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PREFACE

Initiated in 2016, the International Conference on Climate Change (ICCC) is the premier event of Graduate School, Sebelas Maret University (UNS), Indonesia. It is a collaboration event with Indonesian Universities, overseas' World Class Universities, Indonesia Governmental Organization, United Nation (UN), and Non-Governmental Organizations. The 4th ICCC collaborated with Graduate School, Gadjah Mada University, Indonesia; The United Graduate School of Agriculture Science (UGSAS), Gifu University, Japan; and The Indonesian Association of Environmental Experts (IALHI). The purpose of the 4th ICCC 2019 is to accommodate the new related inspiration about how to minimize the climate change impact that occurred at this time. Attendees can access practical and valuable information to help them provide an excellent international forum for sharing knowledge and research results in theoretical and practical aspects of climate change and global warming as well as their industrial applications.

The 4th ICCC was held in 2019 at Graduate School of Gadjah Mada University, Yogyakarta, Indonesia on 18 -19 November 2019. This conference provide a venue to share and discuss various issues regarding climate change, as well as develop the knowledge, research, techniques, and method for adaptation and mitigation through a sustainable approach for supporting SDGs 2030.

We understand that we cannot stand alone to address the global problems occurred. We must stand together, unite to unite, to formulate the appropriate action and preparing the future plan. The 4th ICCC 2019 produced useful information, as well as a mutual and fruitful collaboration among participants.

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Soil erosion at pineapple plantations in Indonesia under the climate change issue

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Abstract. Global climate change triggered the heavy and extreme rainfall in forms of intensity, pattern, duration, amount, and frequency. This condition strongly influences the occurrence of soil erosion, especially in the humid tropic region. The purpose of this research is to analyse the soil erosion rate under pineapple cultivation in Central Lampung, Indonesia. The results show rainfall erosivity using Bols equation is around 2109-3211 metric ton/h/ha. Soil erodibility is ranging 0.007-0.080 was categorized low to very low due to the amount of sand and silt is too low. The Slope also categorized low around 1-4%. The crop factor value is around 0.01-1. The rate of erosion in pineapple was 2016 is 1.51 ton/ha/year until 15 ton/ha/year; that value is under standard permissible erosion (18.5-25 ton/ ha/ year).

1. Introduction

Soil erosion information from pineapple field is still very rare, especially for plantation scale. Therefore, the results of erosion studies reported from various regions of pineapple plantations are very diverse. It have been reported that the soil erosion from pineapples which are grown on steep slopes (up to 40%) in southeast Queensland, Australia, were very high, up to 178 t/ ha, however, soil erosion as well as runoff were decreased in the second and third year after planting [1]. Previous study revealed that runoff and soil erosion was affected by plastic mulch in a Hawaiian pineapple field [2]. Early research indicated that soil loss from Hawaiian pineapple land ranged up to 35 t/ ha/ year and was higher than that from sugarcane fields, which attributed to the unpaved field access roads and exposed field during tillage and early growth stage [3]. Study on the soil erosion from pineapple in humid tropical area of Ivory Coast showed that Crop-Practice value of pineapple were very low (0.002-0.070), and concluded that the major conservation problem is not originally from the pineapple fields, but from the defective road drainage [4]. Therefore, knowledge about the amount of soil erosion in pineapple field needs to be done, considering that erosion is the main cause of land degradation.

Rainfall is the main factor that caused soil erosion in the humid tropical climate, especially in, Lampung, Indonesia. In the last 10 years, from 2005-2016, there were several anomaly rainfall pattern during the dry season (Figure 1). In 2010 and 2013, there were no dry season at all, the rainfall during the dry season were above 200 mm per month, which made the risk of soil erosion would be higher. During the last 10 years, at least there were 3 times of anomaly climate pattern which probably due to the climate change.

