Erosion Prediction with Sediment Delivery Ratio Apprroach of Sekampung Watershed (Study in Watershed of Sekampung – Argoguruh Dam)

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Abstract

Erosion is one of the problem in the Sekampung Watershed. Increased rate of erosion would increase amount of sediment that entering the river. The Sekampung Watershed Sekampung is quite important in Lampung Province, because it is used as a source of agricultural irrigation, hydropower (Hydroelectric Power Plant) and will be planned as water supply to PDAM (Regional Drinking Water Company), therefore the amount of sediment carried by the river flow needs to be researched. This reasearch aimed to estimate the erosion in Sekampung Watershed. This research used two methods to estimatethe erosion there are SDR (Sediment Delivery Ratio) methode and USLE (Universal Soil Loss Equation) method, and that were calculated with the help of GIS (Geographic Information System). The amount of erosion using SDR method to 58.49 tons/ha/yr.Meanwhile estimation of erosion by USLE method were 112.86 tons/ha/yr.

Keywords*: Erosion, SDR, Watershed of Sekampung.*

1. Introduction

Watershed is a unit area of land which is a unity with the river and sub rivers that serves collecting, storing, and flowing the water from rainfall to the lake or into the sea naturally, the border on land is a topographical separator and border in the sea is until water area that still affected by land activities (Law No. 37 of 2014). Sekampung Watershed has the second largest area in Lampung Province. This condition make Watershed Sekampung becomes the foundation of today's society. The utilization of Sekampung Watershed such as a source of agricultural irrigation, hydropower (Hydroelectric Power Plant) and will be planned as a source of raw water by PDAM (Regional Water Company) Rilau Way. The Utilization of Sekampung River (the main river in Sekampung Watershed) as a source of water supply to PDAM Way Rilau by taking the water around 2,500 liters per second. It is to serve around 42000-44000 households customers. The amount is equivalent to 220,000 inhabitants. The statementwas described by Mayor of Bandar Lampung (Sihaloho, 2015).

Condition of Sekampung Watershed that is beneficial to the community nowadays is even more alarming.The water flow of Sekampung River noawadays becoming muddier, it signifies the high erosion in the upstream watershed. In line with the results of Banuwa et al. (2008) that Sekampung upstream Watershed area of 42.400 ha is now very urgent to deal with, because the land use in most of the upstream areas had had been changed into agricultural land.

This condition causes the decreasing of water quality of Sekampung River, whereas it will be planned as a source of raw water and other purposes, so it needs to take watershed management efforts. The result of erosion prediction in a Watershed can be used as the basis for watershed management, particularly in term of land use (Asdak, 2007).

Sediment load calculation based on total suspended solid is one way to predict the amount of erosion in a watershed with sediment load. The statement described by Asdak (2007) if the sediment load calculation can be used as a erosion prediction materialwith SDR (Sediment Delivery Ratio) method. Another common method used to estimate the amount of erosion is USLE (Universal Soil Loss Equation) method.

This research aiSY to gain erosion prediction values by using SDR method and comparing those values to the prediction of erosion using USLE method. The resulting value is then compared with the values of erosion prediction using TSL method that had been obtained through the calculation. Simulation of land improvements carried out based on Act of Forestry No. 41/1999 article 18 paragraph 2, where erosion obtained exceeds theTSL value.

2. Research Methodology

Sediment sampling is the first step of erosion prediction using SDR method. Before the sediment samples were taken, the depth of the river should be determined in advance, using a pole and meter tape. Installation of water tool sampling was conducted at three depths of the river, with the position at the base of the pole, in the central part and the surface of the water. Then plunged the pole that already attached with water taker tools into the river and then pull the lever that was connected with the water taker tool. It aimed to get water samples from three different depths. The water samples were obtained then mixed and taken about one liter.

Sediment sampling was conducted fifteen times in the wet months (April 2015) and fifteen times the dry season (in September 2015). Sampling was conducted at the Argoguruh Dam outlet.Tthe purpose of fifteen times repetitions in sampling was to obtaini a variety of data that can represent the state of the river in that month. Samples that had been obtained, then was dried using a heater (cooker) then dried again until the dry weight of the air using an oven with a temperature of 110°C for 2 x 24 hours.

