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Prediction and alternative conservation techniques of erosion at sugarcane plantation under wet tropical region

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Abstract

Soil erosion is a kind of the worst soil degradation phenomenon in the world which could be due to soil mismanagement. The research aimed to predict the amount of soil erosion and to find out the alternative controlling techniques was conducted at sugarcane plantation in Lawang, Agam Regency and soil laboratory of Universitas Andalas, Padang, Indonesia. Soil sampling was taken at 5 slopes (0-8%, 8-15%, 15-25%, 25-40%, and >40%). Soil parameters were collected and analyzed at field and laboratory to get soil erodibility data. Soil erosivity was calculated based on rainfall data in that area from the last 10 years. Soil erosion was predicted using USLE formula and tolerated erosion using Hamer concept. The results showed that eroded soil increased by steeper slope from 0 to 40%. The predicted soil erosion was higher than the tolerated one for each slope level except under rather flat area (0-8% slope). The erosion hazard level in the research site belonged to low (for 0-8% slope), medium (for 8-15%), and high (for >15% slope). Therefore, alternative techniques should be introduced to control the erosion, among which were soil hummock for all slope levels and terraces for steep slopes. Constructing traditional terrace at area having 8-15% slope, and perfect bench terrace at area having >15% slope would decrease the actual erosion from 34.73 to 18.52 t/ha/y (at 8-15% slope), from 147.4 to 6.55 t/ha/y (at 15-25% slope), from 415.4 to 18.46 t/ha/y(at 25-45% slope), and from 203.2 to 18.04 t/ha/y (at >40% slope).

Keywords: Conservation techniques, Predicted erosion, Slope, Sugarcane plantation, Wet tropical region

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Introduction

Erosion can happen any where in the world. The impact will result in low *in situ* soil fertility (Tuo et al., 2018) as well as produce natural disaster, especially flood during rainy season and drought during dry season for *ex situ*. Land susceptibility order to erosion from the smallest to the largest were arable land, fallowed floodplain, cultivated floodplain, erosion site (Njoku, 2018). Eroded land has low soil fertility either the physical, chemical, or biological fertility of the soil. Physical properties of eroded soils will change due to organic and mineral soil particle loss. Both materials have effects on soil aggregate stability, water retention and transmission, as well as infiltration rate of the soil. Based on several studies, there was a positive correlation between soil organic matter (SOM) and soil aggregate stability, especially soils having fine texture, such as Ultisol (Yulnafatmawita et al., 2013a; and Yulnafatmawita, 2016). The SOM was also reported to affect water retention and transmission, rate of infiltration, bulk density and total pore values, and soil consistency (Yulnafatmawita, 2012).

Besides soil physical properties, good soil chemical properties also disappear from the top soil due to erosion. Soil cations are washed out, SOM disappears, therefore, the soils become acidic, low cation exchange capacity (CEC), high toxic elements. The SOM that can hold plant nutrients as well as provide them after being degraded is easily moved with runoff either in form of dissolved or particulate organic matter (POM). Yaghobi et al. (2018) found that organic carbon (OC) loss increased as the increasing soil eroded associated with increasing slope level from 0% to 30%. However, Yulnafatmawita et al. (2013b) and Yulnafatmawita et al. (2017) found that there was no correlation between the amount of soil eroded and nutrient loss at 3% and 25% slope in Ultisol under wet tropical areas of Limau Manis Padang. Yulnafatmawita and Yasin (2018) also noticed that there was a downward movement of SOM from the upper to the lower slope position under oil palm plantation. The movement of SOM also correlated to the movement of fine particle in the soil. Furthermore, since the soil water retention and transmission are affected, SOM decreases and soil reaction become acidic due to erosion, the soil organisms cannot be well developed. While the soil organism population and activity are known as an indicator of soil health. Decrease in soil organisms caused low soil fertility. Therefore, this soil must be improved before using it for farming activities.