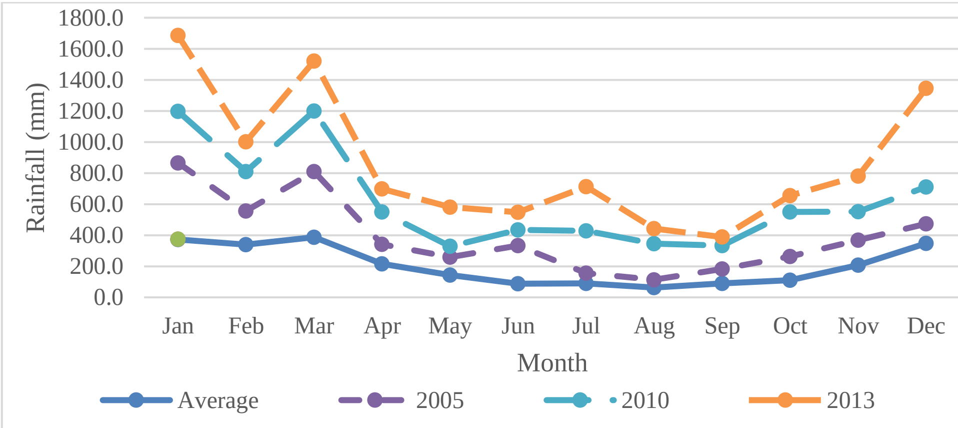

Figure 1. Pattern of rainfall in Central Lampung from 31 years data (1981-2016)

The Universal Soil Loss Equation (USLE) which were developed by Wischmeier and Smith (1978) was widely used as soil erosion prediction tools in world. In Indonesia, the USLE was officially used by the government as a tool for calculating soil erosion [5,6]. Although there are several revisions of the parameters in USLE equation, however, the basics equation up till now it is still widely used in many countries in the world [7].

The use of USLE for calculating soil erosion in pineapple plants would be very difficult, especially for estimating crop (C) factor. Pineapple has a long-life cycle, and harvested 15-18 months after planting, and after that it could be continued as ratoon crop for about 15 months. The coverage of pineapple canopy increased as the age increased, and six months after planting, the canopy of pineapple would totally cover the soil surface, hence would greatly effect on soil erosion. Due to the fact that soil erosion would be effected of the number of canopies that cover the soil surface, the soil erosion in pineapple field will be vary during the pineapple growth. This research aims to calculate the amount of soil erosion in pineapple using ULSE equation in several phases of pineapple growth.

2. Materials and methods

2.1. Experiment site

The research was conducted in pineapple plantation in Central Lampung, Indonesia (Figure 2). Six locations were chosen based on the age of the pineapple, from 0 month after planting until harvest (18 months after planting).

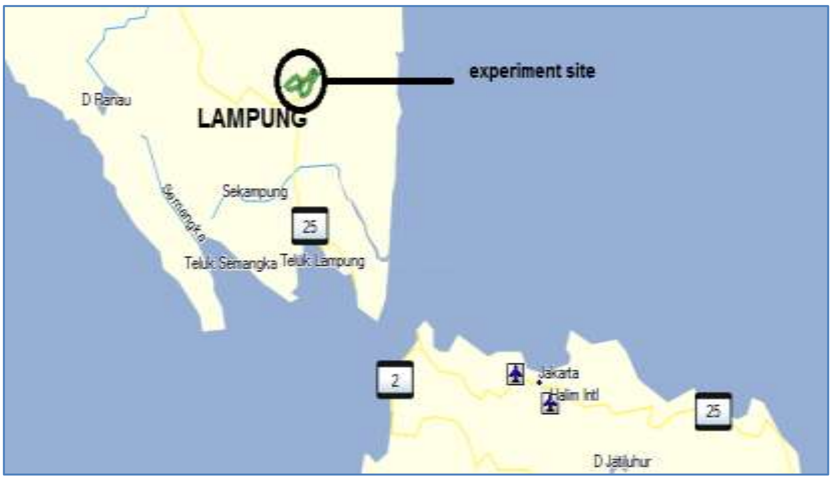

Figure 2. Location of experiment site, Lampung Province, Indonesia

2.2. Data collection and erosion calculation

Soil erosion was calculated based on the USLE equation developed by Wischmeier and Smith [8]:

$$A = R \times K \times L \times S \times C \times P \quad (1)$$

where A is the soil erosion rate; R is rainfall runoff erosive factor; K is soil erodibility factor, LS as slope length (L) and slope steepness (S) factor; C: landcover and management factor P stands for conservation practices factor (dimensionless).

