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Original research article

Analysis of Erosion and Land Conservation Based on Geographic Information System in Way Sekampung Subwatershed

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ABSTRACT

Way Sekampung subwatershed is the watershed area of Way Sekampung dam. The changes in land use that occurred in the Way Sekampung subwatershed caused flooding and landslides. To reduce existing problems, vegetative and mechanical land conservation efforts are needed. In this study, the USLE method was used to estimate the rate of erosion and then map the distribution of the Erosion Hazard Index in the Way Sekampung Subwatershed with the help of Geographic Information System (GIS). Based on existing conditions, the erosion rate in 2017 was 29626.262 tons/ha/year; in 2022, the erosion rate was 76617.579 tons/ha/year. The results of the analysis of the Erosion Hazard Index in 2017 and 2022 showed four criteria, namely low with a difference of -1.115%, moderate with an increase of 1.140%, high with a difference of -0.097%, and very high with a difference of 0.071%. Conservation with new land use, construction of terraces, and check dams has resulted in a reduction in erosion in the Way Sekampung Subwatershed with an Erosion Hazard Index, which is a low index increase of 26.992% from the existing condition and a very high 22.819% reduction from the existing condition. These results show that land conservation can reduce erosion in the Way Sekampung Subwatershed.

1. Introduction

Watershed management is a significant effort to ensure water quality and a balanced environment. Currently, watershed management is experiencing an imbalance in the carrying capacity of the available land [1]. Watershed management also looks at the relationship between land, soil, and water and between upstream and downstream watersheds [2]. Land use changes in residential and industrial areas are increasing along with the population. Improper land management in watershed areas can cause erosion [3]. Following the Republic of Indonesia Ministry of Forestry regulation no. P. 39/Menhut-II/2009 states that in Indonesia there are 108 watersheds in critical condition [4].

This research occurred in the Way Sekampung Sub-watershed, Lampung Province, the Water Catchment Area of the Way Sekampung Dam. The Way Sekampung Dam is used for various purposes as a regulating dam downstream of the Batutegi Dam [5]. Natural and human changes, such as surface erosion and land degradation, are significant problems in the Sekampung watershed and can reduce agricultural or plantation production capacity [6]. The Way Sekampung Subwatershed area has experienced land use changes in recent years. The land is used not by soil and water conservation can cause problems such as the emergence of critical land, loss of fertile land, and soil pollution [7]. Changes in land use significantly impact erosion, with increases in rates of erosion and sedimentation that can be directly proportional to changes in land use. In 2019, the thickness of erosion in the Way Sekampung Sub Watershed is 8.26 mm/year, which exceeds the maximum limit for eroded soil thickness in Indonesia, which is 2.5 mm/year [5]. The following factors influence and contribute to erosion: terrain, soil, vegetation, cover crops, and human activity [8]. Three phases make up the erosion process: a) separation from the environment, b) movement of the separated particles, and c) positioning of the moved particles [9]. Natural phenomena such as erosion have the potential to have a significant impact on the integrity of ecosystems, the quality of water, and the entire condition of soil [10], [11], [12]. Significant environmental, social, and economic repercussions result from soil erosion, which impacts both natural ecosystems and agricultural areas [13]. Therefore, it is necessary to manage land use well to reduce the negative impacts of erosion and optimize environmental functions.

Recent developments in water erosion modeling have given scientists and researchers powerful instruments for understanding, quantifying, and managing the water erosion

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process. Numerous models have been built based on actual data, physical principles, or a combination [14]. This study uses the USLE method to analyze erosion rates in the Way Sekampung Subwatershed. The advantage of the USLE method lies in its simplicity and ease of application, which makes it widely used despite its limitations. The USLE model requires fewer parameters compared to more complex models, making it easier to apply in areas with scarce data. When field measurements are unavailable, the inference of USLE parameters is made easier by the development and availability of space-borne data, computational resources, and processing techniques. A few of the literature-sourced USLE parameter computation methods are compiled in this part [15]. They rely on statistical analysis and observed data to generate empirical relationships, frequently requiring a narrow set of input parameters [16]. Therefore, for this study, erosion estimation and conservation planning use a combination of the USLE method with GIS because of its practicality, accuracy, and ease of obtaining data [13]. Furthermore, the erosion rate analysis results can determine conservation by the conditions of the Way Sekampung Subwatershed. Recommendations for handling erosion with land conservation can be made vegetatively and mechanically [17]. The study aims to analysis erosion rate with the USLE method, mapping of erosion hazard index with GIS, and determine the most effective method option for conservation and erosion control.

2. Material and Method

The study site is located in the Way Sekampung Subwatershed of Lampung Province, Indonesia, which covers two districts: Pringsewu District and Tanggamus District. The subwatershed covers an area of 292 km^2 and is between 104°33'20" and 104°55'0" E and 5°30'0" and 5°8'20" S. The location of the research is shown below in **Figure 1**.

There are three rain stations in the Way Sekampung Sub Watershed area. Rainfall data in 2013-2022 from the three rain stations, namely R.072, R.067, and PH.018, was used to carry out hydrological analysis as a rain erosivity parameter to calculate rain erosivity. Based on Harmonized Web Soil Database data from FAO, the soil types in the Way Sekampung Sub Watershed are Humic cambisols, Umbric andosol, and Ferric acrisol. The dominant soil type is Humic cambisols, including clay loam soil with high permeability, which means the soil is more susceptible to erosion [18].

Land use in the Way Sekampung Sub Watershed consists of shrubs, secondary dryland forests, settlements, dryland agriculture, rice fields, open land, and water bodies. Individuals who produce primary commodities such as coffee, cocoa, pepper, bananas, and sugar cane own dryland farming in this area. Based on the results of land use digitization, changes in land use have occurred from 2017 to 2022. Land use is dominated by mixed dry land agriculture, but residential land use has increased by 1.151% from the 2017 land use area, while mixed dry land use has decreased by -2.213%.

