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Erosion hazard index [EHI] on different land use in sub-watershed Kaos, Jambi

Erosion hazard index [EHI] on different land use in sub-watershed Kaos, Jambi

S Ramadhan[1]*, Hermansah[2], B Rusman[2], and S Yasin[2]

[1]Department of Agricultural Science, Faculty of Agriculture, Andalas University, Padang, West Sumatra, Indonesia

[2]Department of Soil Science, Faculty of Agriculture, Andalas University, Padang, West Sumatra, Indonesia

Email: syahrugis@gmail.com

Abstract. Soil degradation that occurs in watershed Batanghari is generally caused by accelerated erosion due to land conversion. Sub-watershed Kaos is one of the sub-watershed from watershed Batanghari that has forest conversion to oil palm plantations is 7,846 Ha from the period 1995-2018. This research aims to assess the Erosion Hazard Index [EHI] on forest land use, land clearing, and oil palm plantation in Sub-Watershed Kaos-Jambi. The data analysis method used the survey method and erosion prediction using the Universal Soil Loss Equation [USLE] model. The EHI was counted by the amount of soil eroded [ton/ha/year] divided by soil erosion that can be tolerated [ton/ha/year]. The result of this research showed that the forest's erosion value is 9.80 ton/ha/year, land clearing is 249.17 ton/ha/year and oil palm plantation is 89.12-122.94 ton/ha/year. The soil erosion can be tolerated on the forest is 36.54 ton/ha/year, land clearing is 57.71 ton/ha/year and oil palm plantation is 54.42-57.49 ton/ha/year. Furthermore, the lowest value of EHI is 0.27 [low grade] and the highest value of EHI is 4.32 [high grade], whereas the EHI value on oil palm plantation is between 1.64 to 2.14 [medium grade]. The EHI in Sub-Watershed Kaos is in low, medium, and high categories. The medium grade and high grade of The EHI will cause soil degradation, such as decreasing soil quality and also loss of organic matter and soil nutrients because of erosion and runoff. Therefore, it must apply soil conservation and agrotechnology application in land clearing and oil palm plantation.

Keywords: land clearing, oil palm plantation, erosion hazard index [EHI], soil degradation, sub-watershed Kaos

1. Introduction

Currently, several watersheds in Indonesia are damaged. Watershed damage that occurs due to land-use change can be seen from the lowering of forest area and land degradation. Increased land conversion will damage watersheds such as a decrease in the ability of the soil to absorb and retain water and an increase in surface runoff and erosion, which will result in land degradation. Land degradation that occurs in watersheds is generally caused by accelerated erosion due to human activities, so that erosion will affect natural resources [1]. Erosion will impact the surface layer of the soil, which is generally high in organic matter and nutrients, causing a nutrient loss for plants [2].

The problems that occur in watershed Batanghari include land conversion. Sub-watershed Kaos one region from watershed Batanghari that have forest conversion to oil palm plantations since 1995. Forest conversion to oil palm plantations in Sub-watershed Kaos has an area of 7,846 ha from 1995 - 2018 period [Interpretation Results, 2019]. Land-use change will have a major impact on soil erosion [3]. Erosion is the process of losing or eroding soil or part of the land from a place that is transported by water or wind to another place. For areas with wet tropical climates in Indonesia, the erosion process is generally caused by water [4].

According to Arianti [5] to find out whether soil conservation measures are necessary or not, calculations must be made regarding the erosion hazard index. It is important to know and understand the dangers of erosion that occur [6]. So that the purpose of this study was to determine the erosion hazard index of forest land use, land clearing, and oil palm plantations.

2. Materials and methods

2.1. Location and time

The research location is land use map of study area Sub-watershed Kaos, Watershed Batanghari [Figure 1]. Soil sampling was conducted in Bukit Baling Village, Sekernan District, Muaro Jambi Regency, Jambi Province. After taking the soil sample, a soil analysis was carried out at the Soil Laboratory of the Environmental Department of Jambi Government Province. The research was conducted from October 2018 to April 2019.