The rain erosivity index was calculated based on the formula which was widely used in Indonesia that developed by the Bols in 1978 [9]

$$R = 6.119(MM)^{1.21}(D)^{-0.47}(M)^{0.53} \quad (2)$$

R is monthly rain erosivity index; MM is the amount of monthly rainfall (cm); D is the number of monthly rainy days; M is maximum rain 24 hours in the month (cm).

The daily rainfall data was obtained from climatology station located in the pineapple plantation of PT Great Giant Pineapple (GGP) for the year of 2016.

The soil erodibility index was calculated based on the formula of Wischmeier, Johnson, and Cross [10]:

$$100\,K = 1.292\{2.1\,M1.14(10-4)(12-a) + 3.25(b-2) + 2.5(c-3)\} \quad (3)$$

Where M = (% of very fine sand and silt) x (100 -% clay); a =% of organic matter; b = soil structure code; c = soil permeability class.

The soil particle and organic matter, and structure were observed in the upper layers, while permeability was the average of the upper and lower layers of the soil profile. The soil was analyses using sieving and hydrometer method for soil particle, organic carbon using Walkey and Black methods; soil permeability using permanent head methods, and soil structure was observed in the field. The organic matter is approached through the C-organic content, by multiplying the C-organic by 1.72.

The length and slope steepness were observed directly in the field, and the results were input in the LS factor formula [11]:

$$LS = \left(\frac{x}{22.13}\right)^n \times (0.065 + 0.045s + 0.0065s) \quad (4)$$

in which: x: the length of the slope (m); s: percent of slope.

Crop factor (C-factor) was calculated based on canopy coverage which depends on the growth phase of pineapple. The C-factor was calculated as followed: (a) The value 1 was given for bare condition; (b) The value 0.4 was given for pineapple which planting time from 1-3 month. In this condition, the pineapple plant grew very slowly with no significant amount the canopy coverage; (c) Around 9 month after planting, the canopy coverage of pineapple almost totally covered the soil surface, so the value of C-factor was given 0.01; (d) From 4-9 month after planting, the pineapple has fast growth rate, hence the C-factor was given 0.3-0.2.

In pineapple plantation, the tillage applied and the design of a pineapple field were usually similar using drainage ditch and contour tillage, so the P-factor was 0.5.

2.3. Tolerable soil erosion

The amount of tolerable soil erosion for pineapple was calculated based on Hamer (1982) [12]. Data needed to calculate the tolerable soil erosion were(a) soil suborder, b) effective soil depth(c) the depth of the roots of pineapple plants; (d) Soil physical and chemical fertility.

$$T = \frac{Dp}{UT} + Sf \text{ if } Dp + Ds < KE \quad (5)$$

$$T = \frac{Dp - Ds}{UT} + Sf \text{ if } Dp + Ds > KE \quad (6)$$

$$T = Sf \text{ if } KE < Ds \quad (7)$$

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T: allowable soil erosion; Dp = equivalent depth; KE = soil depth or effective soil depth (mm); FK = soil depth factor; UT land use life (400 years); Sf : the rate of soil formation; Ds : the minimum soil depth required by certain plants.

The value of the rate of soil formation is determined for tropical regions in Indonesia at 2 mm/ year [5,13]. The effective soil depth is determined from soil profile. Soil depth factor was determined based on the soil suborder (Soil Taxonomy) found in the site. The soil type was Typic Kanhapudults). The land use life is a sufficient period of time to maintain the preservation of the land (a mean value of 400 years).