The sediment samples that had been dried and weighed in graSY, would be the Cs (sediment concentration) value. The value would be calculated with the value of river flow, the result of the calculation would be Qs (discharge of sediment transport) value. River flow that was used come from three discharge datas (average daily river flow in last 10 years, the average daily river flow in wet months and dry months and daily river flow atthe time of sampling). Value of sediment load (SY) is obtained by entering Qs value in the SY value equation that described by Permenhut No. 61 in 2014. The SDR value isobtained using equation bouce (1975, in Alimuddin 2012).

$$SDR = 0{,}41 \times A^{(-0{,}31)} \quad (1)$$

note :

A = Watershed Area (ha)

SDR = Sediment Delivery Ratio (Bouce, 1975 in Alimuddin, 2012).

Value sediment Yield (SY) which has been obtained is then calculated using the value of the SDR. SY and the SDR value calculation would result in erosion. The calculation of the value erosion by Regulation Ministry of Forestry Regulation no. 61 in 2014.

A = SY : SDR
(2)

note :

SY = Sediment Yield (ton/ha/yr)
A = erosion (ton/ha/th)
SDR = Sediment Delivery Ratio

Prediction of further erosion using USLE (Universal Soil Loss Equation). Estimation of erosion by USLE method is based on the equation Wischmeier and Smith (1978, in Banuwa 2013). USLE method has several factors that need to be calculated andin the first set.

A = R x K x L x S x C x P
(3)

note:

A : Erosion loss per unit Area
R : The Rainfall and runoff factor
K : The Soil Erodibility Factor
L : The Slope-length Factor
S : The Sope-steepnes Factor
C : The Cover Manajement Factor
P : The Erosion-control practice Factor (Wischmeier dan Smith, 1978 in Banuwa, 2013).

Rain erosivity factor (R) obtained by collecting rainfall data over the last 5 years at four sites scattered rain posts at the research site. Rainfall respectively calculated using Lenvain DHV equation (1989, in Asdak 2007). The results of calculation of the monthly erosivity value, then summed in a single year and the data is averaged with the last 5 years, we will get the value of the average annual R. Rain territorial division performed with the help of GIS using Thessen Polygon menu.

Soil erodibility value factor (K) can be determined by overlaying a map of soil types into Sekampung Watershed maps. K value is obtained by comparing the type of soil based on the value of K, defined by Yuwono (2011).

The length and steepness of the slope factor (LS) can be determined by overlaying maps of slope into Sekampung Watershed maps. Values obtained by entering a value LS slope and slope length between 1 to 20 meters, then calculated based on the value equation, described by Arsyad LS (2006).

Vegetation cover factor, and the use of conservation techniques (CP) .Can be determined by overlaying a map of the land use map into Sekampung Watershed. Cp values obtained by comparing the value of land use into forecasts CP factors on various types of land use based Abdurachman et al (1984, in Asdak 2007).

The calculation of TSL (Tolerable Soil Loss) value or erosion that can be tolerated by the Wood and Dent equation (1983), described in Banuwa (2013). The depth equivalent value (DE) in the calculation of TSL, obtained by drilling the ground at 9 locations to get the value of the effective depth of the soil and the depth factor value is determined by Hammer (1981, described in Arsyad 2006). Minimum soil depth value (dmin) is obtained by analyzing the use of land with dmin value of each type of plant and the age of land use (UGT) and the rate of soil formation (LPT) is determined by Wood and Dent (1983, described in Banuwa 2013).

Analysis of the results of erosion prediction with IE (Erosion Index) is based on Regulation No. 61 2014. Simulation of Sekampung Watershed management using GIS (C factor improvements as much as 30%) based on Act Forestry No. 41/1999 Article 18, paragraph 2.

3. Results and Discussion

3.1 Ressults

From the sediment samplin was obtained sediment concentration values Cs contained in one liter of water samples. The water samples were taken at three different depths for two months (April 2015 and September 2015). Cs value in wet month showed greater value than the value of Cs in the dry months. Comparison Cs value was 1: 8. Cs value can be seen in Table 1.

