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Erosion Hazard Levels in Padang Batung Sub-district, Hulu Sungai Selatan Regency, South Kalimantan Province, Indonesia

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Abstract: Erosion is a form of damage to the soil caused by changes in land function on certain plains without management. The Padang Batung Sub-district area experienced land damage which was characterized by the distribution of critical land area reaching half of the area. The purpose of this study is to analyze the level of erosion hazards that occur in Padang Batung Sub-district. This study used a terrain unit map as the basis for the sample analysis unit. The number of samples in this study was 20 samples using the purposive random sampling method. The data analysis used is in the form of the Universal Soil Loss Equation (USLE) equation which can predict the level of erosion hazard through several parameters in the study area. The results showed that the erosion hazard level in Padang Batung Sub-district was dominated by severe criteria with an affected area of 74 km^2 with an average erosion rate of 345.27 tons/ha/yr. One of the dominating factors causing the high erosion in Padang Batung Sub-district to be included in the medium and high classification is rain intensity, high erodibility, unstable topography and land cover vegetation.

Keywords: Erosion, Land, USLE

INTRODUCTION

Geographically, Indonesia is located in a disaster-prone area surrounded by two continents and two oceans and has a mountain path that stretches from the western tip of Sumatra to the eastern tip of Papua, so Indonesia has a diverse regional topography and making the Indonesian state potentially catastrophic (Tjandra, 2017). Natural disasters that generally often occur in Indonesia are landslide-prone areas and flood-prone areas. The two natural disasters are related to soil erosion activity (Pandiangan, 2019). Erosion damage reduces crop productivity by beginning with a decrease in soil productivity, losing nutrients, and affecting the fertile soil layer (Atmojo, 2016). Such damage will have an impact on the development of plant roots. Indirect damage will also occur, such as mud and silting in reservoirs and ecosystem damage to crops. Conditions like this are very worrying because they are the main factor in damage to land or critical land (Hartono, 2016; Maryono, 2020). Critical land is related to erosion because its impact on land significantly damages forest areas. Based on data from the Ministry of Environment and Forestry on watershed management and protected forests, Indonesia has 14 million Ha of critical land area, with a forest area of around 95.6 million Ha. The critical land area to forest area ratio ranges from 14.6 percent (Nugroho, 2020).

South Kalimantan Province has been recorded to have an average erosion rate of 1890.15 tons/ha/year. This activity is caused by mining activities and plantation management that are not environmentally friendly (BPDASHL Barito, 2018). Forest conditions in South Kalimantan cover an area of around 1,779,982 ha. Meanwhile, critical land conditions affect an area of around 640,708.7 ha (BPDASHL Barito, 2018). In comparing critical land to forest, 36% of the total forest condition is critical land spread across various regencies/cities. One of the regencies that experiences critical land is Hulu Sungai Selatan Regency, with an average erosion rate of 15.90 tons/ha/year and a forest area of 57,387.74 Ha (Badan Pusat Statistik (BPS), 2022). The critical land area in Hulu Sungai Selatan Regency has an area of 33,263 ha, which is incorporated from several categories of critical land, including the critical land category covering an area of 29,701 ha and very critical land covering an area of 3,562 ha, which is spread in almost every Sub-district in Hulu Sungai Selatan Regency (BPDASHL Barito, 2018).

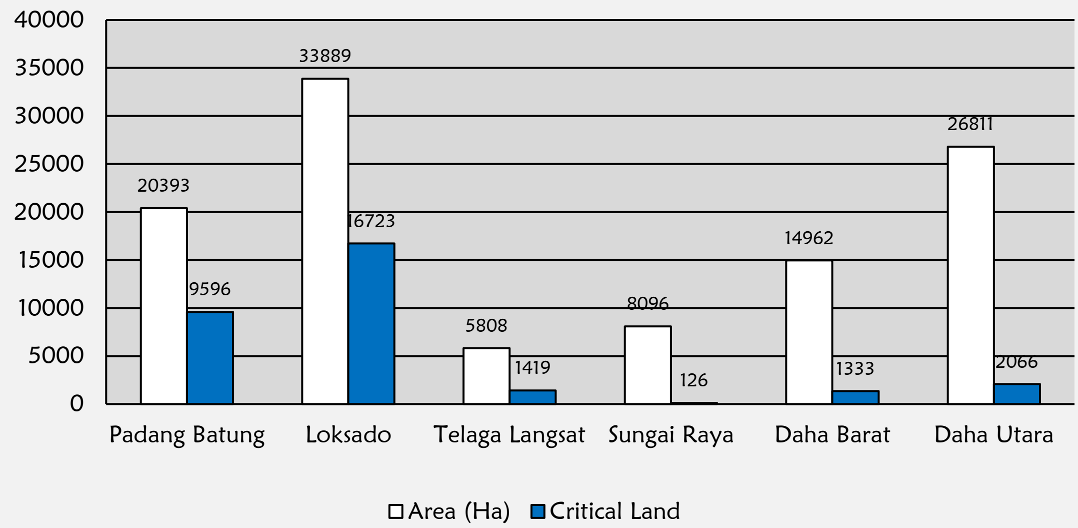

Figure 1. Diagram of the distribution of critical land in Padang Batung Sub-district

Padang Batung Sub-district is located in Hulu Sungai Selatan Regency, South Kalimantan Province, with natural conditions in the form of plains-hills-mountains with rather steep slopes (15-30%) with structural and denudational landforms (Safitri et al., 2021). Land use in communities in Padang Batung Sub-district is in a location with a relatively steep slope. The land use procedure causes land damage (Muhaimin et al., 2021). The case of erosion can be determined by one of the factors of damage to land or critical land in the area (Wahyunto & Dariah, 2014), as in Padang Batung Sub-district can be seen from the area of critical land in (Figure 1). Based on critical land data in Padang Batung Sub-district in 2020, it has a critical land area of 9,596 ha (BPDASHL Barito, 2018). The amount of critical land in Padang Batung Sub-district is equal to half the area of its territory. The condition of critical land and a large amount of erosion in Padang Batung Sub-district can affect people's lives.