2.1. *Methods*

The first research stage was the hydrological analysis of rainfall data for 2013 – 2022 at three rain stations using a consistency analysis with a double mass curve, absence of trend analysis, stationary analysis, and persistence analysis. This hydrological analysis was carried out to determine the suitability of the data before calculating the erosivity of rain. The rain erosivity factor (R) analysis uses the Lenvain formula at each station. Then, the erosivity results are input into the digitized Theissen polygon map according to the area of each rain station. Calculating soil erodibility (K) uses the Wischmeir formula by entering several parameters such as soil structure class, soil permeability class, and percent organic matter in each type of soil, which are known from the Harmonized World Soil Database map. Analysis of slope length and slope (LS) using Geographic Information Systems (GIS) involves the use of a digital elevation model (DEM) to calculate slope values and produce a slope map. After creating the slope, the next step is to classify the slope class based on the slope percentage. Land use maps for 2017 and 2022 sourced from the Ministry of Environment and Forestry were digitized to obtain plant management and soil conservation (CP) factor values.

Geographic Information Systems (GIS) is an efficient tool for calculating erosion in this study, which helps determine the Erosion Hazard Index (EHI). The first step is an analysis of the required data, such as rainfall, soil type, slope, and land cover. The data is then used as a base map using GIS. Then the Universal Soil Loss Equation (USLE) formula is used to calculate the erosion rate. It involves combining several factors, namely rain erosivity, soil erodibility, slope slope, and crop management. The value of each factor is then entered into the USLE formula to obtain the erosion rate calculation results. The advantages of using GIS in calculating erosion are very significant. One of its main advantages is the ability to process complex geospatial data easily. GIS allows the integration of data from various sources, thereby providing a completer and more accurate picture of land conditions. Apart from that, GIS also allows data visualization in the form of maps, which makes analysis and interpretation easier. In this way, the results of erosion calculations can be displayed visually, making it easier to identify areas that are most vulnerable to erosion.

2.1.1. *USLE (Universal Soil Loss Equation)*

The Universal Soil Loss Equation (USLE) method is a tool for calculating and predicting soil erosion. It was developed by Wischmeier and Smith in 1978 and has been used widely in various applications, including land management, conservation planning, and erosion research [19], [20]. The Universal Soil Loss Equation (USLE) is a popular soil erosion prediction model that can measure the modulus of soil erosion in many circumstances and depict the connection between soil erosion and varied impact [21]. As is well known, the product of five driving factors yields the Eq. (1), which represents the simple mathematical structure [20].

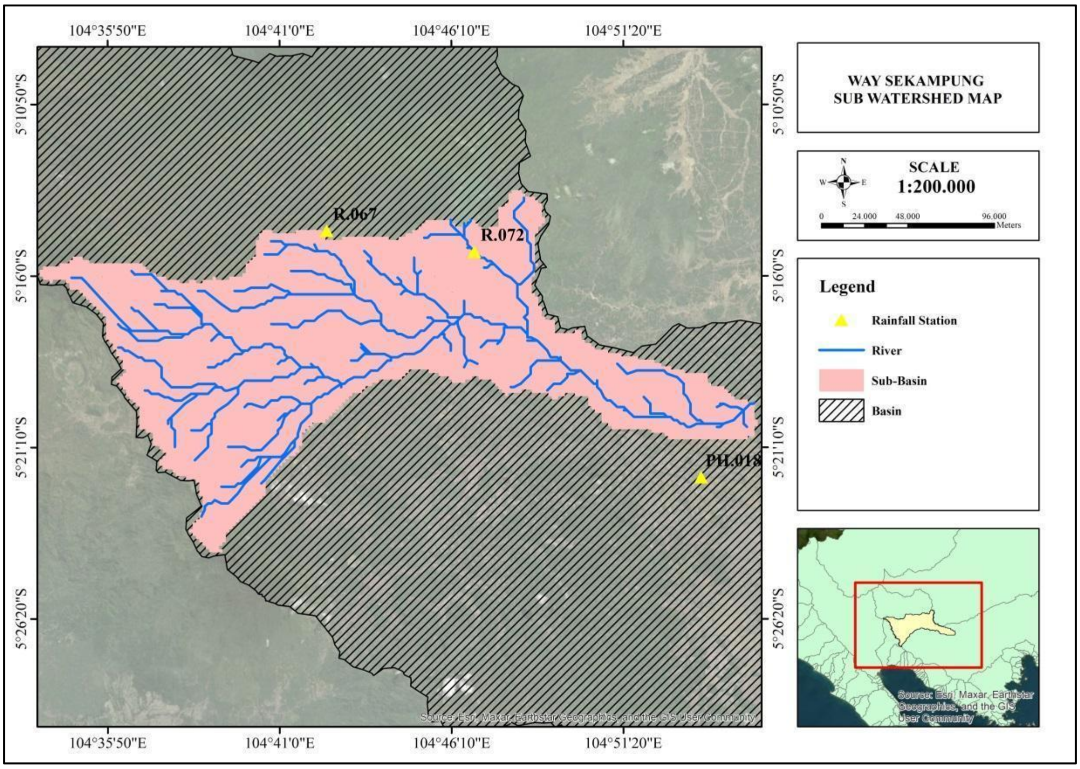

Figure 1. Research location

$$A = R.K.LS.CP \quad (1)$$

Where A is the annual shown tons per hectare of soil loss, the effect of rainfall intensity and amount on erosion is represented by the rainfall erosivity factor, or R. The soil erodibility factor, or K, represents the soil's vulnerability to erosion. The slope length and steepness factor, or LS, illustrates how a slope affects erosion. The cover and management factor, or C, represents the effect of vegetation and management techniques on erosion. The impact of conservation efforts on erosion is represented by the support practice factor or P.

2.1.2. *Rain Erosivity (EI_{30})*

Rainfall erosivity (R) is the force of rain that causes erosion. Rainfall erosivity is influenced by factors such as rainfall intensity, duration, and frequency, as well as the slope and land use of the area [22]. The total of the EI_{30} values for each erosive storm that occurred throughout the month was used to calculate the EI_{30} values [23]. The method for calculating rain erosivity uses the Lenvain formula [5].

$$EI_{30} = 2.21\, x\, (Rain)_m{}^{1.36} \quad (2)$$

Where EI_{30} is monthly rainfall erosivity (kJ/ha), and (Rain) is monthly rainfall (cm).