3. Results and discussions

3.1. Soil erosion factors

The monthly erosivity index was presented in Table 1 and Figure 3. The total rain erosivity index in a year was 2918.79 metric tons/ hour/ ha. The highest erosivity occurred in February and March, while the lowest occred in August in the dry season. The obtained of R value for this humid tropical area was still within the limits of reasonableness. With the Bols formula, Karyati [14] obtained an R value in the Serawak area of 2929.18 metric tons/ hour/ ha, while As-Syakur [15] obtained a number in Bali of 2127.4 [14]. For the West Lampung, Afandi et al. [16] obtained an average value of 1845 metric tons/hour/ha, with the highest value of 3370 metric tons/ hour/ ha.

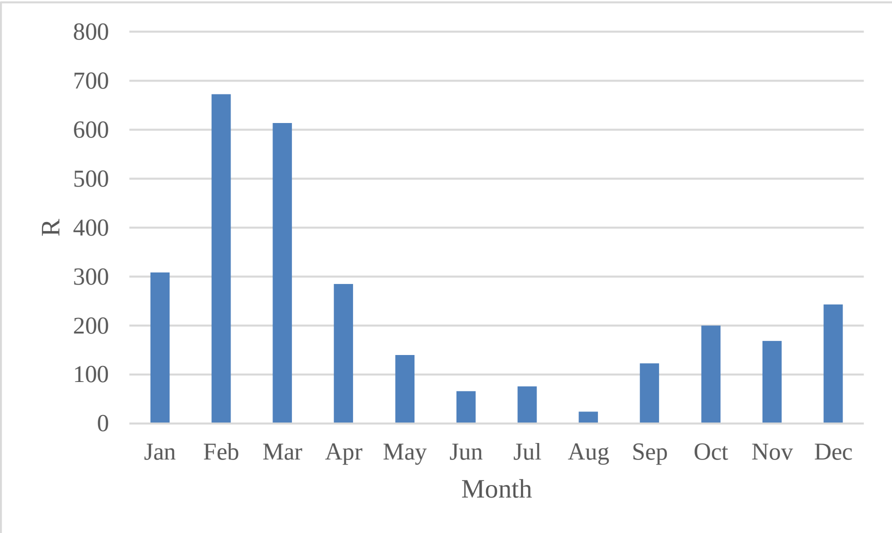

Figure 3. Distribution of rain erosivity index during a year

The results of soil analysis to calculate the soil erodibility index (K) are presented in Table 2 and Table 3. The value of organic matter, permeability, and soil structure, were sensitive to erosion, however, the materials that are easily eroded (very fine sand and silt particles) are very small. The amount of fine sand and silt were 5-10%, so the K value is very low, between 0.007–0.080.

Erosion will greatly depend on the material available for erosion and the ability of surface runoff to transport erosion. As a result of very small material, the value of soil erodibility will be small. The small amount of material can be caused by the material is very small or has been eroded; all that remains is the rest.