In wet tropical area, erosion was highly caused by water due to its high annual rainfall. Yulnafatmawita and Adrinal (2014) also reported that total amount of soil erosion during soybean cultivation at 25% slope in Ultisol Limau Manis followed the trend of rainfall. Erosion increased as the total rainfall received increased. Lal (1984) stated that soil erodibility as an indicator of susceptibility of a soil to erosion was determined by the properties, either physical, chemical, or biological ones. It was affected by the SOM content, soil aggregate stability etc. Furthermore, Wu et al. (2018) explained that different types of soil texture from two different soils (Luvisol and Ferralsol) caused different concentration of sediment resulted from erosion.

The erosion could be controlled if farmers realize how important is the soil and the water conservation for sustainable agriculture and environment. Yulnafatmawita et al. (2017) reported soybean cultivation at sloping area (approximately 8% slope) could reduce the soil erosion by 54-72% and runoff by 8-27% in the plot using *Tithonia diversifolia* as an alley fence compared to plots without any alley fence. Based on Gathagu et al. (2018), terrace techniques in sloping areas could decrease runoff by 30%, while combination of terrace and grass waterway was able to reduce sediment as a result of erosion by 81%. Some more methods suggested to control erosion were cropping management and cultivated calendar (Pham et al., 2018), use of elephant grass and *Sesbania* sp (Sinore et al., 2018), implementing conservation tillage such as no-till, buffer strips, contour farming (Labriere et al., 2015).

Sugarcane plantation is a kind of farming in which the soils are not intensively cultivated. However, if the area is located in sloping land and also under wet tropical area, the probability of erosion is high enough. This is due to the canopy of the sugarcane crops has low percentage of covering land surface. Ramos-Scharron and Thomas (2017) found that bare soil contributed more (>90%) sediment at coffee plantation in Puerto Rico came from unpaved roads which was only 15% of the total area.

Sugarcane plantation in Lawang, Agam regency West Sumatra belongs to small scale farmers who do not have any special convention among them, but their plantation is next to each other. They farm the plantation traditionally without having enough knowledge how to manage the land sustainably. Therefore, the sugarcane plantation was not well developed. The amount of soil erosion predicted as well as the alternative ways to control the erosion is important to identify for sustainable sugarcane plantation, and sustainable development.

Material and Methods

This research was conducted at sugarcane plantation in Lawang, Agam Regency West Sumatera, Indonesia. The research was started by collecting secondary data such as maps, especially soil, land use, topography, and administration map of the research area. Then, the climate of the site specifically rainfall amount was also collected from the closest weather station for the last 10 years (Fig.1). Maps were needed for determining sampling location, while rainfall was important to calculate the erosivity number.

The geographical position of the research site was between 100°14'00"-100°17'00" and 0°14'45"-0°16'50" S. The area was located between 825-1,140 m above sea level with annual rainfall between 2500-4000 mm. The plantation was on sloping area. So far, the farmers did not implement the correct conservation techniques to manage the sugarcane plantation. They only used crop residue that functioned as mulch but it was not evenly distributed on the soil surface.

Soil order at sugarcane plantation in Lawang was classified into Inceptisol. The depth of the soil solum was > 150 cm and the effective depth was > 50 cm. The effective depth increased as the slope percentage tended to decrease.

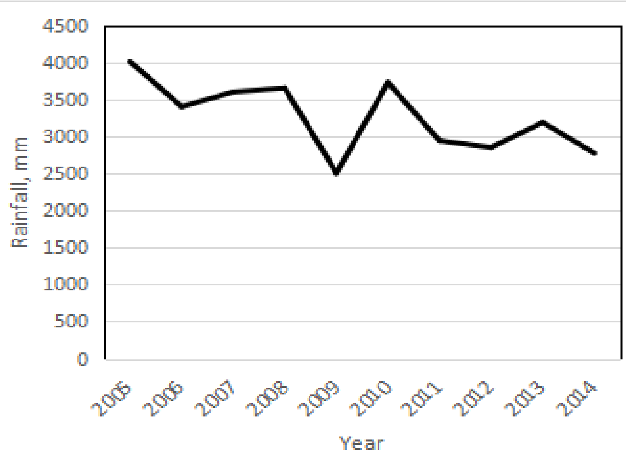

Figure-1: Total rainfall for ten years (2005-2014) in Lawang, Agam Regency

Table-1. Land unit in order Inceptisol at sugarcane plantation in Lawang, Agam Regency

