Analyzing Erosion Using GIS in Way Besai Watershed

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Abstract. The impact of erosion globally shows huge losses in food production. Economic damage due to erosion is related to the total rainfall that falls in an area. High rainfall due to extraordinary climate change will have an effect on soil erosion. Specific planning in various regions will restrain erosion impact. Erosion prevention such as environmental rehabilitation through reforestation of land can be done by managing land that has erosion potential. Universal Soil Loss Equation (USLE) is the most popular method for really used method predicting amount of erosion. Geographic Information Systems (GIS) can facilitate the process of visualization and geographic exploration of the secondary data obtained, especially in identifying the level of erosion hazard. The erosion hazard level in Way Besai watershed is 505.7502 tons/ha/year which is classified as Erosion Hazard Class V or very high. Sediment in Way Besai watershed is 352485.91 tons/year for an area of 38865 Ha. Erosion hazard percentage according to slope classification is 0 – 8 (1.89 %), 8 – 15 (6.6 %), 15 – 25 (14.62 %), 25 – 40 (32.08 %), and > 40 (44.81 %). The erosion hazard area with high classification is located in a mountainous area with large slope.

Keywords: Erosion, Way Besai Watershed, USLE, GIS.

1 Introduction

The impact of erosion globally shows huge losses in food production [1]. Economic damage due to erosion is related to the total rainfall that falls in an area [2]. High rainfall due to extraordinary climate change will have an effect on soil erosion [3]. Specific planning in various regions will limit the impact of erosion [4]. Erosion prevention such as environmental rehabilitation through reforestation of land [5] can be done by managing land that has the potential for erosion [6]. Changes in land cover and climate are one of the causes of large erosion in river watersheds [7]. Prevention of the dangers of erosion can be done by reforestation, improving vegetation and ecology, and land use planning [8].

Ignorance and apathy are factors that perpetuate the danger of erosion and sedimentation [9]. Of course, with relevant policies by stakeholders and policies [10] to improve environmental, social and economic conditions [11]. By carrying out intensive land management, total erosion can be reduced compared to existing land management practices [12].

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One of the indicators to determine the critical level of a watershed is to analyze the amount of erosion that has occurred. Universal Soil Loss Equation (USLE) which is the most popular and widely used method for predicting the amount of erosion. Due to its simplicity and small data input requirements, the USLE method has been universally applied across continents [13].

Geographic Information System (GIS) is designed to collect, store, and analyze objects and phenomena where geographic locations are important characteristics to be analyzed. Geographic information systems can facilitate the process of visualization and geographic exploration of the secondary data obtained, especially in identifying the level of erosion hazard in the study area [14].

The purpose of this study is to analyze the rate of erosion and sedimentation in Way Besai watershed using GIS software, map the distribution of the erosion hazard index in Way Besai watershed, and provide directions for land rehabilitation and soil conservation according to the conditions of Way Besai watershed.

2 Methodology

2.1 Research Location

The location of this research study is in Way Besai Watershed, which is located in Sumber Jaya District, Air Hitam, Way Tenong, Kebun Tebu, and Gedung Surian. In this study, 4 Rain Post data were used (R.275 Bungin II, R 003 Pajar Bulan, R.232 Kebon Tebu, R234 Air Itam) which are presented in map form in Fig. 1.

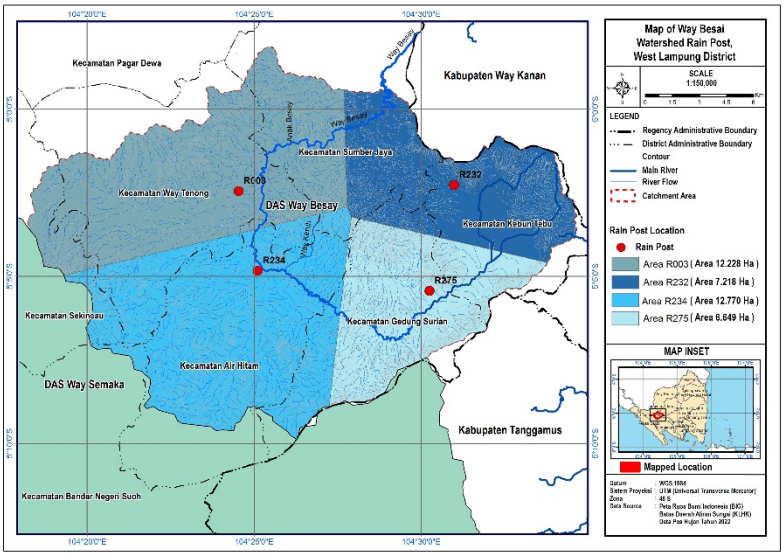

Fig. 1. Map of Way Besai Watershed Rain Post.