As one of the largest agricultural sector areas in Hulu Sungai Selatan Regency, Padang batung Sub-district has the most commodities in the form of rubber plants (Ardhana & Qirom, 2017). The agricultural sector in Padang Batung Sub-district makes the average land use in the area more dominant than the plantation area. The increase in critical land is caused by erosion, and human activities, such as converting forest land into agricultural areas, can cause damage to a morphological ecosystem in a forest area (Muhaimin et al., 2022). In addition, critical land can also cause a weakening of soil resilience which can cause various kinds of disasters, such as landslides and floods (Polawan & Alam, 2019).

The problems posed by erosion must be measured because the impact will only be sustainable if not controlled. Estimation activities are one alternative that can be done to find out the condition of an area regarding the magnitude of the erosion rate (Nura'ban, 2018). The erosion hazard level is one way to estimate the reduced amount of soil lost in the land if crop management and land conservation are not carried out correctly (Azmeri, 2020; Mardiatno & Marfai, 2021). Quantitative erosion hazard level (TBE) analysis can use formulas developed by the United States Department of Agriculture–Agriculture Research Services (USDA-ARS) in the form of the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) equation (Arsyad, 2010).

The Universal Soil Loss Equation (USLE) is designed to estimate the mean value of long-term erosion in an agricultural area with a special cropping and management system (Arsyad, 2010; Asdak, 2010; Syahputra et al., 2018). The Universal Soil Loss Equation (USLE) brings together several erosion-causing parameters to estimate soil loss from the groove and sheet erosion under certain circumstances over a long period (Hanafi & Pamungkas, 2021; Sinukaban et al., 1989). In addition to particular areas of agriculture, the USLE equation can predict erosion on non-agricultural lands, such as forestry areas, watersheds, settlements, roads, mining areas, and so on (Suripin, 2004; Wahyunto & Dariah, 2014; Widyantara et al., 2015). The use of the USLE equation is relatively simple, and the input parameters of the required method are easy to obtain.

The impact of erosion needs to be considered because the impacts caused by erosion can cause damage in various aspects, including the agricultural, disaster, and land use sectors. Predicting the erosion rate is one alternative to determining the factors and distribution of the impact of erosion activities. The use of mapping media in predicting erosion is one solution for determining the distribution of areas prone to erosion hazards (Anggriani et al., 2020).

METHOD

Study Area

The study area is in the Padang Batung Sub-district, which has coordinates of 2°42'39" S to 2°53'41" S and 115°21'27" E to 115°35'57" E. Padang Batung Sub-district has boundaries based on its geographical location, with the eastern boundary bordering Loksado Sub-district. The western boundary is bounded by Kandangan Sub-district and Sungai Raya Sub-district. Tapin Regency is located on the southern boundary. The northern boundary is bordered by Angkinang District and Telaga Langsat Sub-district (Figure 2). Padang Batung Sub-district is 203.09 km² in size. The research site was chosen because this district has a critical land area that is nearly half the size of Padang Batung Sub-district.