Land unit	Slope (%)	Area	
		(Ha)	(%)
1	0-8	485.3	53.5
2	8-15	291.8	32.2
3	15-25	8.5	0.9
4	25-40	69.4	7.7
5	>40	51.3	5.7
Total		906.3	100.0

This research used survey method, the soil samples were taken based on purposive random sampling. Soil samples were only taken at soil order Inceptisol, the biggest area being planted with sugarcane. Based on overlay soil order map, land use map, as well as slope map, it was got 5 land units in this research site (Table 1).

Field survey was conducted to take either undisturbed or disturbed soil samples for laboratory analyses as well as soil samples to be directly analyzed for the structure types at field site. Disturbed soil samples were taken using sample ring having 7 cm diameter and 4 cm height, while disturbed soil samples were taken by using mineral soil bore (Belgium Bore). Soil samples were taken from 0-20 cm soil depth for 3 replications at each land unit.

Soil samples from field site were brought into soil laboratory at Universitas Andalas to be processed such as air-dried, ground, and then sieved using 2.0 mm and 0.5 mm diameter sieves. Undisturbed soil samples were used for measurement of soil bulk density (gravimetric method) and hydraulic conductivity (constant head method) based on Darcy's law. Disturbed soil samples were used for analyses of soil texture (sieve and pipette method) and organic carbon (wet oxidation method).

Soil erosion prediction was calculated using USLE method (Arsyad, 2010).

$$A = R * K * L * S * C * P$$ ………….. Equation 1

A= Amount of predicted erosion (t/ha/y); R= Erosivity, based on rainfall data; K= Erodibility, based on soil properties such as soil texture, SOM, soil hydraulic conductivity, and soil structure type; L= Length of slope (m); S = Slope steepness (%); C = Crop management; P = Soil conservation technique.

Erosivity value was calculated based on EI_{30} as reported by Lenvain (1975 cit Torri, 1997).

$$El_{30}=2.34R^{1.98}$$ ……………………… Equation 2

El_{30} = Erosivity; R= Monthly rainfall (cm) average of the studied area

Erodibility value of the soil was determined using an equation suggested by Wischmeier (1978).

$$100\ K = 2.1[M^{1.41}(10^{-4})(12 - a) + 3.25(b - 2) + 2.5(c - 3)]$$ Equation 3

K= Soil erodibility; M = (% silt + % very fine sand) x (100-%clay); a= % organic matter; b = Soil structure code; c = Soil hydraulic conductivity class code

Slope length and steepness was calculated based on equation explained by Arsyad (2010).

$$LS = \sqrt{X}(0.0138L + 0.00965s + 0.00138s^2) \quad \text{... Equation 4}$$

LS = Slope factor; X = Slope length (m); S = Slope steepness (%)

Crop management factor (C) was listed and suggested by Arsyad (2010). It was found that crop management factor for sugarcane was 0.2, because the canopy of the crop was not heavy and the biomass residue was not enough to cover the soil surface.
Conservation techniques (P) applied for the sugarcane plantation was generally just contour based planting. Therefore, based on table suggested by Arsyad (2010), it was found that the value for conservation techniques applied in this plantation was 0.50 for 0-8% slope, 0.75 for 9-20% slope, and 0.90 for >20% slope.
Tolerated soil erosion was calculated as suggested by Hardjowigeno (2010):

$$E_{tol} = \left[\frac{DE-DM}{UT} + LPT\right] xBDx10 \text{ ...... Equation 5}$$

E_{tol} = Tolerated erosion rate (t/ha/y); DE= Depth equivalent (=Ke x FKT); Ke= Effective depth; FKT = Soil depth factor based on soil suborder; DM= Soil minimum depth for crop growth (mm); UT= Soil age (y); LPT= Soil formation rate (mm/y); BD= Soil bulk density (t/m^3).