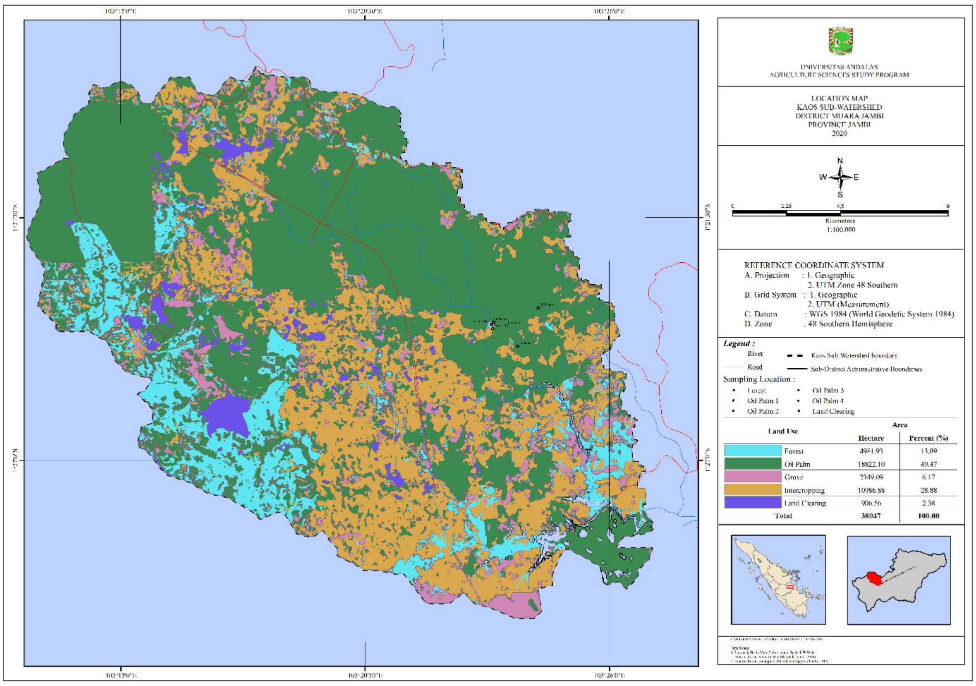

Figure 1. Landuse map of study area of the Kaos Sub-watershed

2.2. Research methods

The research method used in this research is the area survey method and using the purposive sampling method for soil sampling on forest, land clearing, and oil palm plantation on the same slope and soil type. Then the soil sample is taken to the laboratory for analysis with the parameters are in table 1.

Table 1. Indicators of soil physical properties

Analysis	Indicator	Unit
Soil physical	Organic Carbon [C]	%
	Soil Texture [Coarse sand, fine sand, silt, and clay]	%
	Permeability	cm/hour
	Bulk Density [BD]	g/cm^3

Based on table 1, the indicators of soil physical properties are used to determine the soil erodibility. Furthermore, data analysis to estimate the amount of erosion using a mathematical equation based on [7] which is commonly known as the USLE equation:

A = R*K*LS*C*P……[1]

A = Estimated average annual soil erosion [ton/ha/year]
R = Rain erosivity factor
K = Soil erodibility factor
LS = Slope length and steepness factor
C = Cover and management factor
P = Soil Conservation factor

The purpose of determining the erosion hazard index is to know the extent of erosion that has occurred and could endanger the sustainability of land productivity [8]. Erosion hazard index is determined by the equation of Wood and Dent [1983] cit[8]:

$$\text{Erosion Hazard Index} = \frac{\text{Soil eroded [ton/ha/year]}}{\text{Soil erosion can be tolerated [ton/ha/year]}}$$

The results of the erosion hazard index on land that have been obtained from these calculations are classified in table 2 [9].

Table 2. Classification of erosion hazard index [9]

Erosion hazard index	Class
≤1.00	Low
1.01-4.00	Medium
4.01-10.00	High
≥10.01	Very High

3. Result and Discussion

3.1. General Condition Sub-watershed Kaos

The Kaos Sub-watershed has an area of 38,046 ha. Administratively, the research location is located in Bukit Baling Village, Sekernan District, Muaro Jambi Regency, Jambi Province. For details on the research, the location is in table 3.

Table 3. Details of research locations

Landuse	Sampling Location	Soil Types
Forest	1° 24' 1.177" S 103° 23' 22.744" E	Ultisols
Oil Palm Plantation 1 [age 0-5 years]	1° 23' 52.310" S 103° 23' 24.018" E	Ultisols
Oil Palm Plantation 2 [age >5-10 years]	1° 24' 24.869" S 103° 23' 56.378" E	Ultisols
Oil Palm Plantation 3 [age >10-15 years]	1° 23' 57.044" S 103° 23' 41.651" E	Ultisols
Oil Palm Plantation 4 [age >15 years]	1° 23' 32.719" S 103° 24' 24.055" E	Ultisols
Land Clearing	1° 23' 55.291" S 103° 23' 21.026" E	Ultisols

3.2. Estimated Soil Erosion

3.2.1. Rain erosivity factor [R]

Rain erosivity components in the study area are rainfall, rainy days, and maximum rainfall for 24 hours obtained from the secondary climatology station [BMKG Sungai Duren] for 10 years from 2010-2019. The value of the rain erosion index [EI] in Indonesia is calculated by multiplying the amount of rain energy [E] with the maximum intensity for 30 minutes [EI30]. The EI30 value in Sub-watershed Kaos is in table 4. In table 4(the end page), it can be explained that the erosivity value of monthly rain at the Sekernan climatology station ranges from 43.60-214.71 ton/ha/cm of rain. The lowest erosivity of monthly rain occurs in July, while the highest erosivity of monthly rain occurs in December. The main process that contributes to erosion is climate caused by rainfall intensity [10], [11].