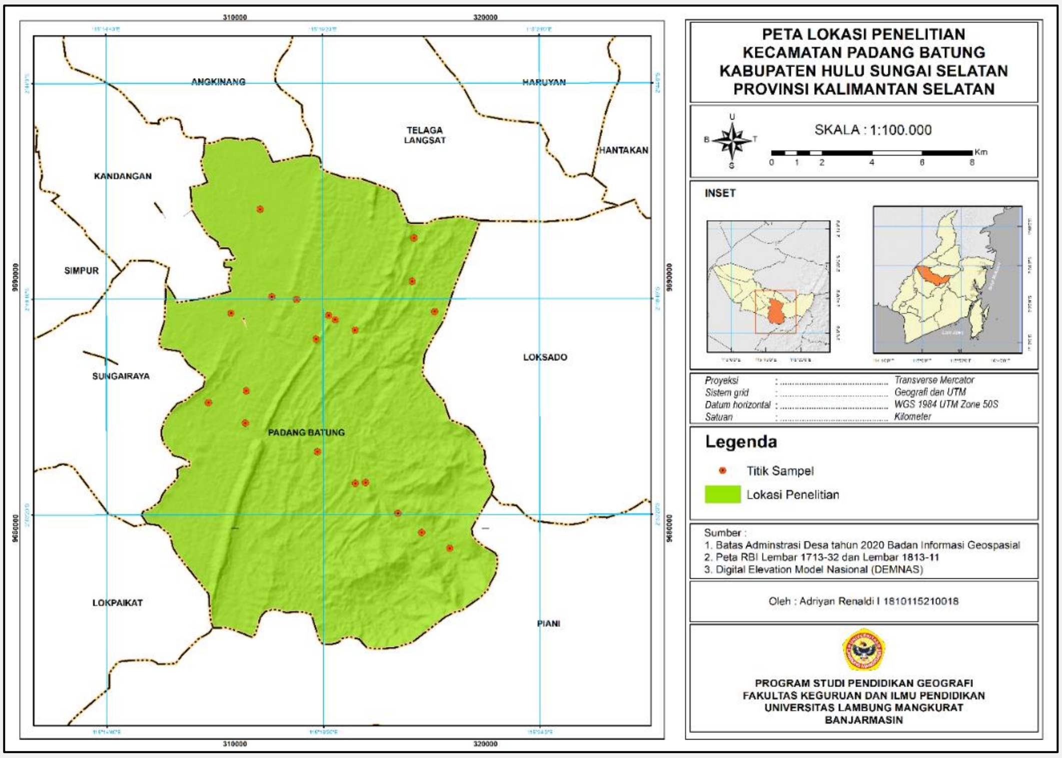

Figure 2. Research location

Tools and materials

Research tools used in this activity include hoes, soil drills, Abney levels, Yallon, Global Positioning System (GPS), roll meters, knives/machetes, plastic samples, tally sheet paper, and stationery. The materials used in this study were soil-type samples and terrain unit maps.

Sampling Method

The basis for sampling in this study uses terrain units. Terrain units are terrain categories/groups that define terrain forms or landscape complexes similar in characteristics and components in the field. There are 13 terrain units in Padang Sub-district (Table 1). The terrain units consist of the results of the intersect overlay on several data such as landform, slope, and soil type. Terrain units function as units of analysis used to analyze an area based on its characteristics. The sampling method uses a purposive random sampling technique, taking into account the layout of the sampling points that can be reached by transportation per terrain unit. Each research sample is determined based on the area of each terrain unit. Samples were taken at 1 sample point every 10 km², for a total of 20 samples. The terrain units in Padang Batung Sub-District can be seen in Figure 3.

Table 1. Terrain units in Padang Batung Sub-district

No	Terrain units	Area (km²)	Sample
1	D1-III-KPMKL	15,27	1
2	D1-IV-KPMKL	22,22	2
3	D1-IV-PMK	13,07	1
4	D2-III-OGH	5,41	1
5	D2-III-PMK	18,06	1
6	D2-II-OGH	5,11	1
7	D2-II-PMK	40,77	4
8	D2-I-OGH	1,62	1
9	D5-III-OGH	13,25	2
10	D5-II-OGH	23,55	2
11	D5-I-OGH	25,10	2
12	S1-III-OGH	3,06	1
13	S2-II-OGH	8,56	1
Total		203,93	20

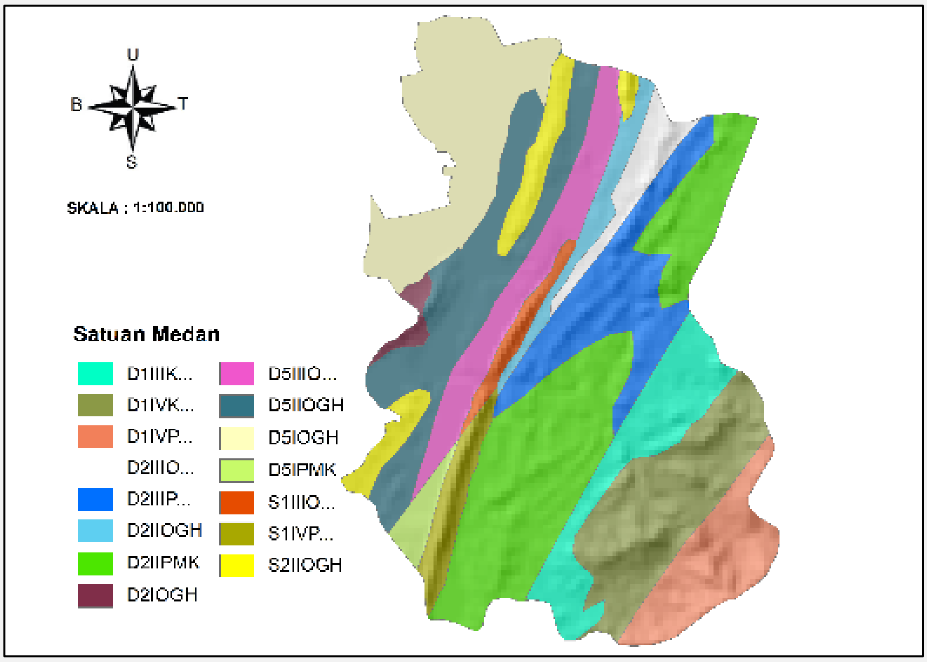

Figure 3. Terrain units

Data Collection

This study used two types of data in the form of secondary data and primary data. Primary data consist of physical and chemical data (soil structure, soil texture, organic matter content, and soil permeability), slope length and slope, and land cover vegetation. Meanwhile, secondary data includes rainfall data for the last 10 years, from 2012-2021 in Padang Batung Sub-district (Table 2).

Physical properties in the form of soil structure are obtained from the results of observation and sampling in the field. In soil chemical properties such as soil texture, permeability, and C-organic levels, these three parameters must be carried out in laboratory tests to obtain data. The primary data in this study came from observations and measurements made in the field, such as the length and slope of the slopes, as well as the vegetation and conservation of the land cover. All samples are contained in 20 places. The twenty locations are determined based on the Terrain units in Padang Batung Sub-district, produced from an overlay of three maps: landform maps, slope maps, and soil type maps. Each soil sample is taken at a depth of 0-20 cm consisting of 20 whole soil samples, and 20 sample rings.