2.1.3. *Soil Erodibility (K)*

Soil erodibility (K) is a factor in the sensitivity of soil to erosion. Erodibility is also influenced by the presence of vegetation [24]. Sand, silt, and clay make up the particle size in the soil erodibility factor (K) calculation model [25], [26]. Soil erodibility values are obtained based on the Harmonized World Soil Database soil type map. Consequently, there is a stronger correlation between the K-factor and the physical characteristics of soil. Then, calculations were carried out using the Wischmeier & Smith, 1978 equation [27].

$$K = \frac{1.292\,(2{,}1\, M^{1,14}\,(10^{-4})(12-a) + 3.25\,(b-2) + 2{,}5\,(c-3))}{100} \quad (3)$$

Where K is erodibility of soil (Mg h/MJ/mm), M is a product of (100 – clay%) × (very fine sand (0.05–0.1 mm) + %silt), (a) refers to organic matter (%), (b) shows the soil structure class, and (c) shows the permeability class [28].

Based on the classification of soil permeability in cm/h, the following six classes are identified (**Table 1**) [20]. The approach proposed divides soil structure into four classes as follows (**Table 2**) [20].

2.1.4. *Erosion Hazard Index*

The Erosion Hazard Index (EHI) was used in this study to assess soil erosion by providing a quantitative measure of erosion risk. The EHI is defined as a ratio value between potential erosion, as indicated by measured erosion values,

Table 1. Classification of soil permeability

No	Soil Permeability	Code
1.	Very low (<0.125 cm/hour)	1
2.	Low (0.125-0.5 cm/hour)	2
3.	Moderate to low (6.25-12.5 cm/hour)	3
4.	Moderate (2- 6.25 cm/hour)	4
5.	Moderate to high (0.125-0.5 cm/hour)	5
6.	High to very high (>12.5 cm/ hour)	6

Table 2. Classification of soil structure

No	Soil structure class (diameter size)	Code
1.	Very fine crumb and granular structure	1
2.	Fine crumb and granular structure	2
3.	Moderate crumb and granular structure	3
4.	Massive structure	4

and tolerable erosion (T) of land [29]. The erosion hazard index is used to assess the extent of erosion and potential threats to land productivity [30]. The EHI is helpful for various engineering purposes, such as planning erosion control measures and designing strategies for watershed management. It helps identify areas at risk of erosion and provides a framework for evaluating the effectiveness of erosion control measures. By using Erosion Hazard Index (EHI) in this study, land can be classified based on the level of erosion risk. This classification helps in identifying land that is most vulnerable to erosion so that more effective conservation actions can be taken. Table 3 shows the distribution of erosion hazard index levels [29].

2.1.5. *Bench Terrace*

A bench terrace is a type of artificial land formation used to convert mountainous slopes into arable land. It consists of a series of level or virtually level strips running across the slope at vertical intervals, supported by steep banks or risers. Bench terracing is commonly used to reduce soil erosion and facilitate agriculture, particularly in areas with steep slopes and limited soil depth. It is well-suited for slopes between 25-50% with stable soil and can improve crop yields by slowing runoff, increasing infiltration, and allowing different crops on benches. To calculate the vertical distance (VI), use the Hillman formula on erosion-sensitive soil as follows [31].

$$VI = 8(S\%) + 60\ cm \quad (4)$$

Where VI is vertical horizontal and (S%) is percent slope. Then, to calculate the horizontal interval (HI) planning, use the Utomo equation (1994) with the following formula [32].

$$HI = \frac{VI\ x\ 100}{S\%} \quad (5)$$

3. Result and Discussions

3.1. *Hydrological Analysis*

Hydrological analysis is the first stage in calculating rain erosivity. Hydrological analysis is carried out to test whether existing hydrological data has appropriate value for use in advanced hydrological calculations. The hydrological data that will be tested is rainfall data for 2013 – 2022 to determine the value of rain erosivity. The stages of hydrological analysis are consistency analysis (double curved mass), analysis of the absence of trend using the Spearman method, stationary analysis and persistence analysis.

Table 4 shows that the results of consistency analysis, trendlessness analysis, stationary analysis, and persistence analysis on rainfall data for 2013–2022 at the three stations in the Way Sekampung Sub Watershed are reliable and suitable for use for further hydrological analysis to calculate rainfall erosivity as one unity parameter in the USLE method.

3.2. *Calculation of Rain Erosivity (EI_{30})*

Rainfall calculations using the Lenvain equation (1975) produce EI_{30} in the Way Sekampung Sub DAS from the analysis of the three stations. Based on Table 5. EI_{30} is calculated using the Lenvain formula (EI_{30}). The largest annual average is at station R.072, with an average erosivity value of 2140.571 kJ/ha and an influence area of 8263.590 ha. Meanwhile, the largest area of influence is at station R.067 with an area of 17614.647 ha, and the average value of rain erosivity is 1814.599 kJ/ha. Then, at station PH.018, the area of influence is 3341.223 ha with an average erosivity value of 1031.254 kJ/ha.

3.3. *Calculation of Soil Erodibility Factor (K)*

Soil erodibility values are obtained based on the Harmonized World Soil Database soil type map. Using the Wischmeier & Smith (1978) equation, input soil parameters such as organic grain size, % organic, soil structure, and soil permeability [29]. Additionally, the method has been extensively applied to mapping regional soil erosion surveys [33], [34], [35].

An example of calculating the K value using equation 3 for Humic Cambisols soil according to the parameters in the Harmonized World Soil Database (Table 6) is as follow Eq. (6). Then. The same analysis of other soil types will be done to get the soil erodibility (K). The greater the erodibility value. The greater the level of sensitivity of the soil to erosion. The most considerable K value is in the dominant soil type in the Sub Watershed area is Humic cambisols. Humic cambisol soil has a dark red to dark reddish brown soil horizon and a medium to fine soil texture. The erodibility of this soil or K value = 0.28, which is included in medium permeability (Table 7).

