test.

Application of soil and water conservation had an effect on nutrient loss in the group of land capability class VI, especially in Nitrogen, Phosphorus and Potassium. The biggest loss was found in none soil and water conservation (control treatment). Among the

treatments tested, sediment trap was able to suppress the loss of organic C, N, cover plants P and K.

In general, on oil palm plantations, soil erosion is commonly checked by early cover crop establishment, strategic placement and treatment of pruned fronds,

and old palm trunks with felling, terracing, construction of silt pits/sediment trap, and mulching with empty fruit bunches or weeds (Hartemink, 2006).

4. Conclusion

1. Application of soil conservation techniques to each group of land capability could control surface runoff and erosion.
2. On land capability class III, Cover plants + Manure was able to control runoff, erosion and reduce leaching of N, where soil conservation produced the lowest erosion (3.73 t/ha), and N (0.25 %).
3. On land capability class IV, Sediment Trap + cover plants + manure was able to control runoff, erosion and reduce C organic and P leaching, that soil conservation produced the lowest runoff (127.77 m³/ha), erosion (12.38 t/ha), C organic (1.14 %), and P (1.28 ppm).
4. On land capability class VI, soil and water conservation was able to control runoff, erosion and soil nutrient leaching.

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