Table 2. Sources of research data

	Data Type	Source	Data Usability
Primary Data	Soil structure Soil Texture Soil Permeability Content of Organic Materials	Soil sample laboratory test	This parameter is used to indicate the value of soil erodibility.
	Slope Length and Slope Vegetation Land Cover and Conservation	Field observation	Determination of the results of the LS value. Matching CP values in field conditions.
Secondary Data	Rainfall Data for the last 10 years (2012-2021)	BMKG	Data determining the erosivity of rain

Data Analysis

Universal Soil Loss Equation (USLE)

Analysis of erosion hazard levels using the USLE equation. The approach is broadly based on five factors: rain erosivity, soil erodibility, slope length, and slope, land cover vegetation and land conservation practices (Zaied et al., 2021) Predicting erosion on agricultural land in Padang Batung Sub-district is carried out by taking samples on each land unit. The formula is used as follows (Arsyad, 2010):

$$R \times K \times LS \times C \times P \qquad \text{(Syahputra et al., 2018)} \qquad (1)$$

Description:
A : Many soil values experience erosion (tons/ha/year),
R : Erosivity of rain ,
K : Soil erodibility,
LS : Length of slope (L) and slope (S)
C : Vegetation land cover
P : Land conservation management

Rain Erosivity (R)

Rain erosivity is measured using rainfall data from the last ten years in Padang Batung Sub-district, from 2012 to 2021. Precipitation data were analyzed using the calculation of the value of aggressiveness using the equation of erosivity by Lenvain (1989), as follows:

$$R = 2{,}21\ (Rt)^{1{,}36} \qquad \text{(Lenvain, 1989 in Asdak, 2010)} \qquad (2)$$

Description:
R : Rain erosivity index
R_t : Annual rainfall (cm)

Soil Erodibility (K)

Soil erodibility was obtained from the results of soil laboratory test data, including soil texture, soil structure, permeability, and C-organic content. Hoes, drills, and sample rings are used for soil sampling. Soil drills are used for texture and organic matter samples, and hoes are used for soil structure to obtain undisturbed soil samples. Sample rings are used for permeability to maintain soil aggregates while testing the time water seeps into the soil. Soil samples were sent to the laboratory to be able to process texture, permeability, and C-organic content tests. Meanwhile, the soil structure was observed and tested directly in the field. The determination of the erodibility value uses the soil erodibility equation (K) as follows:

$$100K = 1{,}292\{2{,}1(M^{1{,}14})(10^{-4})(12-a) + 3{,}25(b-2) + 2{,}5(c-3)\} \qquad \text{(Arsyad, 2010)} \qquad (3)$$

Description:
M : Percentage of particle size (% dust + % very fine sand)
(a) : (100 - % clay)
(b) : Percentage of organic matter elements (% C 1.74)
(c) : Soil structure classification code (granular, platy, massive, etc.)

Slope Length and Slope (LS))

Data on the length and slope of the slope were obtained from field measurements. The tools used are Abney level, yallon, and meter. The length and slope factors of the L and S slopes are determined as follows:

$$L = (X/22)^m \quad \text{(Arsyad, 2010)} \tag{4}$$

Description:
L : Actual slope gradient (%)
X : Slope length in meters
m : A constant whose magnitude is equal to 0.5, the slope is more than 5% steep.

$$S = 65{,}41\ \mathrm{Sin2}(S^{\wedge\circ}) + 4{,}56(S^{\wedge\circ}) + 0{,}065 \quad \text{(Arsyad, 2010)} \tag{5}$$

Description:
S : Actual slope (%)

$$LS = \sqrt{L}(0{,}0138 + 0{,}00965(S) + 0{,}00138(S)^{\wedge}2) \quad \text{(Arsyad, 2010)} \tag{6}$$

Description:
L : Slope length (m)
S : Slope (%)

The Ministry of Forestry gives the slope factor value of the slope, which is established by slope class (Kironoto & Yulistiyanto, 2000) (Table 3).

Table 3. Assessment of slope classes and LS factors

Slope Class	Slope	LS value
I	0 - 8	0,40
II	8 - 15	1,40
III	15 - 25	3,10
IV	25 - 40	6,80
V	> 40	9,50

Table 4. Approximate value of CP factors of different types of land use

Plant Type/land use	CP Value
Shrubs:	
a. undisturbed	0,01
b. partly grassy	0,10
Groves:	
a. groves-talun	0,02
b. groves-yard	0,20
Plantation:	
a. perfect ground cover	0,01
b. partial soil cover	0,07
Grassland:	
a. perfect ground cover	0,01
b. partial land cover; overgrown with reeds	0,02
c. reeds; burning once a year	0,06
d. citronella	0,65
Agricultural Crops:	
a. tubers	0,51
b. grain	0,51
c. nuts	0,36
d. mixture	0,43
e. irrigated rice	0,02
Field:	
a. 1 year of planting-1 year of birth	0,28
b. 1 year planting-2 years growing	0,19

Vegetation Land Cover and Soil Conservation (CP)

CP sampling was carried out in the field with observation techniques in each field by matching the description/area description regarding ground cover vegetation and soil conservation based on the CP factor assessment of experts matching it (Abdurachman et al., 1984). Table 4 shows the approximate value of CP factors for various types of land use.

Determination of Erosion Hazard Level

The calculation of erosion hazard level using the Universal Soil Loss Equation (USLE) equation is calculated based on equation (1). The classification of erosion hazard levels used in the study using the classification proposed by the Ministry of Forestry (1998), as shown in Table 5.