3.4. *Slope Length and Slope Factor (LS)*

The LS factor is the most sensitive parameter in USLE soil loss estimation [36]. The length and slope are classified from the DEM map with the help of Geographic Information Systems (GIS) and then given an LS value according to the

Table 3. Erosion hazard index classification

Erosion Hazard Index	Classification
≤ 1.0	Low
1.01 – 4.0	Moderate
4.01 – 10.00	High
≥ 10.01	Very high

$$K = \frac{1.292\ (2.1\ (3002)^{1.14}\ (10^{-4})(12-4) + 3.25\ (3-2) + 2.5\ (c-4))}{100} = 0.28 \quad (6)$$

Table 4. Erosion hazard index classification

HydrologicAnalysis	Rain Station		
	PH.018	R.067	R.072
Consistency Analysis	Consistency	Consistency	Consistency
Absence of Trend Analysis	Accepted/None trend	Accepted/None trend	Accepted/None trend
Stationary Analysis	Acceptable/ Variance homogeneous data	Acceptable/ Variance homogeneous data	Acceptable/ Variance homogeneous data
Persistence Analysis	Accepted/Random	Accepted/Random	Accepted/Random

Table 5. Rain erosivity of the way Sekampung Sub Watershed

No	Rain Station	Erosivity (kJ/ha)
1	PH.018	1031.254
2	R.067	1814.599
3	R.072	2140.571
Total		**4986.42**

Table 6. Harmonized world soil database

Soil Type	M	a (OC%)	b (soil texture)		c (permeability)	
			class	texture	class	cm/hour
Humic Cambisols	3002	4	3	Medium angular	4	6.3 – 12.7
Ferric Acrisols	2336	2	3	Medium angular	4	6.3 – 12.7
Umbric Andosols	4524	7	2	Fine angular	3	2.0 – 6.3

Table 7. K value

No	Soil Type	Area (ha)	K
1	Humic Cambisols	24223.35	0.28
2	Umbric Andosols	2553.19	0.26
3	Ferric Acrisol	2423.38	0.20
Total		**29200**	

Analysis of Land Rehabilitation and Soil Conservation Pattern Preparation Guidelines Table [37]. The slopes in the Way Sekampung Sub Watershed are dominated by a slope level of 15-25% with a relatively steep classification, covering an area of 7533.852 ha, or 25.8% of the total area of the Way Sekampung Sub Watershed (Table 8). Meanwhile, there is also a slope above 45% or very steep with an area of 1198.046 ha. Erosion is affected by changing slope slopes on land with very steep to extremely steep levels in sub-watersheds [38].

3.5. *Crop Management and Soil Conservation Factors (CP)*

The CP value shows the influence of land cover on erosion [39]. Although this effect is characterized in terms of the highest and lowest circumstances of erosion potential, land cover has a substantial impact on soil loss [40]. Because vegetation aids in the retention of soil and water. the C factor describes how surface vegetation cover is restricted concerning soil erosion [41]. If there exists fundamental data for plots, extrapolating from the plot scale is an acceptable way to compute the C-factor; if not, qualitative evaluation is the appropriate approach [42]. The determination of CP is based on land use maps for 2017 and 2022 have been digitized using the GIS application. Based on the results of land use digitization. Table 9 GIS found that the CP value was greatest in settlements and open land with a CP value is 0.95.

It can be seen in Table 9 that the land cover in the Way Sekampung Sub Watershed area is dominated by dry land agriculture with the area of land cover in 2022 being 27.112.19 (92.791% of the total area of the Sub Watershed area). Dryland farming, which dominates in the Sub Watershed area is located on a rather steep slope with a slope of (15-25%) by Table 8. Dryland farming which has a rather steep slope, tends to experience more intensive erosion due to rainwater. It does not settle well and flows down easily. Slightly steep slopes on dry land can cause faster erosion because rainwater can flow down quickly and erode the soil.

3.6. *Erosion Calculation USLE Method*

Calculating erosion rate using the Universal Soil Loss Equation (USLE) method involves several steps, which is overlaying each factor using Geographic Information Systems (GIS) [43]. The raster layers of various elements can be superimposed to get a result raster of average yearly soil loss, potential soil loss, and other factors using the raster calculator in GIS spatial analyst tools [44]. USLE is an empirical model used to estimate the rate of soil erosion, which is obtained in Table 10. The erosion rate in the Way Sekampung Sub Watershed for land use in 2017 and 2022 has increased quite significantly.

Table 10 shows the results of increasing erosion rates from 2017 to 2022. The thickness of eroded soil can be calculated by dividing the average existing erosion rate by the weight of the soil content at the research location; the weight of humic cambisol soil content is 1.48×10^3 kg/m^3, with rate conversion average erosion is mm/year. The results in Table 10 show the existing thickness of erosion in 2022 is 14.1 mm/year; the existing thickness of erosion is still above the maximum limit for erosion thickness in Indonesia, which is 2.5 mm/year. The increase in erosion is caused by changes in land use from year to year, which shows that land conservation has yet to be carried out in the Way Sekampung Sub Watershed. Land conservation can be carried out based on erosion rate values to obtain Erosion Hazard Index mapping. After erosion hazard index mapping, it can be used as a reference for land conservation.

Table 8. LS value of the Way Sekampung Subwatershed

No	Slope	Classification	Area (ha)	LS
1	0 - 8%	Flat	6890.810	0.25
2	8 - 15%	Sloping	7213.755	1.2
3	15 - 25%	Slightly Steep	7533.852	4.25
4	25 - 45%	Steep	6381.747	9.5
5	>45%	Very Steep	1198.046	12
Total			**29200**	

Table 9. CP Land Use Management for the Way Sekampung Sub-Watershed

No	Land Use Management	2017	2022	CP
		Area (ha)		
1	Bush	54.828	22.88	0.3
2	Secondary Dryland Forest	632.24	690.709	0.01
3	Settlement	188.794	525.236	0.95
4	Dryland farming	20.78	20.78	0.28
5	Mixed Dry Land Agriculture	27759.776	27112.19	0.19
6	Ricefield	310.604	310.604	0.01
7	Open Land	24.263	74.406	0.95
8	Waterbody	228.168	461.697	0.05
Total		**29200**	**29200**	

Table 10. The current Erosion Rate of the Way Sekampung SubWatershed

Year	Erosion Rate (tons/ha/year)	Erosion Thickness (mm/year)
2017	29626.262	14.1
2022	76617.579	

3.7. Existing Erosion Hazard Index Mapping

The Erosion Hazard Index compares the erosion that occurs on land and the permitted erosion [30]. This study uses the allowable erosion value (T) to determine the erosion hazard index in land criticality analysis. The allowable erosion in the Sekampung Hulu watershed for erosion estimation is 38.7 tons/ha/year [45]. The estimated soil erosion rate is classified into four soil erosion classes. Then the results of the erosion comparison are classified in **Table 11**. The results of the Erosion Hazard Index distribution based on land use in 2017 and 2022 are dominated by low indexes or critical potential but have increased to the very high class by 0.071% of the land area (**Figure 2**). The use of mixed dryland agricultural land has quite large erosion because the land cover is dominated by plant annuals [46]. The increase in the erosion hazard index classification in the high to very high class indicates the need for land conservation in the Way Sekampung Subwatershed area.