Table 1. Data sediment concentration (Cs) in the Rainy season (April) and a dry Season (September)

Location: Sekampung, Outlet Dam Argoguruh Tigeneneng				
	Rainy season		Dry Season	
o	Date	Cs (mg/liter)	Date	Cs (mg/liter)
	02-Apr-15	763.40	11-Sep-15	63.70
	04-Apr-15	3653.90	12-Sep-15	18.00
	06-Apr-15	957.60	14-Sep-15	94.40
	08-Apr-15	3078.80	15-Sep-15	25.10
	10-Apr-15	4148.30	16-Sep-15	17.00
	12-Apr-15	679.70	17-Sep-15	151.80
	14-Apr-15	207.50	18-Sep-15	22.50
	16-	214	19-	2

	Apr-15	3.30	Sep-15	0.80
	18-	263	20-	6.
	Apr-15	2.40	Sep-15	40
	20-	293	21-	2
0	Apr-15	.50	Sep-15	2.00
	22-	103	22-	1
1	Apr-15	1.50	Sep-15	2.90
	24-	819	24-	2
2	Apr-15	.70	Sep-15	0.50
	26-	798	26-	3
3	Apr-15	.50	Sep-15	85.30
	28-	252	28-	5
4	Apr-15	.20	Sep-15	17.20
	30-	719	30-	4
5	Apr-15	.70	Sep-15	16.50

The calculation of the value erosion using SDR (Sediment Delivery Ratio) are listed in Table 2. The value of the three calculations erosion sediment load (SY) different (Based on the value of discharge). The average value erosion by using the value of SY with an average daily river flow in wet months and dry months had a value nearly equal to the erosion value with SY using river flow at the time of sampling. Erosion value obtainedusing SY with the average river flow over the last ten years had smaller value of the two calculations thereafter. The value indicates if the average daily river flow over the last ten years less than the value of river flow at the time of sampling and the average river flow in wet and dry months.

Table 2. Value Estimation of erosion by the SDR method (Sediment Delivery Ratio)

o	Description	Erosion Value (SDR) (ton/ha/yr)		
		Rainy Season	**Dry Season**	**average**
	value erosion prediction methods SDR to discharge the daily average during the past 10 years	85.38	6.91	46.14
	The value of SDR methods erosion prediction with an average daily discharge (wet months and dry months) over the last 10 years.	126.59	3.57	65.08
	estimation value erosion SDR method with daily discharge at the sampling time	124.84	3.64	64.24
	Average	**112.27**	**4.71**	**58.49**

The total area of research	**214,092.20 ha.**
SDR Number	**0.04**

Rain erosivity factor (R) was obtained by using annual rainfall data expressed in centineters (Cm). R value data was obtained using average rainfall over the last five years on a four-point observation posts scattered rain in the research area. R shows the amount of rain the ability to be eroded soil, erosivity value in this study can be seen in Table 3.

Table 3. Erosivity rain value (R) and rainfall (CH) annual (2011-2015)

o	Location	The annual rainfall (average 5 years) (cm)	annual R (average 5 Years)	Percentage (%) area of research
	South Lampung	111,14	684,338	11,02
	Pesawaran	133,064	835,546	23,03
	Pringsewu (Pagelaran)	164,576	1047,458	21,44
	Tanggamus (Batutegi)	211,482	1472,594	44,51

Soil erodibility at research sites in the Sekampung Watershed has two values. The soil erodibility value was obtained from two types of soil. The most dominating soil type is the type of research sites Inceptisol with presenttase 95%. Erodibility value and soil types can be seen in Table 4.

Table 4. Values soil erodibility (K) on erosion prediction location

No	Soil Type	Number of K	Area (Ha)	Presentage (%)
1	Inceptisol	0.29	10,379.86 ha	5
2	Latosol	0.23	203,712.33 ha	95
The total area			214,092.20 ha	100

LS factors obtained an average value obtained on the slope (%) by entering a value of slope length (L) of 1 meter to 20 meters. LS factor value on each slope can be seen in

Table 18.