2.2 Method

Beginning with data collection, spatial data model development using GIS, and data analysis. The rainfall data used in this study are for the last 10 years (2013 – 2022) which are contained in Way Besai watershed. The soil type map was obtained from FAO Map Soil, the land use map was obtained from the 2022 Sentinel 2 Image and the Slope Slope Map was obtained from DEM Data from USGS. Data processing and analysis was carried out using the GIS approach, namely using the ArcGIS application. Processing and data analysis with the three types of maps and rainfall data for the values of the factors of each erosion parameter needed in the calculation of the level of erosion hazard. The three types of maps are soil type maps for K values, slope class maps for LS values, land cover maps for CP values, and rainfall data for R values. The data is used by linking the USLE method and GIS applications that can predict erosion and sedimentation.

3 Results and Discussion

3.1 Rain Erosivity Index (R)

Regional average rainfall analysis was carried out to obtain the annual average maximum rainfall that fell in study area, which in this study used Thiessen Polygon method with 4 Rain Stations. Furthermore, determining the erosivity index (R) [15] in USLE method is as follows:

$$R = 2.21 \, . \, Cr^{\,1,36} \tag{1}$$

Where:
R = Rain Erosivity Index
Cr = Monthly Average Rainfall (cm)

Table 1. Rain Erosivity Index Calculation Using Thiessen Polygon Method (January – June).

Year	Jan	Feb	Mar	Apr	May	Jun
2013	286.4	182.4	230.1	290.3	229.0	106.2
2014	201.7	172.9	163.7	189.4	186.6	100.2
2015	207.3	267.4	199.2	132.6	180.6	96.3
2016	298.3	408.5	562.5	244.8	226.2	119.7
2017	77.0	253.9	255.8	257.5	232.4	86.9
2018	132.9	224.0	402.0	192.0	103.0	145.2
2019	385.8	403.4	312.9	385.9	113.2	77.1
2020	401.7	235.5	370.0	343.7	400.5	169.1
2021	222.7	269.2	416.0	277.3	210.2	113.1
2022	674.4	249.6	276.3	316.6	295.7	207.7
Average	**288.8**	**266.7**	**318.9**	**263.0**	**217.8**	**122.1**
Rain Erosivity	**214.2**	**192.2**	**245.1**	**188.6**	**145.9**	**66.5**

Source: Analysis 2023

Table 2. Rain Erosivity Index Calculation Using Thiessen Polygon Method (July – December).

Year	Jul	Aug	Sep	Oct	Nov	Dec
2013	342.8	82.0	138.9	165.1	234.4	365.0
2014	172.0	85.2	20.5	72.3	339.6	285.3
2015	27.8	14.5	28.6	15.2	157.8	301.2
2016	181.3	115.1	456.0	251.7	399.2	105.5
2017	119.0	67.1	126.6	253.5	404.9	180.3
2018	100.8	66.1	66.0	162.5	296.4	276.0
2019	23.1	16.7	12.1	48.1	123.0	498.1
2020	91.9	91.6	117.2	252.6	124.7	129.0
2021	98.0	142.2	63.4	232.6	303.0	428.0
2022	134.6	184.8	132.6	404.2	300.5	181.8
Average	**129.1**	**86.5**	**116.2**	**185.8**	**268.4**	**275.0**
Rain Erosivity	**71.7**	**41.6**	**62.1**	**117.6**	**193.8**	**200.4**

Source: Analysis 2023

Table 3. Rainfall Classification.