3.8. Combined Land Conservation Efforts (Vegetative and Mechanical)

Ecosystems and biodiversity are significantly impacted by soil erosion [13]. So, conservation efforts need to be combined with new land use directives and additional mechanical conservation to reduce erosion on land. **Table 12** shows changes in land use as a combined conservation effort. Additional mechanical conservation carried out in this study area was the construction of terraces and check dams. Combining these two approaches, namely mechanical and vegetative conservation, can create watershed management strategies that are more effective in maintaining environmental sustainability, improving degraded ecosystems, protecting habitats, and supporting sustainable development [47].

Table 11. Existing erosion hazard index classification

No	Erosion Hazard Index	Land Criticality	2017 Area (ha)	2017 Area (%)	2022 Area (ha)	2022 Area (%)	Difference (%)
1	Low	Potentially Critical	12659.384	43.357	12361.483	42.335	-1.022
2	Moderate	Semi Critical	8631.842	29.563	8937.948	30.610	1.047
3	High	Critical	1167.819	4.000	1139.599	3.903	-0.097
4	Very high	Very Critical	6738.866	23.080	6759.935	23.151	0.071

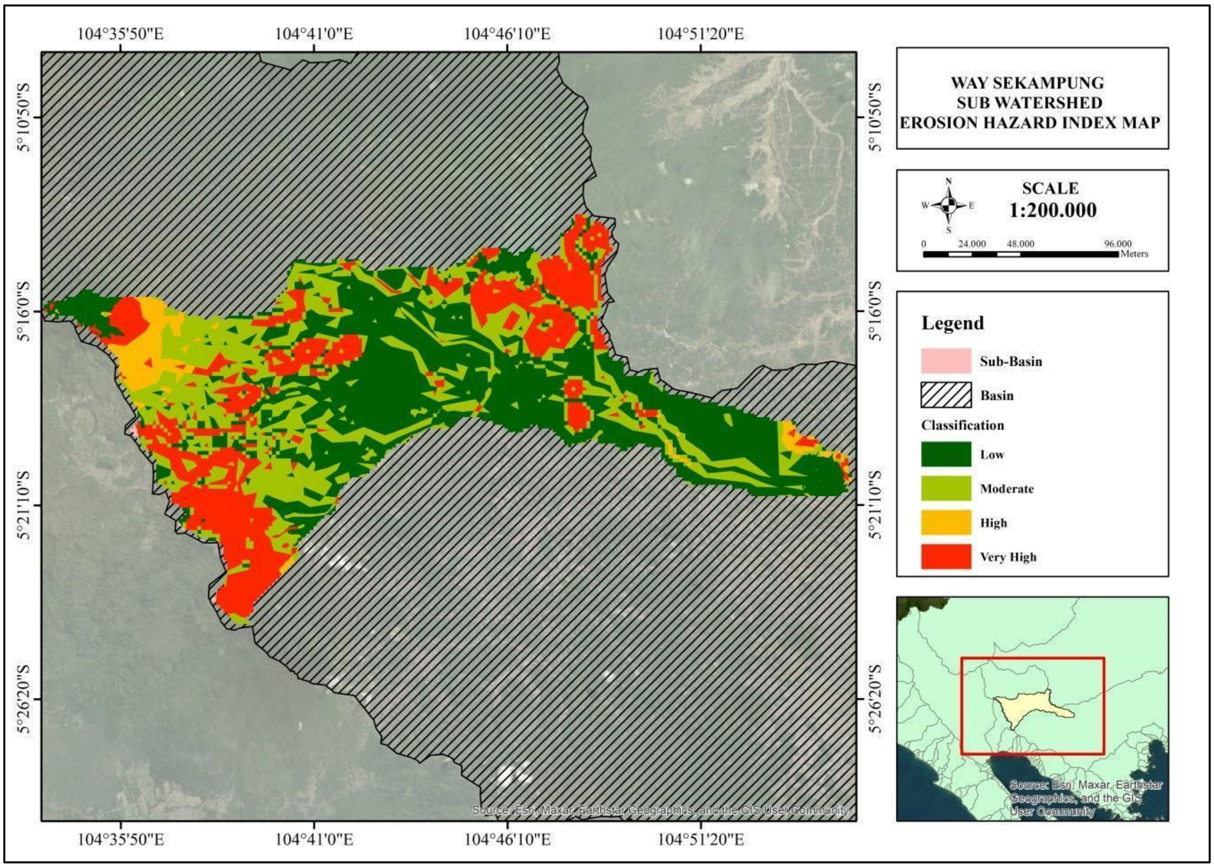

Figure 2. Existing erosion hazard index Way Sekampung Sub Watershed

Table 12. Comparison of conservation Land Use directions in the Way Sekampung Sub Watershed

No	Land Use Management	Existing		Combination Conservation		Difference (%)
		Area (ha)	Area (%)	Area (ha)	Area (%)	
1	Bush	22.88	0.078	0.000	0.000	-0.078
2	Secondary Dryland Forest	690.709	2.364	17608.359	60.305	57.941
3	Settlement	525.236	1.798	525.236	1.799	0.001
4	Dryland farming	20.78	0.071	0.000	0.000	-0.071
5	Mixed Dry Land Agriculture	27112.194	92.791	2731.904	9.356	-83.435
6	Ricefield	310.604	1.063	310.604	1.064	0.001
7	Open Land	74.406	0.255	0.000	0.000	-0.255
8	Waterbody	461.697	1.580	461.697	1.581	0.001
9	Bench Terrace	0.000	0.000	2606.119	8.925	8.925
10	Contour Terrace	0.000	0.000	4936.715	16.907	16.907
11	Ridge Teracce	0.000	0.000	18.330	0.063	0.063
	Total	**29200**	**100**	**29200**	**100**	