Notes: If the predicted erosion was higher than the tolerated one, the erosion is considered having high level of erosion hazard. Therefore, alternative techniques must be introduced to the land in order to control the erosion.

Erosion hazard level (EHL) was determined by comparing the value of actual erosion (A) to the tolerated erosion predicted as suggested by Hardjowigeno and Widiatmaka (2007). If the level of erosion hazard >1, it means that the land must be conserved by applying some techniques to reduce erosion. Two factors that can be changed within USLE are crop management and conservation techniques.

$$EHL = \frac{A}{E_{tol}} \text{ .... Equation 6}$$

EHL= Erosion hazard level; A= Actual erosion; E_{tol} = Tolerated erosion rate

To reduce soil erosion below the tolerated one, Arsyad (2010) suggested to improve crop performance (C factor) and conservation technique applied (P factor) to farming land. The value of C factor times P factor must be less than the value of E_{tol}/RKLS as presented at the following equation:

$$CP \leq \frac{E_{tol}}{RKLS} \text{ .... Equation 7}$$

E_{tol} = Tolerated erosion (t/ha/y); RKLS= Potential erosion must be ≤ 1 t/ha/y; C = Crop management; P = Soil conservation technique

Results and Discussion

Soil physical properties
Based on Table 2, it was found that the soil in the research site was generally classified as course textured soil. Each land unit contained >50% sand with coarse sand was > 44% of the total soil particles. It means that the soil was able to transmit water easily from soil surface into soil profile, then the probability of runoff will be low. However, coarse textured soil is used to be low in soil aggregate stability index. Dispersed soil aggregates due to cultivation could cause soil dispersion, and then the single particle would fill the pore space among the particles. Therefore, the infiltration rate becomes lower and the chance of runoff will be higher. Finally, erosion cannot be avoided.
Furthermore, percentage of silt plus very fine sand ranged between 2% to 29% (25.8% in average), and soil particles other than clay ranged between 68% to 76% (71.8% in average). These factors affected the erodibility (K) of the soil in the sugarcane plantation. Low clay content causes low aggregate stability even though the soil have enough SOM content, because besides SOM, clay is important in flocculation process during soil aggregate formation and stabilization. Coarse soil texture in this research site was due to the soil order. The soil was developed from relatively new materials derived from eruption of Mount Tinjau in Maninjau. Based on the level of soil development, the soil was still being developed (order Inceptisol). It means that the weathering process of the soil was not yet complete.

Table-2: Particle size distribution and texture class of soil under different slopes in sugarcane plantation in Lawang, Agam Regency

Land unit		Particle size distribution (%)				Texture class
No	Slope (%)	Coarse sand	Fine sand	Silt	Clay	
1	0-8	44	9	15	32	SC = Sandy clay
2	8-15	45	14	13	28	SCL = Sandy clay loam
3	15-25	48	17	8	27	SCL = Sandy clay loam
4	25-40	46	16	8	30	SCL = Sandy clay loam
5	>40	47	20	9	24	SCL = Sandy clay loam

Table-3: Soil organic matter content, structure types and hydraulic conductivity of soil under different slope levels at sugarcane plantation in Lawang, Agam Regency

Land unit		SOM %	Structure		HC	
No	Slope %		Type	Code	Rate (cm/h)	Code
1	0-8	10.6	Medium-coarse granular	3	14.6	2
2	8-15	9.5	Medium-coarse granular	3	14.6	2
3	15-25	8.6	Medium-coarse granular	3	7.0	3
4	25-40	7.0	Medium-coarse granular	3	11.3	3
5	>40	8.3	Medium-coarse granular	3	8.8	3

Note: SOM = Soil organic matter, HC = Hydraulic conductivity

Based on Table 3, the SOM content of the soil at research site was classified into medium to high, with structure type was granular having medium size. The hydraulic conductivity of the soil was slightly fast to fast criteria. High OM content of the soil was beneficial for some soil physical properties. This high OM as well as sand content of the soil increased hydraulic conductivity of the soil causing less runoff.