Table 5. Erosion Hazard Classification

Erosion Hazard Class	Land lost, (A) in (Tons/Ha/Year)	Description
I	< 15	Very Low
II	15 – 60	Low
III	60 – 180	Medium
IV	180 – 480	High
V	< 15	Very High

RESULT AND DISCUSSION

Rain Erosivity (R)

The erosivity index of rain in the entire Padang Batung Sub-district was determined using literature study data from the Agency for Meteorology, Climatology, and Geophysics in South Kalimantan, namely in the form of combined data or average results from rainfall gauges (Table 6). Rainfall data is one way to measure the erosivity index of rain. This method is the same as Pamungkas (2020)'s research by grouping rainfall values for the last ten years to obtain consistent changes in climate patterns. This study uses the equation in the form of the Lenvain formula (1989) because it is easier and more practical to use the equation only using monthly rainfall data. In processing the erosivity data that has been applied, it is entered into the ArcGIS software using the Inverse Distance Weighting (IDW) interpolation technique to obtain more complex results from the erosivity of rain. Based on the calculation of the erosivity index of rain in the Padang Batung Sub-district area, it has a value of 4513.29, which is included in the reasonably high category (Figure 6a).

Table 6. Erosivity of rain at the rainfall post point in the Padang Batung sub-district

No	Rain gauge	10 Year Average Rainfall (cm) (2012-2021)	Rain Erosivity (R)
1	SMPK Sungai Raya	259	4231.36
2	Padang Batung/Durian Rabung	288.9	4909.18
3	Telaga Langsat / Mandala	278	4659.01
4	Lumpangi / Loksado	260	4253.59
	Total average	271.48	4513.29

The Padang Batung Sub-district area has a reasonably high rain erosiveness value. It can be dangerous because it can cause disasters, as in Fauzi & Maryono (2017)'s research which said that an area that has a high level of rain erosivity must be balanced with good and correct land management because if not managed in an integrated manner, the land can lose large amounts of land and cause various kinds of disasters such as landslides (Pandani et al., 2022).

Soil Erodibility (K)

The soil erodibility at the study site had results with an average erodibility value of 0.25, which belongs to the moderate category. The level of soil erodibility is also the smallest and largest. The most excellent soil erodibility value indicates the potential for soil to be prone to erosion. Conversely, the smaller the erodibility value indicates, the lower the potential for the soil to undergo erosion (Harjadi & Agtriariny, 2012).

Table 7. Soil erodibility in Padang Batung Sub-district

Terrain units	Sample number	Value (K)	Average	Type soil
D1-III-KPMKL	1	0,17	0,20	Komp. Pods. Mr-Kng Lato - Lito
D1-IV-KPMKL	1	0,24		
	2	0,18		
D1-IV-PMK	1	0,11	0,15	Red-Yellow Podzolic
D2-III-PMK	1	0,16		
D2-II-PMK	1	0,11		
	2	0,12		
	3	0,11		
	4	0,12		
D2-III-OGH	1	0,43	0,22	Organosol Glei Humus
D2-II-OGH	1	0,21		
D2-I-OGH	1	0,37		
D5-III-OGH	1	0,34		
	2	0,19		
D5-II-OGH	1	0,26		
	2	0,15		
D5-I-OGH	1	0,08		
	2	0,11		
S1-III-OGH	1	0,20		
S2-II-OGH	1	0,12		

The varying erodibility values in certain areas are due to one of the components of soil texture, organic matter content, and soil permeability. The high level of soil erodibility in an area compared other regions is due to the condition of the soil texture, namely the low texture of clay, the high percentage of dust, and sand (Dariah et al., 2004).

Length and Slope (LS)

The slope and the length or LS factor in the Padang Batung Sub-district area have various classes. Based on measurements in the field, there are several classes of LS factors: sloping, moderate, rather steep, and steep. The difference in LS factors in Padang Batung Sub-district is influenced by its land formations in plains, hills, and mountains (Pandani et al., 2022). The LS factor on the plains has a low slope and slope with a value of 0.53-1.98.

Table 8. Length and slopes in Padang Batung Sub-district

Terrain units	Sample number	Value (LS)	Average	Slope Criteria
D1-III-KPMKL	1	5,15	5,55	IV
D1-IV-KPMKL	1	4,07		
	2	4,71		
D1-IV-PMK	1	3,63		
S1-III-OGH	1	3,33		
D2-III-OGH	1	5,41	2,98	III
D2-III-PMK	1	1,7		
D2-II-PMK	1	2,11		
	2	1,47		
	3	4,15		
	4	2,89		
D2-I-OGH	1	0,26		
S2-II-OGH	1	3,54		
D2-II-OGH	1	3,36	1,98	II
D2-II-PMK	2	1,47		
D5-III-OGH	1	1,32		
	2	2,32		
D5-II-OGH	1	0,26		
	2	3,17		
D5-I-OGH	1	0,4	0,53	I
	2	0,66		

The low value of the LS factor is caused by the morphological form of the results of the weathering of denudational hills in the form of almost plains, and this causes the amount of damage that occurs due to erosion in areas with The landform of the plains is very low, so this statement is following the research of Ashari (2013) that the morphology of an area influences the topography of the land, the morphology of the plains has a low amount of surface runoff acceleration unlike on the slopes of hills and mountains.