Year	Rainfall (mm/year)	Classification
2013	2652.69	High
2014	1989.40	Low
2015	1628.46	Low
2016	3368.94	Very High
2017	2314.99	Medium
2018	2166.90	Medium
2019	2399.56	Medium
2020	2727.56	High
2021	2775.78	High
2022	3358.82	Very High

Source: Analysis 2023

In Table 1 and 2, the values obtained are $R = \sum 2.21 \,.\, Cr^{1,36} = 1739.62$. In Table 3, the rainfall classification [16] in Way Besai Watershed from 2013 to 2022 has increased. This climate change can affect the amount of erosion and sedimentation that occurs in our study.

3.2 Soil Erodibility Index (K)

The soil erodibility index shows a level of soil susceptibility to erosion. Very fine soil textures will be washed away more easily than coarse soil textures. Soil erodibility index values can be obtained based on types of soil that exist in Indonesia. Soil erodibility values based on existing soils in Indonesia [17] [18] are presented in Table 4.

Table 4. Value of K in several types of soil.

No	Type of Soil	Nilai K
1	Latosol Dermaga (Haplorthox)	0.03
2	Latosol Citayam (Haplorthox)	0.09
3	Regosol Tanjungharjo (Troporthents)	0.14
4	Grumosol Jegu, Belitar (Chromoderts)	0,27
5	Podsolik Jonggol (Tropudults)	0.16
6	Mediteran Citayam (Tropohumults)	0.10
7	Mediteran Putat (Tropudalfs)	0.23
8	Mediteran Punung (Tropaqualfs)	0.22
9	Podsolik Merah Kuning Pekalongan, Lampung Tengah (Tropudults)	0.32
10	Andosol (Dystrandep)	0.16

Source: Analysis 2023

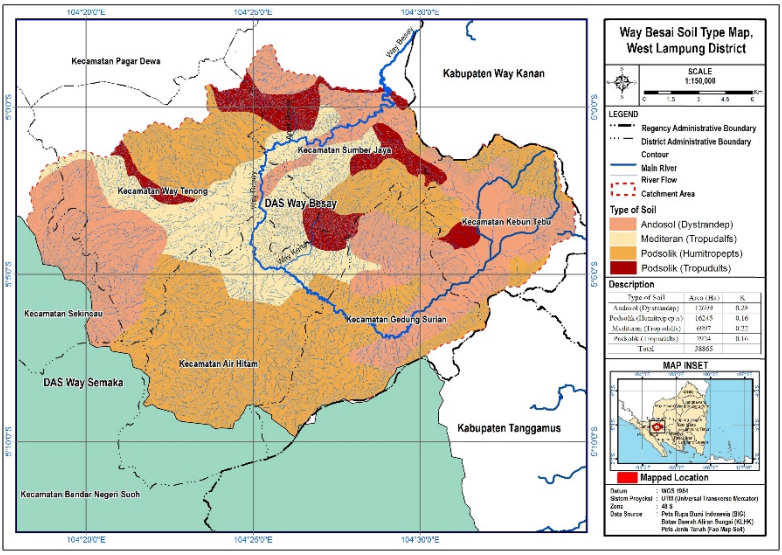

Fig. 2. Way Besai Soil Type Map.

Table 5. Soil Erodibility Value (K).

No	Type of Soil	Area (Ha)	K	A_i x K_i
1	Andosol (Dystrandep)	12699	0.16	2031.84
2	Podsolik Merah Kuning (Humitropepts)	16255	0.32	5198.4
3	Mediteran (Tropudalfs)	6997	0.23	1609.31
4	Podsolik (Tropudults)	2921	0.16	467.84
	Total	**38875**		**9307.39**
	K		**0.23948**	

Source: Analysis 2023

3.3 Slope Index (LS)

In determine Slope Index (LS), ArcMap analysis is used which is determined based on slope with 5 criteria [15]. The slope classification was made based on DEMNAS contour data, then an analysis with ArcMap application. Results of spatial analysis of LS in Way Besai watershed are presented in Fig. 3.

Table 6. Value of LS in several types of Slopes.