3.8.1. *Terrace Planning*

Terrace/terracing is a mechanical soil and water conservation structure created to shorten the slope length and reduce the slope [31]. The following are the steps for determining terracing:

- Erosion Hazard Index Calculation.
- Slope and slope length (LS) analysis
- Determination of the type of terrace or mechanical conservation based on the length and slope of the slope (LS)

By increasing water absorption and reducing the speed of surface runoff, terraces are created to minimize soil loss [31]. Terracing planning is carried out on land with high and very high erosion hazard index criteria. Mechanical conservation takes the form of making terraces, divided into three types of terraces, namely bench terraces, contour terraces, and ridge terraces. The land area of each bench terrace is 8.925% of the land area, the contour terrace is 16.907%, and the ridge terrace is 0.063% of the land area. Based on the results of the following analysis, terracing planning is a mechanical conservation effort in the Way Sekampung Sub Watershed (**Figure 3** to **Figure 5**).

Terrace Bench - The bench terrace is shaped like a bench with terraced rice fields. Bench terraces are made on land with a slope of 25-50%. The following is an example of a horizontal interval calculation (HI) bench terrace at a known vertical interval (VI) and slope (%). Vertical interval (VI) on erosion-sensitive soil according to equation 4 with a slope of 25%, the vertical distance is 1.8 meters. Furthermore, with a slope of 25% and a vertical interval (VI) is 1.8 meters, the horizontal distance based on equation 5 is 7.2 meters.

Contour Terrace - Contour terraces are made on land with a slope of 10-40% to prevent the loss of soil layers. In the field at a slope of 20-40%. Contour terraces are added with reinforcement plants or grass planting. The construction of Contour terraces is based on the following dimensions:

HI	= 10 m
Channel width	= 0.4 m
Channel depth	= 0.2 m
Belt height	= 0.6 m
Contour width	= 0.75 m

Ridge Teracce - The ridge terrace is planned on a slope of 3–10% and with high rainfall. The terraces are planted with terrace-strengthening plants that can withstand sediment. Plants to strengthen the terrace should be kept close together and planted with grass. The ridge score dimension planning is as follows:

HI	= 12 m
Channel width	= 0.4 m
Channel depth	= 0.2 m
Belt height	= 0.6 m
Contour width	= 0.75 m

3.8.2. *Alternative Location of Check Dam*

A check dam is a transverse structure used to control erosion and collect sediment [51]. Location determination check dam uses the Geographic Information System (GIS) and

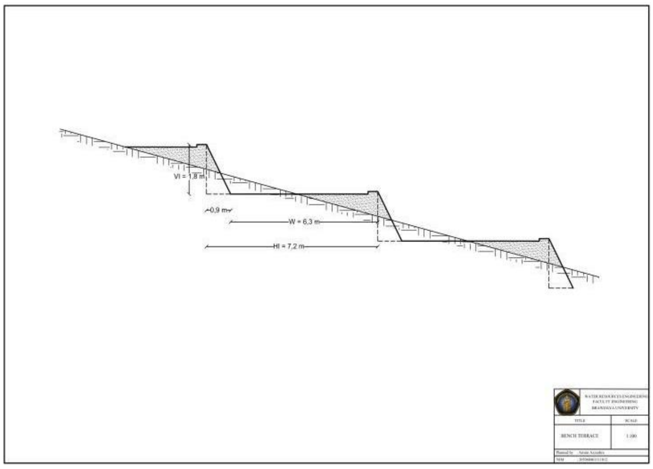

Figure 3. Bench terrace

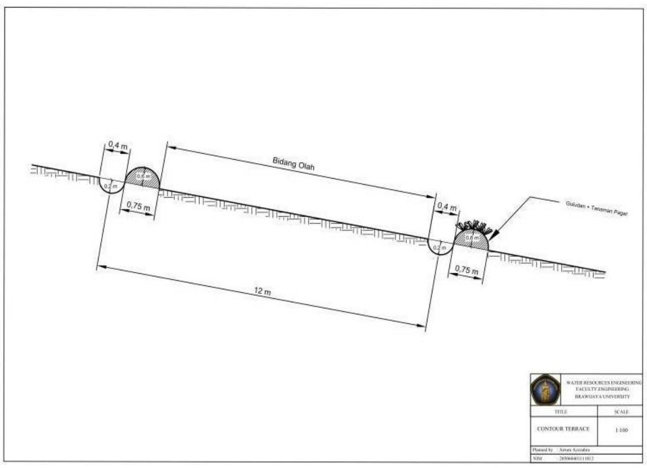

Figure 4. Contour terrace

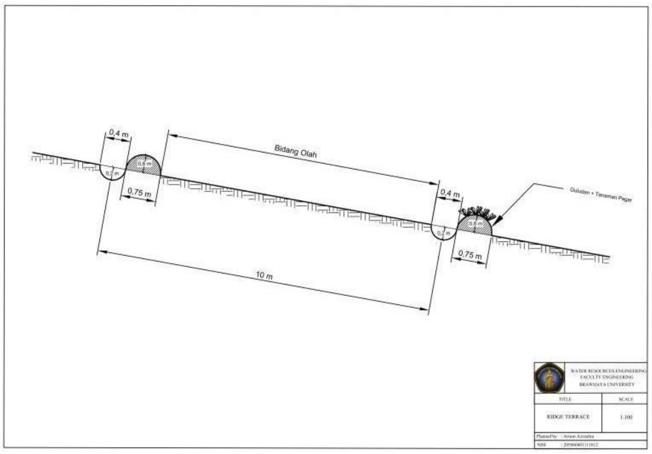

Figure 5. Ridge teracce

is guided by SNI-2851 concerning Sediment Retaining Buildings. This check dam point is an alternative sediment control plan but does not take into account the effectiveness of reducing sediment due to erosion. The alternative placement of check dam points is based on slope, stable soil, and tributaries with small catchment areas. The analysis results in Table 13 this is the planning location point check dam—and 18 alternative point placements check dam in the Way Sekampung Sub Watershed area are presented in Figure 6.