Table 5. LS factor value

o	S (%) (L= 1m-20m)	average value LS	Precentage (%) area
	3-8 %	0.32	23
	8-15 %	0.96	61
	15-25 %	2.30	6
	25-45 %	6.29	0
	45%	9.56	10

CP factor is a combination of vegetation cover factor (C) and factors of soil conservation techniques and water (P). CP factor in estimating the value erosion by USLE method is the only factor that can be changed by man. The use of land and the forecast value of the CP can be seen in Table 6.

Table 6. Land use and value of CP on erosion prediction location

o	Land Use	CP Value	Area (ha)	Precentage (%)
	Dry Land Scondary Forest	0.05	9,558.33	4.46
	Bushes	0.10	13,213.05	6.17
	Water	0.00	1,219.10	0.57
	Plantation	0.07	9,473.68	4.43
	Setllement	0.20	15,311.19	7.15
	Minning	0.20	60.70	0.03
	Dry Land Agriculture	0.43	30,398.87	14.20
	Unirrigated Agricultural Field	0.19	131,911.48	61.61
	Savannah	0.02	566.14	0.26
0	Rice Field	0.02	2,379.67	1.11

Total Area		214	100.00

,092.20

Erosion prediction value using USLE showed a greater value than the comparative value erosion by using SDR, but both the erosion prediction showed a greater value than the value of TSL. These conditions indicated if most of the land among the sites have erosion value greater than the TSL value. Comparison of the value erosion of the value of TSL can be seen in Table 7.

Table 7. Comparison of the calculation results of erosion using USLE approach SDR and methods, as well as the calculation of the value of TSL

o	Description	Value
	Average erosion using SDR method	58.49 Ton/ha/yr
	Average erosion using USLE (984 land units)	11.86 Ton/ha/yr
	Average TSL	31.26 Ton/ha/yr
	Average TSL: Average erosion using SDR method	1 : 1.86
	Average TSL: Average erosion using USLE method	1 : 3.6
	Average value erosion using USLE method: The average value erosion using SDR method	1,93 : 1

Simulation that conducted for CP factor under Law No. 41, 1999, is applied only to some land use that is allowed tobe converted into forest land use. Simulation of land use changes can be seen in Table 8.

Table 8. Comparison number of CP and CP simulation

o	Land Use	P Value	Si mulation of CP value	Area (ha)	Pr ecentage %
	Dry Land Scondary Forest	.05	0. 01	9,558.33	4. 49
	Bushes	.10	0. 10	13,213.05	6. 21
	Plantation	.07	0. 07	9,473.68	4. 45
	Setllement	.20	0. 20	15,311.19	7. 19
	Minning	.20	0. 20	60.70	0. 03

Dry Land Agriculture	.43	0.05	30,398.87	14.28
Unirrigated Agricultural Field	.19	0.05	131,911.14	61.97
Savannah	.02	0.02	566.14	0.27
Rice Field	.02	0.02	2,379.67	1.12
Total Area			212,873.10	100.00

IE value after land improvement simulations showed a very significant influence, a very high IE grade can be lowered. comparison value of the actual IE and simulation IE is shown in Table 9.

Table 9. Comparison Value of erosion index Classification (IE) and after simulating the actual state land improvement

o	Before Simulation (actual condition)			After Simulation (simulation of land use)		
	Erosion Index (EI)	Area (ha)	Precentage (%)	Erosion Index (EI)	Area (ha)	Precentage (%)
	Very Low	36,292.97	17.05	Very Low	93,941.00	44.13
	Low	21,827.17	10.25	Low	84,594.70	39.74
	Moderate	45,056.94	21.17	Moderate	9,825.50	4.62
	High	2,590.44	1.22	High	2,614.75	1.23
	Very High	107,105.30	50.31	Very High	21,896.85	10.29
	Total	212,872.80	100.00	Total	212,873,1	100.00

3.2 Discussion

Water sampling in Sekampung River aimed to obtain sediment samples. Sediment is part of the land which is transported by water from a place that suffered erosion in watersheds (DAS) and flow into a body of water (Arsyad, 2006). The statement indicates if the sediment samples can be used to calculate erosion, as described by Asdak (2007), the sediment load calculation can be used as a material erosion estimation method SDR (Sediment Delivery Ratio).