3.2.2. Soil erodibility factor [K]

Erodibility will indicate whether or not the soil is easily eroded which is determined by soil physical properties. The calculation of soil erodibility [K] in Sub-watershed Kaos is in table 5.

Table 5. Soil erodibility [K]Sub-watershed Kaos

Land use	Texture [%]				Organic matter	Structure	Permeability	Erodibility	
	Coarse sand [1.00-0.50 mm]	Fine sand [0.25-0.10 mm]	Silt [0,05-0,002 mm]	Clay [<0,002 mm]		Code	Code	Value	Class
Forest	51.90	9.92	16.77	21.41	5.30	2	3	0.11	low
OPP1	51.54	9.90	19.80	18.76	3.18	3	4	0.25	medium
OPP2	51.53	8.21	17.52	22.74	3.63	3	4	0.21	medium
OPP3	46.76	10.64	18.99	23.61	4.18	3	4	0.22	medium
OPP4	46.23	8.59	20.47	24.71	4.58	3	4	0.20	low
LC	53.70	8.78	13.16	24.37	2.78	3	4	0.19	low

Note : OPP: Oil Palm Plantation

Based on table 5, low erodibility values were demonstrated for forest land use, oil palm plantation 4, and land clearing. Meanwhile, the medium erodibility value in land uses oil palm plantation 1, oil palm plantation 2, and oil palm plantation 3. The erodibility value has an important role in erosion because it is related to soil conservation strategies. This is following the results of research by Shabani [12] that the erodibility value is closely related to soil physical properties and plays an important role in soil conservation.

3.2.3. Slope length and steepness factor [LS]
The slope length and steepness factor [LS] of the Kaos Sub-watershed are in table 6.

Table 6. Slope length and steepness factor [LS] Sub-watershed Kaos

Land use	Slope length [m]	Slope steepness [%]	LS
Forest	25	8	0.67
Oil Palm Plantation 1	25	10	0.79
Oil Palm Plantation 2	24	10	0.77
Oil Palm Plantation 3	25	9	0.73
Oil Palm Plantation 4	24	9	0.72
Land Clearing	25	10	0.79

3.2.4. Land cover management factor [C] and Soil Conservation factor[P]

The value of land cover management and soil conservation in Sub-watershed Kaos are in table 7.

Table 7. Land cover management [C] and soil conservation [P] Sub-watershed Kaos [16]

Land use	Value cover management [C]	Value Soil Conservation [P]
Forest	0.20	0.40
Oil Palm Plantation 1	0.50	0.75
Oil Palm Plantation 2	0.50	0.75
Oil Palm Plantation 3	0.50	0.75
Oil Palm Plantation 4	0.50	0.75
Land Clearing	1.00	1.00

Source :[16]

Based on table 7, the lowest C value is on forest land use and the highest C value is in land clearing. According to [17] that the value of C is equal to 1 indicating the absence of ground cover, while the value of C which is close to 0 indicates the effect of well-protected soil cover and management. The lowest P value is on forest land use and the highest P value is in land clearing. A high P value in land clearing implies poor conservation practices. This is consistent with [10] that the P values range from zero for good conservation practices to one for bad conservation practices.

3.2.5. Prediction of Erosion

Erosion prediction using the USLE method is widely used in many countries to estimate the magnitude of erosion and to determine and evaluate the application of existing soil and water conservation techniques. The amount of eroded land in the Kaos Sub-watershed are in table 8.

Table 8. Soil Erosion in Sub-watershed Kaos

Land Use	R	K	LS	C	P	Erosion [ton/ha/year]
Forest	1660.13	0.11	0.67	0.20	0.40	9.80
Oil Palm Plantation 1	1660.13	0.25	0.79	0.50	0.75	122.94
Oil Palm Plantation 2	1660.13	0.21	0.77	0.50	0.75	101.19
Oil Palm Plantation 3	1660.13	0.22	0.73	0.50	0.75	100.06
Oil Palm Plantation 4	1660.13	0.20	0.72	0.50	0.75	89.12
Land Clearing	1660.13	0.19	0.79	1.00	1.00	249.17

Based on table 8, the lowest erosion value was in forest land use of 9.80 ton/ha/year and the highest was in a land clearing of 249.17 ton/ha/year. Land clearing and oil palm plantation are still higher than the value of soil erosion can be tolerated. Soil erosion causes damage to agricultural land in the form of deterioration of soil characteristics, reducing land productivity [18]. Land clearing and oil palm plantation, the erosion value [A] exceed soil erosion can be tolerated so that soil and water conservation planning is needed in Sub-watershed through planting soil-filled plants and repairing terraces [14].