Table 12 explains changes in land use conservation. This land function adjustment is not carried out for land use in the form of rice fields and residential areas because it is private property; this also applies to land cover of water bodies. Land cover in the form of shrubs and empty land was converted into secondary dry land forest; this was done as an alternative use of new land as part of vegetative conservation. Vegetative conservation is carried out by changing empty land cover into forest or land that is productive and functions optimally. This land cover change is also to minimize the value of crop management (CP). Then add terraces to rice fields that have steep slopes. This land use change can be carried out using GIS to determine the land cover map and slope of the existing watershed.

Table 13. Check dam coordinate point

Check Dam	Coordinate		Area	*Check Dam*	Coordinate		Area
	X(S°)	Y(E°)	km²		X(S°)	Y(E°)	km²
1	-5.30877	104.8211	5.019	10	-5.2925	104.645	8.056
2	-5.3009	104.8114	6.296	11	-5.29692	104.6375	9.097
3	-5.27661	104.7555	6.991	12	-5.2973	104.6369	4.852
4	-5.27764	104.7542	7.079	13	-5.3069	104.739	5.578
5	-5.27211	104.7224	7.654	14	-5.32314	104.7149	11.212
6	-5.2727	104.7205	6.676	15	-5.30458	104.6684	7.083
7	-5.27802	104.6906	15.951	16	-5.32287	104.6637	11.131
8	-5.27854	104.6909	6.276	17	-5.32423	104.6501	8.076
9	-5.29197	104.7332	4.649	18	-5.32384	104.6504	10.471

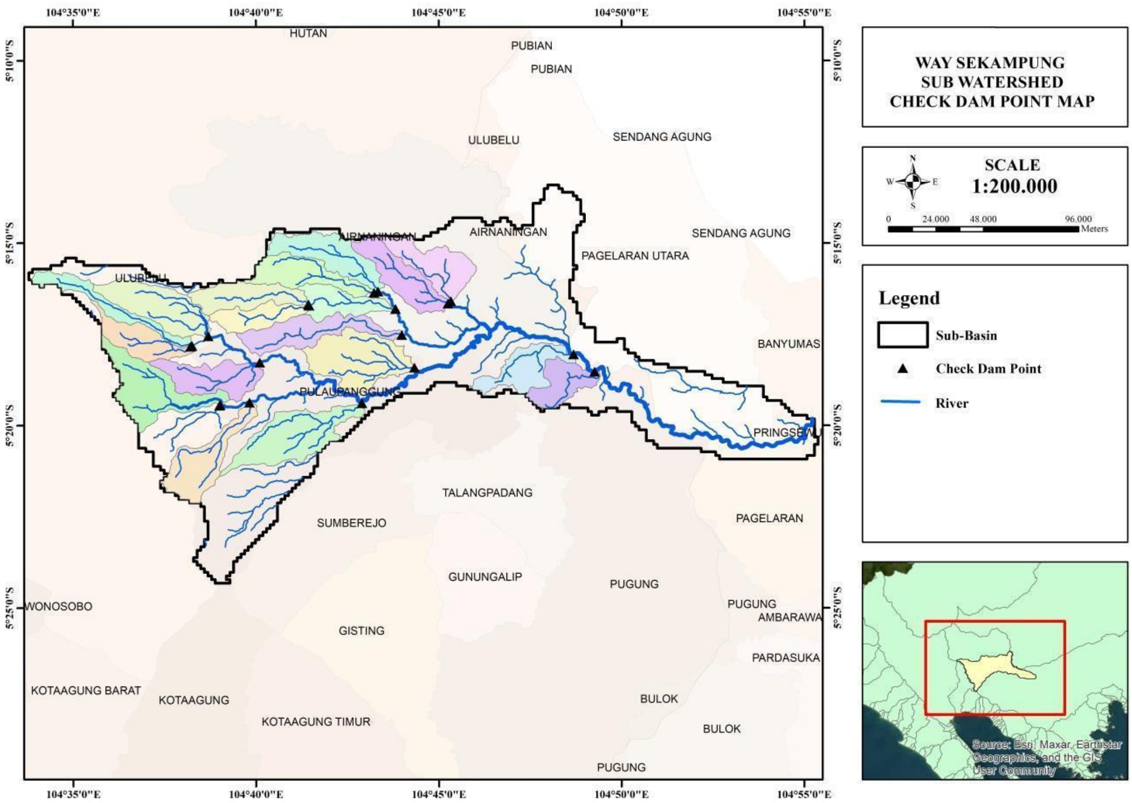

Figure 6. Check dam point

3.9. Erosion Rates Following Land Conservation

Calculating erosion rates on land that has been conserved still uses the Universal Soil Loss Equation (USLE) method. The difference is in the new land cover parameters (CP) in accordance with the recommendations for land use directives. The following are the results of calculating the estimated rate of erosion in the Way Sekampung Sub Watershed after conservation.

Based on the data in Table 14 shows that the calculation of the erosion rate in conservation land use has reduced the erosion rate by 83.354% and the thickness of erosion on conservation land is 2.2 mm/year. Due to conservative changes in land use, specifically land scenarios and terrace construction, the erosion rate decreased from 76617.579 tons/ha/year to 12753.5211 tons/ha/year. Application of these combined conservation techniques involves changes to crop management and soil conservation factor (CP) values. Changes in CP values are carried out through vegetative conservation by considering existing land cover and additional mechanical planning in the form of terracing on steep agricultural land. These changes resulted in a new land use scenario in Table 12. Then the results of the land use scenario map were analyzed using the USLE method with the help of a Geographic Information System (GIS) to determine the erosion rate value and erosion hazard index map in the land use scenario. Land conservation has shown very significant results in reducing the rate of erosion in sub-watersheds. Then, the erosion rate results are mapped to determine the classification of the Erosion Hazard Index (Figure 7).