Slope Class	Value of LS
0 – 8 %	0.4
8 – 15 %	1.4
15 – 25 %	3.1
25 – 40 %	6.8
> 40 %	9.5

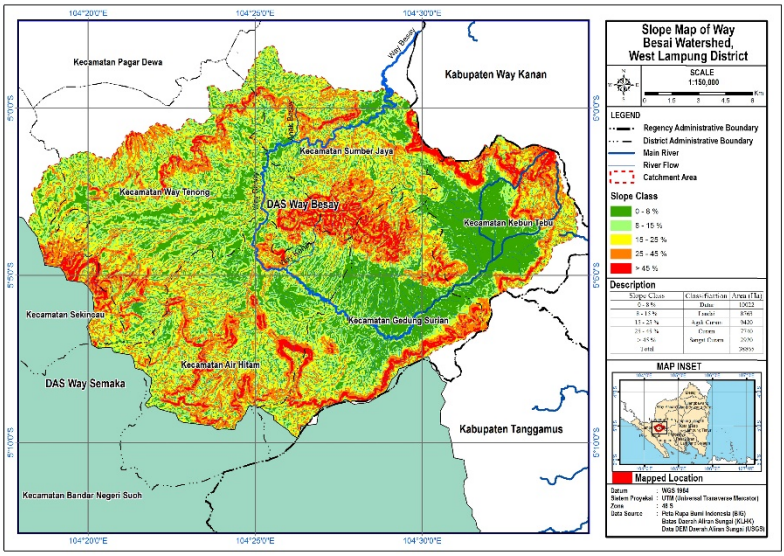

Fig. 3. Slope Map of Way Besai Watershed.

3.4 Factors of Plant Management and Soil Conservation (CP)

Factors of Crop and Pattern (CP) was obtained based on land use data in Way Besai watershed and correlated with the CP index [19] based on crop management and soil conservation factors Table 7.

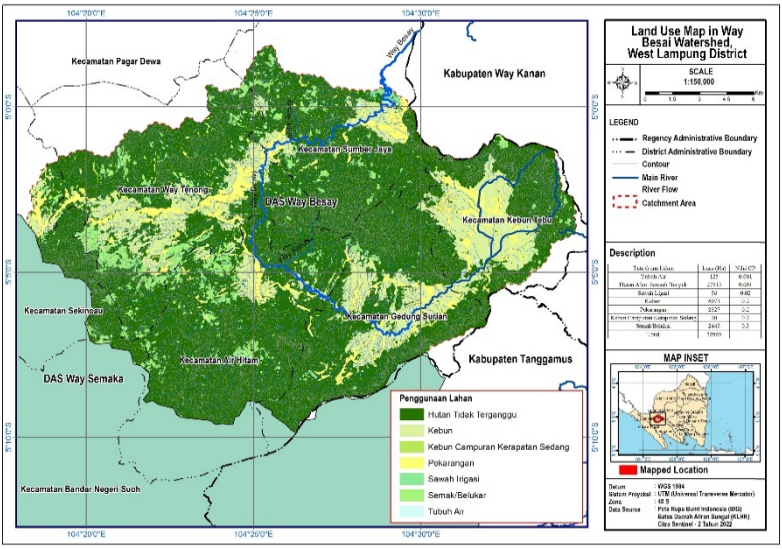

Fig. 4. Land Use Map in Way Besai Watershed.

Table 7. Crop and Pattern Value (CP).

Land Use	Area (Ha)	CP	A_i x CP_i
Natural Forest	34818.75	0.05	1740.9375
Irrigated Fields	181	0.02	3.62
Garden	1518.25	0.01	15.1825
Yard	2327	0.2	465.4
Mix Garden	20	0.02	0.4
Total	38865		2225.54
CP		0.05726	

Source: Analysis 2023

3.5 Erosion Hazard Level Calculation

The level of erosion hazard in Way Besai area can be calculated using the USLE equation. The calculation results can be seen in Table 8 .

Table 8. Erosion Value in Way Besai Watershed.