The erosion value of land clearing and oil palm plantation 1 is high due to the slope length and steepness value [LS] is high. This is in accordance with the research results of [5], [19], [20] that the higher the slope, the greater the erosion and surface runoff that occurs. Besides the high erosion is caused by land use and the shape of the canopy of plants which can increase or decrease the effect of rain falling on the land. This is in accordance with [21] that in an open canopy, soil loss through the erosion process will also be increased due to the rain process that occurs. The land cover will play an important role in erosion intensity [6], [22], [23].

3.3. Soil erosion can be tolerated[ETOL]

The value of EHI in Sub-watershed Kaos is in table 10.

Table 10. Erosion Hazard Index [EHI] Sub-watershed Kaos

Land use	Erosion [ton/ha/thn]	ETOL [ton/ha/thn]	Erosion Hazard Index [EHI]	Grade
Forest	9.80	36.54	0.27	Low
Oil Palm Plantation 1	122.94	57.49	2.14	Medium
Oil Palm Plantation 2	101.19	56.94	1.78	Medium
Oil Palm Plantation 3	100.06	56.23	1.78	Medium
Oil Palm Plantation 4	89.12	54.42	1.64	Medium
Land Clearing	249.17	57.71	4.32	High

Based on table 10, the land clearing and oil palm plantation have soil conservation measures are needed. According to Arianti et al., [5] that soil conservation measures must be carried out mechanically and vegetatively. Soil conservation measures such as leveling the soil, making terraces, and providing straw mulch that can minimize erosion and runoff [24]. In this way, known erosion can be used as a reference in management planning, at the policy level, and in land use planning [25].

4. Conclusions

The erosion hazard index [EHI] value Sub-watershed Kaos is classified as low on forest land, medium on oil palm plantation 1-4, and high on land clearing. The impact of the erosion hazard index [EHI] value at medium and high grade is soil degradation with decreasing soil quality such as soil physical, chemical, and biological properties as well as the loss of organic matter and soil nutrients due to erosion. Land clearing and oil palm plantation cultivation must apply soil conservation techniques and use agrotechnology to reduce surface runoff and soil erosion.

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Table 4. Value of EI30 [R] Sub watershed Kaos

Year	Rainfall [cm]												Total
	January	February	March	April	May	June	July	August	September	October	November	December	
2010	11.2	7.4	22.5	16.8	1.1	5	7.8	11.3	13.2	16.4	27.5	10	150.20
2011	10	6.8	2.9	21.2	10.9	4.4	1.2	0.9	3	24.3	31.5	14.6	131.70
2012	1.2	6.5	7	8.2	X	X	X	X	X	X	15.8	9.7	48.40
2013	X	X	31	25.3	8.5	10	22.5	9.7	37	12.7	23.9	25.2	205.80
2014	19.6	-	9	16.6	17.2	7	3.1	21	7.5	11.4	16.1	28.4	156.90
2015	16.2	18.7	22.9	16.2	16.5	13.4	4.2	4.4	0	8.1	13.2	28.1	161.90
2016	27.9	30.4	24.1	12.7	13.9	13	10	14.7	19.6	17.7	44	7.4	235.40
2017	11.8	31.2	31.2	31.8	11.9	22.5	3	19.3	16.5	13.7	24.7	38	255.60
2018	25.5	15.2	31.8	31.3	31.7	11.7	5	6.7	15.7	18.8	22.7	35.1	251.20
2019	23.9	45.9	18	45	9.1	6.5	3.5	1.2	3.5	16.4	17.7	26.4	217.10
Rain	16.37	20.26	20.04	22.51	13.42	10.39	6.70	9.91	12.89	15.50	23.71	22.29	181.42
Maxp	5.02	4.74	4.71	4.68	4.57	4.14	2.59	3.28	4.21	5.32	4.97	5.77	
Days	9.00	10.00	11.00	13.00	8.00	8.00	6.00	7.00	7.00	10.00	14.00	11.00	
EI30	150.85	180.23	169.52	179.78	119.26	83.09	43.60	73.80	115.82	138.62	190.87	214.71	
∑EI30	**1660.13**												