Table 1. Rainfall and rain erosivity index in the experiment site

Date	Jan	Feb	Mar	Ap	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		-	37.0	38.0	-	-	12.5	-	-	-	2.5	1.0
2		-	4.0	44.0	2.0	37.0	-	-	-	5.0	-	14.0
3	2.5	-	17.0	-	45.0	-	-	-	-	2.5	-	-
4		40.0	34.0	-	8.5	-	-	-	-	-	-	-
5		82.0	-	-	-	-	-	-	6.0	-	13.5	-
6	19.0	26.0	25.5	-	-	-	-	-	-	48.0	-	-
7		-	-	-	7.0	-	-	-	-	-	-	-
8		30.0	-	7.0	1.0	3.0	-	-	-	42.0	-	-
9		123.0	2.0	-	2.0	6.0	-	-	-	-	-	9.0
10	11.0	26.0	23.0	-	-	-	-	-	-	-	4.0	-
11	2.0	16.0	5.0	2.0	7.0	1.0	-	-	-	16.0	10.0	8.0
12	68.0	-	-	-	-	-	12.5	8.0	-	18.0	28.0	5.5
13	60.0	5.5	11.5	-	-	-	-	-	8.0	8.0	26.5	15.0
14	7.0	-	3.5	66.0	18.0	-	-	-	-	2.0	3.5	14.0
15	16.0	29.0	-	26.0	-	3.0	-	-	-	22.0	1.5	12.0
16	1.0	68.0	9.0	-	-	3.0	-	-	-	-	6.0	-
17		-	-	-	-	-	-	-	1.0	26.0	23.0	-
18		6.0	52.0	2.0	-	22.0	-	-	-	-	2.0	-
19		-	-	19.5	-	-	-	-	9.0	-	-	29.5
20	23.0	-	16.5	1.0	-	-	-	-	-	-	-	29.0
21		-	-	65.0	-	-	-	-	-	-	-	-
22	41.5	-	15.5	3.5	9.0	10.0	-	2.0	2.0	-	-	12.0
23	14.0	5.0	2.0	2.0	50.0	9.5	48.0	-	-	-	3.0	1.0
24		3.0	39.0	6.0	-	-	-	-	-	14.0	-	-
25	18.0	-	99.0	3.0	-	-	-	-	1.0	15.5	-	5.5
26	3.0	2.0	85.5	10.0	-	-	-	-	48.0	-	-	-
27		-	-	-	5.0	-	-	22.0	12.0	10.0	58.5	61.5
28	2.0	-	-	12.0	10.0	-	0.5	-	22.0	25.0	7.5	-
29		2.0	-	-	-	-	-	-	-	2.5	15.0	54.0
30			37.0	-	13.0	-	-	6.0	38.0	-	-	
31	35.5		-		-		1.5	-		7.0		
MM	323.5	463.5	518.0	307.0	177.5	94.5	75.0	38.0	147.0	263.5	204.5	271.0
D	16.0	15.0	19.0	16.0	13.0	9.0	5.0	4.0	10.0	16.0	15.0	15.0
M	68.0	123.0	99.0	66.0	50.0	37.0	48.0	22.0	48.0	48.0	58.5	61.5
R	308.3	672.2	613.3	284.8	139.7	66.0	75.5	24.4	123.1	200.0	168.4	243.2

Note: *R monthly rain erosivity index; MM amount of monthly rainfall (mm); D number of monthly rainy days; M maximum rain 24 hours in the month (mm)*

Table 2. Soil organic matter, permeability, and soil structure

No	Location	soil organic	Soil permeability		Soil structure	
		%	cm/h	Class	Structure	Code
1	38B	1.3	0.38	6	Very fine granular	**1**
2	42F	2.11	1.43	5	Very fine granular	**1**
3	57A	2.13	4.83	4	Very fine granular	**1**
4	49D	1.88	0.15	6	Very fine granular	**1**
5	49C1	1.53	0.03	6	Very fine granular	**1**
6	49C2	1.57	0.04	6	Very fine granular	**1**

Table 3. Soil particle and soil erodibility (K)

No	location	Coarse sand	Very fine sand	Silt	clay	K
		%				
1	38B	47.47	1.6	3.86	47.07	0.073
2	42F	38.11	2.36	7.65	51.88	0.053
3	57A	34.63	0.1	6.59	58.69	0.007
4	49D	37.5	4.05	4.63	53.81	0.08
5	49C1	41.58	1.98	3.87	52.57	0.072
6	49C2	38.31	0.85	5.79	55.05	0.074

The LS factors in pineapple plantation were very small, from 0.19-0.42, due to the fact that the area were almost flat, from 1-4 % (Table 4). The slope length in the all locations were the same, because the design of the plantation field are entirely the same, have width 38 m, which followed the width of boom spraying for spraying pesticide and foliar fertilization. In areas that are relatively flat, slope factors will not have much effect on erosion, compared to hilly or mountainous areas.