3.10. Erosion Hazard Index after Land Conservation

The calculation of the conservation erosion hazard index value was carried out to determine the reduction of land conservation directives on the rate of erosion that occurs on existing land. In Table 15. it is found that the rate of erosion on existing land use with conservation means that there is a difference in area (%) in each classification, low index increases by 26.992% from existing land, moderate decreases by -3.111% from the classification on existing land, high decreases by 1.062% from existing land and very high classification reduced by 22.819% from existing land. The mapping of the distribution of the erosion hazard index is presented in Figure 7. Agricultural land makes up the majority of the watershed with moderate to high levels of susceptibility [48].

Table 14. Comparison of existing erosion and conservation

Land Use Management	Erosion Rate (tons/ha/year)	Erossion Thickness (mm/year)	Reduction Rate Erosion (%)
Existing	76617.579	14.1	-
Conservation	12753.521	2.2	83.354

Table 15. Comparison of existing and conservation erosion hazard index

No	Erosion Hazard Index	Land Criticality Level	Existing		Conservation		Difference (%)
			Area (ha)	Area (%)	Area (ha)	Area (%)	
1	Low	Potentially Critical	12361.483	42.335	20242.908	69.327	26.992
2	Moderate	Semi Critical	8937.948	30.610	8029.628	27.500	-3.111
3	High	Critical	1139.599	3.903	829.398	2.841	-1.062
4	Very high	Very Critical	6759.935	23.151	97.031	0.332	-22.819

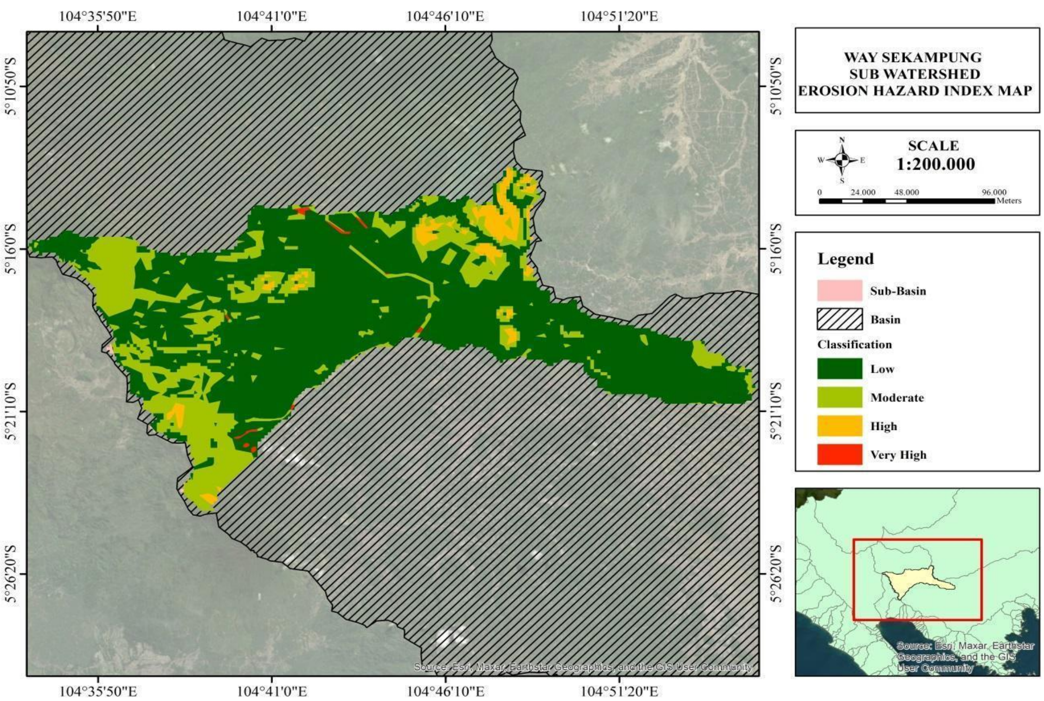

Figure 7. Conservation erosion hazard index

4. Conclusion

The results of estimating the rate of erosion using the Universal Soil Loss (USLE) method in the Way Sekampung Subwatershed based on land use in 2017 were 29626.262 tons/ha/year, and in 2022, it was 76617.579 tons/ha/year with an existing erosion thickness of 14.1 mm/year, which is in accordance with previous research in the Way Sekampung Subwatershed in 2019, when the erosion thickness was 8.26 mm/year. The research results in this study show an increasing trend in erosion thickness in 2022. The Erosion Hazard Index in the Way Sekampung Sub Watershed in 2017 and 2022 were classified as low at 12659.384 ha (43.357% of the area subwatershed); moderate amounting to 8631.842 ha (29.563% of the subwatershed area); high at 1167.819 ha (4.00% of the subwatershed area); and very high at 6738.866 ha (23.080% of the subwatershed area). Meanwhile, in 2022, it will be low at 12361.483 ha or 42.335% of the subwatershed, and moderate, amounting to 8937.948 ha (30.610% of the subwatershed area); high at 1139.599 ha (3.903% of the subwatershed area); and very high at 6759.935 ha (23.151% of the subwatershed area).

Conservation is carried out in the Way Sekampung Sub Watershed using two conservation methods, namely vegetative and mechanical methods; a vegetative method is based on Land Rehabilitation and Conservation Directives with recommended land use scenarios. Meanwhile, the mechanical process is by making check dams and terraces. Terrace and check dam planning is carried out based on the results of the Erosion Hazard Index in critical watershed conditions and by the length and slope of the land. The terraces suitable for the study location are bench terraces, contour terraces, and ridge terraces.

Analysis of the erosion rate after conservation efforts was found to be 12753.521 tons/ha/year, with the estimated average erosion rate being 33.129 tons/ha/year, or 2.2 mm/year. The results of the erosion hazard index analysis after vegetative and mechanical conservation were carried out were the lowest at a very high level of 97.031 ha, or 0.332% of the subwatershed area, and the highest value was in the low classification is 20242.908 ha or 69.327% of the subwatershed area. So with conservation, it can effectively reduce the rate of erosion and the distribution of the erosion hazard index in the Way Sekampung Sub Watershed.

Author Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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