The SOM content, generally, decreased by increasing slope level from 0-8% to 25-40% slope. This was caused by the fact that OM having low density easily moves downward, the steeper the slope the more the SOM moves. The SOM movement can be in form of fresh, particulate, or dissolved OM. All forms of SOM movement will reduce the SOM content of the soil.

However, the SOM content at the slope >40% was higher than that at slope 25-40%. This was due to the conservation technique applied to the location. Based on field observation and discussion with sugarcane farmers, the area had been conserved by creating bench terraces but not perfect. Terrace can slower water as well as SOM movement from the upper to the lower slope position. As reported by Yasin and Yulnafatmawita (2018) that the flatter the area was the higher the SOM content as well as the percentage of clay particles compared to the sloping land.

Soil structure type was the same at all slope level in the research location. It was medium to coarse granular with aggregate size between 2 and 10 mm in diameter. The granular type of soil structure in this research area was due to high SOM content under coarse textured soil. The SOM bound soil particles constructing aggregates, however the aggregates created are not used to be stable, due to less clay content in the soil.

The hydraulic conductivity (HC) rate of the soil in the research area was classified into medium-fast (12.7-25.4 cm/h) and medium (6.3-12.7 cm/h). The higher the HC rate was the lower the HC code meaning the less the erosion could be. This was due to the effect of high SOM and coarse soil texture. Both factors create more soil macropores, in which water can move easily. [Table 3]

Erosion prediction

Erosivity

Erosivity level of the rainfall in the sugarcane plantation area was calculated using mean monthly rainfall for ten years, as suggested by Lenvain (1975). Based on rainfall data, it was got that mean monthly rainfall (R) was 27.25 cm. By using formula EI_{30}, the erosivity value was 1626.45 for all levels of slope, it was due the rainfall data calculated using the following equation.

$$EI_{30} = 2.34\ R^{1.98} = 2.34\ (27.25)^{1.98} = 1626.45$$

Soil erodibility

Based on data provided in Table 4, the erodibility, the condition of soil to be eroded, was categorized into very low. It means that the soil was not easily eroded. This was due to that the soil had high SOM content and coarse texture. Both factors were able to create more soil macropores that can easily infiltrate water from soil surface into soil profile.

The erodibility value of the soil in the research site tended to increase by increasing slope level from 0-8% to 40%. It means that the the soil had low probability to be eroded, on the other words, the soil was stable enough against erosion. Tendency of higher value of soil erodibility at higher slope level was mostly due to the lower SOM content and hydraulic conductivity rate. However, the erodibility, then, decreased from 25-40% to >40% slope level. This was due to higher SOM under >40% slope, as affected by soil conservation technique applied at the slope. Soil OM is able to create crumb type soil aggregates and stabilize them.

Table-4: Soil erodibility values of land under different slope levels at sugarcane plantation in Lawang, Agam Regency

Land Unit		M	a	b	c	K	Criteria
No	Slope %						
1	0-8	1541.8	10.6	3	2	0.03	Very low
2	8-15	1938.6	9.5	3	2	0.05	Very low
3	15-25	1797.4	8.6	3	3	0.09	Very low
4	25-40	1643.8	4.5	3	3	0.14	Very low
5	>40	2200.4	8.7	3	3	0.10	Very low

Note: M= (% silt + % very fine sand) x (100-% clay), a= Soil organic matter content (%), b= Code of soil structure, c= Code of hydraulic conductivity rate, K= Soil erodibility

Slope length and steepness

Length and steepness of slope were given in the field. By applying equation 4 as proposed by Arsyad (2010) the increase the slope level was the increase the LS value, since the slope lengths were not so different. Values of LS were used as component to calculate actual erosion using USLE equation.