The LS factor in hills and mountains is different from plains because of the value of the height from sea level and the speed at which water falls faster than the plains. The LS factor, which has a value of 2.98 - 5.55, is included in the criteria for being rather steep and steep. Marble classes with rather steep and steep criteria already meet the criteria for land with a high potential for erosion in high or very high forms (Sitepu et al., 2017).

(a) (b)

Figure 4. Measurement of Slope Length and Slope at the Study Site, (a) Field Units D2-III-OGH (1) coordinate points 115° 21' 18.209" E and 2° 47' 20.839" S, and (b) Field Units D5-II-OGH (1) coordinate points 115° 18' 14.501" E and 2° 48' 36.914" S.

Plant Management and Soil and Conservation Factors (CP)

Land cover vegetation and conservation factors in the Padang Batung Sub-district area have a variety, from plantations to mixed plant and shrubs, with different conditions. Table 9 shows several types of ground cover vegetation and conservation based on field observations at each sample point.

Table 9. Plant Management and Soil (C) and Conservation Factors (P)

Terrain units	Sample No.	Description	Value (CP)
D1-III-KPMKL	1	Plantations: partial cover	0,07
D1-IV-KPMKL	1	Agricultural crops: mix	0,43
	2	Plantations: partial cover	0,07
D1-IV-PMK	1	Plantations: partial cover	0,07
D2-III-OGH	1	Shrub: partially grassy	0,10
D2-III-PMK	1	Shrub: partially grassy	0,10
D2-II-OGH	1	Plantations: partial cover	0,07
D2-II-PMK	1	Plantation: the perfect cover	0,07
	2	Plantations: partial cover	0,07
	3	Plantations: partial cover	0,07
	4	Shrub: partially grassy	0,07
D2-I-OGH	1	Plantations: partial cover	0,07
D5-III-OGH	1	Shrub: partially grassy	0,10
	2	Shrub: partially grassy	0,10
D5-II-OGH	1	Plantations: partial cover	0,07
	2	Plantation: the perfect cover	0,01
D5-II-OGH	1	Plantation: the perfect cover	0,01
	2	Plantation: the perfect cover	0,01
S1-III-OGH	1	Plantations: partial cover	0,07
S2-II-OGH	1	Agricultural crops: mix	0,43

Plantations with a cover spread throughout the area, which has a moderate hilly topography, are rather steep and steep, this shows that the community still uses the highland areas, with partial cover conditions or little grass vegetation. Meanwhile, plantations with perfect or rich ground cover vegetation are mainly located on lowlands and sloping areas, causing lower erosion (Andriyani et al., 2019). Mixed farming is found in a small number of places in the lowlands, but in this study, mixed farming was found on average in the highlands. Meanwhile, shrubs with grass conditions have almost the same similarities as plantations with cover, meaning that the vegetation cover of shrubs is inferior. Mixed farming is proper crop management in the lowlands based on the research of Kurnia et al. (2004), but in the study in Padang Batung Sub-district, the management of mixed farming is carried out in the highlands, which causes land use mismatch, this can cause soil erosion.

Shrubs do not have strong roots in maintaining soil aggregates such as plantations, and this causes soil units in the area to easily experience erosion due to runoff, soil mass movement, and human activities; this statement following research by Lanyala et al. (2016), states that shrubs/grasslands have low levels of soil aggregates which are very prone to erosion. Figure 5 depicts the condition of land cover vegetation and conservation in the study area.

(a) (b)

Figure 5. Condition of land cover vegetation and conservation at the study area (a) Terrain unit D5-III-OGH (1) (shrubs: partially grass) coordinates 115° 19' 27.732" E and 2° 49' 1.3800" S, and (b) Terrain unit D1-IV-KPMKL (1) (agriculture: mixed) coordinates 115° 21' 27.410" E and 2° 53' 43.591" S.

Calculation of Erosion Rate in Padang Batung Sub-district

The value of each USLE parameter in Padang Batung Sub-district can be seen in (Table 7). The erosivity value of the rain found in the research location is 4513.29 cm/ha/hour. The rain data used to calculate the erosivity value of rain comes from just a few rainfall posts, namely the SMPK Sungai Raya Rainfall Post, Padang Batung/Durian Rabung, Telaga Langsat/Mandala, and Lumpangi/Loksado for the last ten years (2012-2021). The largest maximum rainfall is 288.9 cm, located at the Padang Batung/Durian Rabung rainfall post. Based on the number of annual rains, the Padang Batung/Durian Rabung rainfall post point is the highest with a wet climate level (rain classification based on BMKG, 2021). Thus the value of the erosivity of rain in Padang Batung Sub-district is high. The map of the erosivity of rain in Padang Batung Sub-district can be seen in (Figure 6a).

Table 10. Parameter values for determining soil erosion in Padang Batung Sub-district

No	Parameter	Value
1	Rain Erosivity (R)	4513,29
2	Soil Erodibility (K)	0,15 – 0,22
3	Slope Length & Slope (LS)	0,53 – 5,55
4	Land cover vegetation and soil conservation measures (CP)	0,01 – 1

Soil erodibility factors were determined from each soil type in Padang Batung Sub-district. The highest erodibility values were found in samples from swidden locations and the lowest in paddy fields, which were 0.22 and 0.15, respectively (Figure 4b). The size of the soil erodibility (K) is influenced by C-organic content, soil permeability, soil texture, and structure (Hanifa & Suwardi, 2022). The value distribution of crop management and soil conservation measures (CP) in Padang Batung Sub-district is

0.01-1 (Figure 4c). The CP value is determined by the type of land cover, such as land cover in the form of plantations and paddy fields, with a value of 0.01, while the most significant value can be mining, with a value of 1. CP values categorized as small have resistance to erosion because they can protect the soil surface from the blows of rain grains and surface flows. On the contrary, the largest CP values have a low resistance to damage due to erosion.