Table 4. Value of LS factor in the experiment site

No	Location	Slope length (m)	Slope gradient (%)	Average LS
1	38B	38	2	0.23
2	42F	38	1-2	0.19
3	57A	38	2	0.2
4	49D	38	1	0.2
5	49C3	38	3-4	0.42
6	49C4	38	2-3	0.29

The estimate C-factor for every month were presented in Table 5, which ranged from 0.01- 1. A high C value will be a problem during the rainy season, especially in the months when the R value is high. Locations 49 D and 42 F have a maximum C value in the rainy month.

The P factors at pineapple plantation include contour planting and the creation of drainage channels. Contour plant value is 0.5 for slope of 1-5 degrees. The construction of drainage channels has no value.

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Table 5. Estimate value of C-factor

Location	Status	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
38B	Age (month)	14	15	16	17	18	0	0	0	0	0	0	0
	C-value	0.01	0.01	0.01	0.01	0.01	1	1	1	1	1	1	1
42F	Age (month)	10	11	12	13	14	15	16	17	18	0	0	0
	C-value	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1	1	1
57A	Age (month)	17	18	0	0	0	0	0	1	2	3	4	5
	C-value	0.01	0.01	1	1	1	1	1	0.4	0.4	0.3	0.3	0.2
49D	Age (month)	0	0	0	1	2	3	4	5	6	7	8	9
	C-value	1	1	1	0.4	0.4	0.3	0.3	0.2	0.2	0.1	0.1	0.01
49C1	Age (month)	3	4	5	6	7	8	9	10	11	12	13	14
	C-value	0.3	0.3	0.2	0.2	0.1	0.1	0.01	0.01	0.01	0.01	0.01	0.01
49C2	Age (month)	4	5	6	7	8	9	10	11	12	13	14	15
	C-value	0.3	0.2	0.2	0.1	0.1	0.01	0.01	0.01	0.01	0.01	0.01	0.01

3.2. Soil erosion and tolerable soil erosion

The results of soil erosion prediction using the USLE method showed that the value of soil erosion in pineapple plantation ranged from 1.4 ton/ha/year until 15 tons/ ha/ year (Table 6).
Based on equation (5-7), the tolerable soil erosion was calculated based on the following value:

- effective soil depth (KE) : 1200 mm
- Soil depth factor (Udult- soil suborder) (FK) : 0.8
- The equivalent depth (Dp = KExFK) : 960 mm
- The minimum depth required for pineapple (Ds) : 990 mm
- and Dp + Ds : 1950 mm
- and Dp + Ds (1950 mm) > KE (1200 mm), the equation 6 was used.

The tolerable soil erosion (T) value was 1.925 mm per year or 25.025 t/ ha/ year (with soil bulk density oil is 1.3 g/ cm3) for soil formation of 2 mm per year, or 1.425 mm or 18.525 t/ ha/ year for soil formation of 1.5 mm/ year, or in averaged around 21.75 t/ ha/ year. This result is not different from the proposal of Utomo [16] with an T value reaching 22.4 t/ ha/ year [17].

Table 6. The value of erosion and tolerable soil erosion in pineapple plantation

Location	Soil erosion (t/ ha/ year)	Tolerable soil erosion (t/ ha/ year)	
		Shah (1982)	Dirjen RLPS (2009)
38B	7.41		
42F	3.01		
57A	1.41	**25**	**18.5**
49D	15.00		
49C1	7.60		
49C2	4.30		

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The soil erosion from pineapple field were very low compare to tolerable soil erosion. These results were similar of findings in other research in Ivory Coast [4]. Although located in humid tropical climate with high rain erosivity index, the other soil erosion factor (K, L, S, C and P) in pineapple field were very low.

4. Conclusions

The value of erosion in several research sites in pineapple field were low and below the tolerable soil erosion threshold. Although the R value is high, other other erosion factors USLE equation were low, hence soil erosion becomes low. Soil conservation should always prepare well due to the uncertainly high rainfall in the dry season that caused by climate change.

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