Table-5: The slope factor (LS) values of land under different slope levels at sugarcane plantation in Lawang, Agam Regency

Land Unit		Slope		Slope factor (LS)
No	Slope %	Length (m)	Steepness (%)	
1	0-8	33.7	2.3	0.97
2	8-15	36.2	13.0	2.99
3	15-25	25.0	23.5	5.63
4	25-40	22.0	35.5	10.41
5	>40	20.0	43.0	13.88

Land management

In Table 6, it was listed that land management value was 0.20 for all slope levels, as the land was planted with the same crops, sugarcane. Therefore, the index for the cropping system was the same. However, the value for conservation techniques became higher as the slope level was bigger from slope 0-8% to >40%.

Table-6: The land management (CP) values of land under different slope levels at Sugarcane plantation in Lawang, Agam Regency

Land Unit		Cropping system (C)	Conservation Technique (P)	Land management (CP)
No	Slope %			
1	0-8	0.20	0.50	0.10
2	8-15	0.20	0.75	0.15
3	15-25	0.20	0.90	0.18
4	25-40	0.20	0.90	0.18
5	>40	0.20	0.45	0.09

However, as the conservation technique (traditional bench terrace) was applied to plantation area having >40% slope, the P value decreased into 50% lower than that under 15-40% slope level. This was found to be true that the bench terrace was able to slow down the water movement on soil surface (runoff). Decreasing the P value at >40% slope caused the CP value became lower. As LS, the value of C*P* was used for calculation of actual erosion using USLE formula.

Values of erosion prediction and erosion hazard level

The values of erosion increased by increasing slope level from 0-8% to 25-40%.

The value decreased as slope continue to increase above 40% slope, it was due to traditional bench terrace constructed at the area. Increasing slope levels increased the predicted erosion by 7.7, 31.48, 90.2, and 43.0 times respectively for 8-15%, 15-25%, 25-40%, and >40% slope compared to erosion prediction value under 0-8% slope. As also found by Kurosawa et al. (2009) that slope level increased annual soil loss due to erosion. Furthermore, Yulnafatmawita et al (2013) soil erosion linearly increased by increasing slope level from 3 to 25% at Ultisol under super wet tropical rainforest. The erosion hazard level (EHL) for erosion value < 10 t/ha/y was considered low (L), < 100 t/ha/y was medium (M), and > 100 t/ha/y was high (H). Among the 5 slope levels, three of which were considered high for the erosion hazard level. The EHL value of erosion for almost flat area (0-8% slope) was low and for slope 8-15% was medium.

Table-7: Values of erosion prediction and erosion hazard level of land under different slope levels at sugarcane plantation in Lawang, Agam Regency

Land Unit		R	K	LS	CP	A t/ha/y	EHL
No	Slope %						
1	0-8	1626.4	0.03	0.97	0.10	4.73	L
2	8-15	1626.4	0.05	2.99	0.15	36.47	M
3	15-25	1626.4	0.09	5.63	0.18	148.34	H
4	25-40	1626.4	0.14	10.41	0.18	426.66	H
5	>40	1626.4	0.10	13.88	0.09	203.17	H

Note: R= Erosivity, K= Erodibility, LS= Slope factor, CP= Land management, A= Predicted amount of soil loss, EHL= Erosion hazard level

Tolerated erosion

The thickness of erosion could be tolerated from the sugarcane plantation land was only 2.17 mm per year. The values were the same as between 18 and 22 ton soil loss per ha per year. Based on Table 7, there was only at 0-8% slope level having actual erosion less than the tolerated erosion. Therefore, conservation technique should be applied to conserve the plantation and to reach sustainable agriculture and environment.