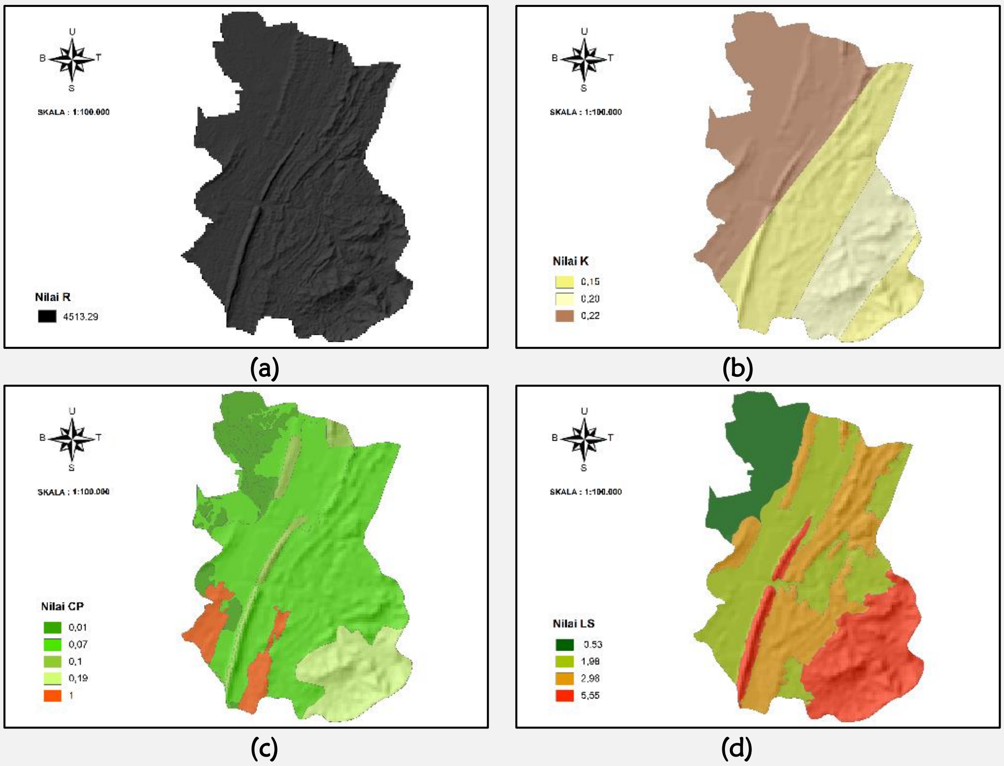

Figure 6. Spatial distribution of erosion parameter values (a) Erosivity of rain (R), (b) Soil erodibility (K), (c) Vegetation land cover and soil conservation (CP), and (d) Length and slope of the slope (LS).

Table 11. Erosion hazard level in Padang Batung Sub-district

Terrain units	Sample	Erosion Prediction (Tons/Ha/Yr)	Class	Description
D1-III-KPMKL	1	308.82	IV	High
D1-IV-KPMKL	1	1895.69	V	Very high
	2	267.85	IV	High
D1-IV-PMK	1	126.15	III	Medium
D2-III-OGH	1	1049.94	V	Very high
D2-III-PMK	1	122.76	III	Medium
D2-II-OGH	1	222.92	IV	High
D2-II-PMK	1	73.33	III	Medium
	2	55.73	II	Medium
	3	170.45	III	Medium
	4	109.57	III	Medium
D2-I-OGH	1	167.16	III	Medium
D5-III-OGH	1	202.56	IV	High
	2	198.95	IV	High
D5-II-OGH	1	21.36	II	Low
	2	21.46	II	Low
D5-I-OGH	1	1.44	I	Very Low
	2	3.28	I	Very Low
S1-III-OGH	1	210.42	IV	High
S2-II-OGH	1	824.45	V	Very high

From the results of observations and calculations of the length and slope of the slopes at each sample point in Padang Batung Sub-district, the LS value was obtained in the range of 0.53-5.55. The higher the LS value, the more extended and steeper the slope (Simanjuntak et al., 2017). The LS value in Padang Batung Sub-district can be seen in Figure 4d.

The erosion rate in terrain units can be seen in (Table 8). The most considerable erosion rate in the Padang Batung Sub-district area is 1895.69 tons/ha/yr. In 2020 the total erosion rate in the Padang Batung Sub-district area studied by Safitri (2021) was 932,933 tons/ha/yr, so it can be seen that the erosion rate in the Padang Batung Sub-district area has increased. This change in value results from the high rain intensity, causing the erosivity index to increase. The value of soil erodibility is also one of the factors, as in soil types dominated by organosol soils that are relatively sensitive to erosion (Giyanti et al., 2014). The height of the slope or the slope of the slope has become a common factor in the occurrence of erosion because the location of the decline or movement of the soil mass from the plateau is a property of erosion. Based on the height of the terrain unit, the steep slope factor has a dominant area with a prediction of very high erosion values (>480 tons/ha/yr) (Figure 7). Another factor that causes the increasing rate of erosion in Padang Batung Sub-district is the land opening due to land use by communities that need to apply proper soil conservation techniques. According to AlKharabsheh et al. (2013), land use management also determines the level of erosion.