Slope Class	R	K	LS	CP	E	Percentage
0 – 8 %	1739.62	0.23948	0.4	0.05726	9.54246	1.89 %
8 – 15 %	1739.62	0.23948	1.4	0.05726	33.39860	6.60 %
15 – 25 %	1739.62	0.23948	3.1	0.05726	73.95404	14.62 %
25 – 40 %	1739.62	0.23948	6.8	0.05726	162.22177	32.08 %
> 40 %	1739.62	0.23948	9.5	0.05726	226.63335	44.81 %
Total Erosion Hazard Level					505.75021	

Source: Analysis 2023

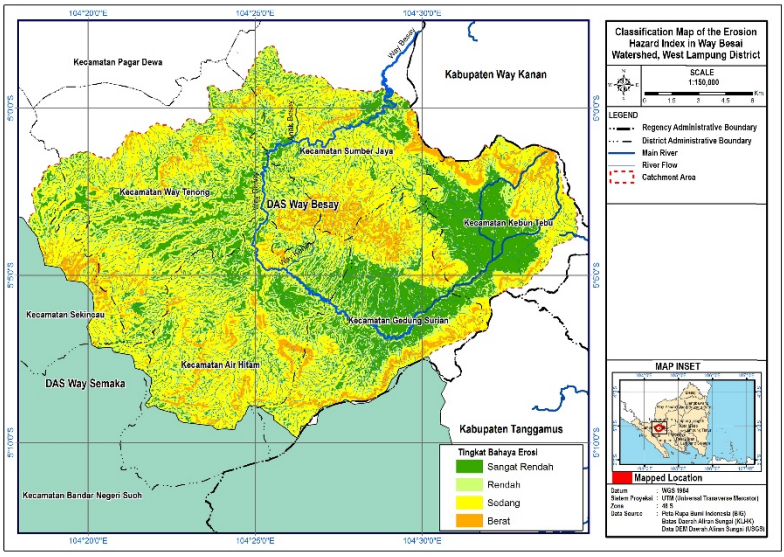

Fig. 5. Classification Map of the Erosion Hazard Index in Way Besai Watershed.

Based on the table, it can be seen that the erosion hazard level in Way Besai Watershed is 505.7502 tons/ha/year which is classified as Erosion Hazard Class V or very high [20]. Figure 5 or Erosion hazard maps is results of analysis of the erosion hazard index classification according to erosion rates are mapped spatially in Way Besai watershed. Erosion hazard maps inform estimates of annual soil loss in a watershed, assist investigations that can be designed to reduce erosion impacts, and provide effective remediation measures [21].

3.6 Sediment Delivery Ratio (SDR) Calculation and Sedimentation Value

Estimating the amount of sediment by calculating the SDR of an area. Sediment Delivery Ratio (SDR) [17] [19] is the ratio between the sediment material produced by an area to total erosion that occurs.

$$\mathrm{SDR} = 0{,}41 \,.\, \mathrm{As}^{-0.3} \tag{2}$$

$$\mathrm{Y} = \mathrm{E} \,.\, (\mathrm{SDR}) \,.\, \mathrm{A} \tag{3}$$

Where:
SDR = Sediment Delivery Ratio
Y = Sedimentation (ton/th)
E = Erosion (ton/ha/th)
As = Watershed Area (km2)
A = Watershed Area (Ha)

The amount of sedimentation that occurred in Way Besai watershed is presented in Table 9.

Table 9. SDR and Sedimentation Value.

Slope Class	Luas		SDR	E	Y
	km^2	Ha			
0 – 8 %	100.22	10022	0.1029	9.54246	9842.65
8 – 15 %	87.63	8763	0.1071	33.39860	31359.50
15 – 25 %	94.2	9420	0.1049	73.95404	73043.47
25 – 45 %	77.4	7740	0.1112	162.22177	139640.58
> 45 %	29.2	2920	0.1490	226.63335	98599.72
Total Sedimentation					352485.91

Source: Analysis 2023

Based on results of sedimentation values that occur in all land units calculated through results of analysis, it shows that the estimated number of sediment production in Way Besai watershed is 352485.91 tons/year for an area of 38865 Ha with various types of land cover.

4 Conclusion

The value of annual average erosion rate with USLE method is 505.7502 tons/ha/year for a watershed area of 38865 ha. Sediment production in Way Besai Watershed is 352485.91 tons/year for an area of 38865 Ha. The amount of rainfall that occurs in Way Besai Watershed also affects the amount of erosion and sedimentation. The percentage of erosion hazard according to slope classification is 0 – 8 (1.89 %), 8 – 15 (6.6 %), 15 – 25 (14.62 %), 25 – 40 (32.08 %), and > 40 (44.81 %). The erosion hazard area with classification of high is located in a mountainous area with large slope.

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