Table-8: Values of tolerated erosion (E_{tol}) of land under different slope levels at sugarcane plantation in Lawang, Agam Regency

Land Unit		**DE**	**DM**	**SU**	**BD**	**E_{tol}**	
No	**Slope (%)**					**mm/y**	**t/ha/y**
1	2.3	800	150	300	0.85	2.17	18.45
2	13.0	800	150	300	0.99	2.17	21.48
3	23.5	800	150	300	0.93	2.17	20.18
4	35.5	800	150	300	0.99	2.17	21.48
5	43.0	800	150	300	0.95	2.17	20.62

Note: DE= Effective depth (mm), DM= Minimum depth for cropping system (mm), SU= Soil usage (y), BD= Bulk density (mg/ha)

Alternative techniques

Types of conservation technique applied to the sugarcane plantation were not the same for different erosion hazard level. At 0-8% slope, soil conservation technique which was suggested to apply by farmers was strip cropping (SC) or nothing. Without any conservation technique applied, the erosion predicted at this area had been lower than the value of tolerated erosion. For higher slope (8-15%), construction of traditional terrace (TT) had decreased the erosion prediction into 86% of the previous actual erosion. This value had been lower than the value of erosion that could be tolerated. While for steep slope levels (15-25%, 25-40%, and >40 %), construction of perfect bench terraces was important to reduce erosion into level below the tolerated values (Table 9). It was due to the fact that terrace could cut the length of slopes causing the runoff minimized or even cut off.

Table-9: Values of erosion prediction and erosion hazard level of land under different slope percentages after applying some conservation techniques.

No	Slope (%)	A (t/ha/y)	EHL	E_{tol} (t/ha/y)	Conservation Technique applied	A t/ha/y	EHL
1	2.3	4.73	L	18.45	SC/-	4.73	L
2	13.0	36.47	M	21.48	TT	18.52	L
3	23.5	148.34	H	20.18	PBT	6.55	L
4	35.5	426.66	H	21.48	PBT	18.46	L
5	43.0	203.17	H	20.62	PBT	18.04	L

Note: - = Nothing, SC= Strip cropping, TT= Traditional terrace, PBT= Perfect bench terrace, EHL = Erosion hazard level, L = light, M = Medium, H= Heavy

As reported by Gathagu et al (2018) that terraces and grassed waterways could reduce sedimentation as a result of erosion by 81%, and only 54% for grassed waterways, while terrace could reduce runoff by 30% in Central Kenya. The same trend was also reported by Kassawmar et al (2018) that change in conservation technique (P) as well as cropping management decreased soil loss by 42% in Ethiopia. [Table 9]

Conclusion

The sugarcane plantation in Lawang, Agam Regency, West Sumatera, Indonesia had 46.5 % of the total area (906.3 ha) was susceptible and 14.3% was highly susceptible to erosion. The actual erosion predicted at area having > 8% slope was predicted higher than the tolerated one. Sugarcane plantation had three different levels of erosion hazard (EHL), those were low (at 0-8% slope), medium (at 8-15% slope), and high (at >15% slope). Therefore, introducing conservation techniques to the plantation area was important to control the erosion to be lower than the tolerated value. Constructing traditional terrace at area having 8-15% slope, and perfect bench terrace at area having >15% slope level would decrease the actual erosion into less than the E_{tol} values, or from 36.47 to 18.52 t/ha/y (at 8-15% slope), from 148.34vto 6.55 t/ha/y (at 15-25% slope), from 426.66 to 18.46 t/ha/y (at 25-45% slope) and from 203.17 to 18.04 t/ha/y (at >40% slope).

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Contribution of Authors

Yulnafatmawita: Conceived idea, conducted study and write up of article
Hermansah: Helped in study and article write up
Purwaningsih R: Helped in study, compilation of results and statistical analysis
Haris ZA: Helped in in study, compilation of results and statistical analysis

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