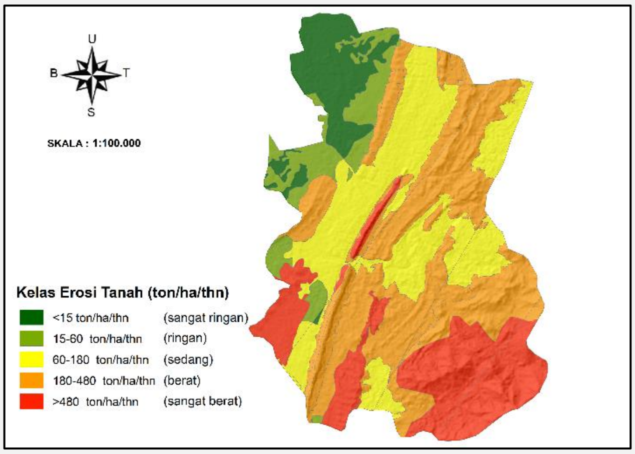

Figure 7. Spatial distribution of predicted soil erosion classes in Padang Batung Sub-district

The observations at the study site showed several types of erosion, namely, sheet erosion and groove erosion. Groove erosion is caused by the flow of water flowing into the basin so that more significant soil erosion occurs. Sheet erosion is the erosion of a thin layer of soil surface on slopes by combining rainwater and runoff water. Visible grooves and sheet erosion found in areas with severe erosion hazard levels can be seen in Figure 8.

(a) (b)

Figure 8. Types of erosion at the study site (a) Sheet erosion (coordinates 115° 19' 27.732" E and 2° 49' 1.3800" S), and (b) Groove erosion (coordinates 115° 21' 18.209" E and 2° 47' 20.839" S).

Erosion Distribution Conditions in Padang Batung Sub-district

The condition erosion hazard level in the Padang Batung Sub-district area has several criteria: very low, low, medium, high, and very high. The area of land in Padang Batung Sub-district can be seen in Table 7. The distribution of areas affected by erosion is based on the following criteria: Very low criteria in the study area with an area of 18 km² (8.34%). The low criteria are 16 km2 (7.20%). The medium criteria are 53 km² (26.05%). The criteria for high are 74 km2 (37.86%), and the criteria for very high are 40 km² (20.55%). Various factors, including natural, biological, and geological factors, influence the level of erosion criteria. Natural factors that influence the level of erosion criteria are soil erodibility and precipitation. The geological factors include the soil type and the slope's height. Meanwhile, biological factors include land cover vegetation and land use (Osok et al., 2018).

Table 12. Classification of Erosion Rate Distribution Area in Padang Batung Sub-district

Erosion Rate Criteria	Village	Area (km²)	Total
Very Low	Pandulangan	4,77	18
	Karang Jawa	3,04	
	Tabihi	2,75	
	Madang	1,67	
	Jembatan Merah	1,50	
	Kaliring	1,29	
	Karang Jawa Muka	1,19	
Low	Jambu Hulu	3,27	16
	Malutu	3,10	
	Madang	2,59	
	Pahampangan	1,63	
	Pandulangan	1,23	
	Kaliring	1,18	
	Padang Batung	0,99	
Medium	Batu Bini	11,16	53
	Malilingin	10,93	
	Malutu	7,25	
	Madang	6,89	
	Mawangi	4,90	
	Jalatang	4,35	
	Batu Laki	4,07	
	Durian Rabung	1,06	
High	Malilingin	21,33	74
	Batu Laki	19,12	
	Mawangi	11,45	
	Batu Bini	7,03	
	Madang	5,53	
	Malutu	4,55	
	Jambu Hulu	1,85	
	Jalatang	1,66	
	Kaliring	1,04	
Very High	Batu Laki	19,62	40
	Malilingin	13,61	
	Malutu	6,71	

Some villages in Padang Batung Sub-district have erosion hazard levels with various criteria, such as high criteria that have land management priorities, because the distribution of erosion prediction rates of high criteria has the most prominent location among other criteria. The villages with a severe erosion hazard include Malilingin, Batulaki, and Mawangi villages. This is due to changes in land use in the village area which resulted in several land management discrepancies that ended up becoming land damage. In addition to the community's ignorance of land management procedures such as conservation techniques, it is also one of the problems that the area becomes very prone to high erosion. For example, land that was supposed to continue to function as a forest turned into oil palm and rubber plantations along the slopes of the Meratus mountains with planting techniques did not follow soil conservation rules. In addition to oil palm and rubber plantations, several illegal mine management practices, such as sand and stone mines, exacerbate the impact of land damage (Osok et al., 2018).

CONCLUSION

The erosion hazard rate in the Padang Batung Sub-district area has the highest erosion rate of 1105.82 tons/ha/yr. The rate of erosion distribution in Padang Sub-district has several criteria, from very low, low, medium, high, and very high The dominating erosion hazard level criteria are found in the weight category with an area of 74 km^2 (37.86%) with an average erosion rate of 345.27 tons/ha/yr. Various factors, such as natural, biological, and geological factors, influence the erosion rate. Natural factors that influence the level of erosion criteria are soil erodibility and precipitation. The geological factors include the soil type and the slope's height. Meanwhile, biological factors include land cover vegetation and land use.

This study's calculation of the erosion rate value results from prediction using the USLE method. In predicting the erosion rate, several other equations exist, such as the MUSLE and RUSLE equations. The use of methods in other research in the future can produce more accurate and objective data so that the direction of management and handling of the research area can be more appropriate to solving erosion problems

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