3.2.1 Calculation of sediment and erosion value prediction using SDR (Sediment Delivery Ratio) method.

The value of SDR in Sekampung River in this research was 0.04, it is smaller than the measured value of SDR in Mamasa River. Alimuddin (2012), states that the measurement of SDR value in Mamasa River is classified into four regions or Chek dam, the SDR value of Chek Dam 1 is around 0,029 with 6,121.20 ha area, Chek Dam 2 is about

0.02 with 21,163.17 ha areas, Chek Dam 4 is around 0,019 with 47,586.01 ha areas, and Chek dam 3 is 0, with 26,897.95 ha areas. The great SDR value indicates if a sizeable erosion in river flows a short distance (Woznicki and Nejadhashemi, 2013).

Values of sediment concentration ratio taken in the dry and wet months was 1: 8. This value is very influential on the erosion value obtained by SDR method in the calculation using the in three different rainfall datas.The average erosion value in the wet months is 112.27 ton/ha/yr, and the average erosion value in dry months was 4.70 ton/ha/yr. These values showed the ability of land and vegetation cover are not optimal to store water during the rainy season and flow it slowly, so it will not become run off that causes soil erosion. The effect of vegetation on runoff and erosion is mainly determined by the ability of vegetation to cover the soil surface (Banuwa, 2013).

Average value of erosion using SDR method from the three calculations of rainfall and sedimentsediment load was obtained amounted to 58.49 tonnes / ha / yr. This value is still lower when compared to previous research conducted in Sekampung Hulu Sub-Watershed. The average value of erosion occurred in the Sekampung Hulu Sub-Watershed is 67.50 tons / ha / year (Nippon Koei, 2003 in Banuwa, et al., 2008).

3.2.2 Prediction of erosion value using USLE (Universal Soil Loss Equation), TSL value and the comparison.

Prediction of erosion using USLE method is an estimation of erosion that is most commonly conducted to estimate erosion. USLE an erosion estimation method using the factors that lead to erosion.

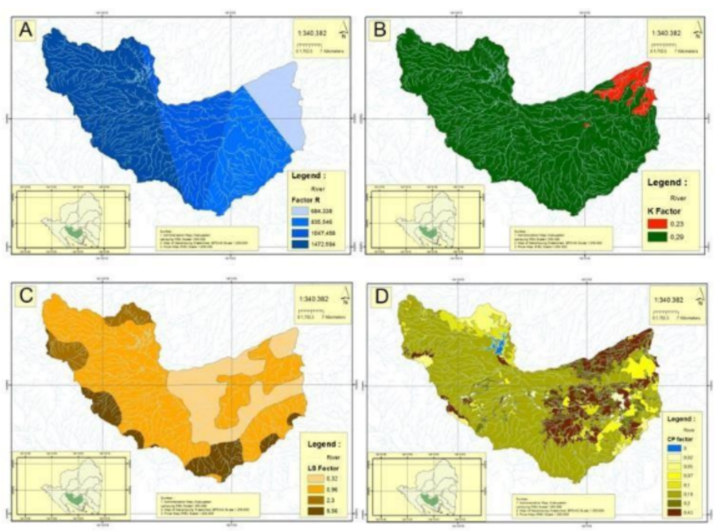

Figure 1. (A) The value of R factor in Regional Research, (B) The value of the K factor in Research Area, (C) Values in the LS factor Research Area, (D) Values CP factor in Research Area.

The erosion factor in USLE method, such as: rainfall erosivity, soil erodibility, land length and angle and vegetation cover, and the use of soil and water conservation techniques. The division of USLE factor at the research sites can be seen in Figure 1.

Body of water use has an area of 1,219.39 ha, the estimation of erosion using USLE method is not included in the count. Body of water is not counted because of the erosion does not occur in the water. The overall area of erosion prediction using USLE method decreased from totalfrom the total area of research. The total area USLE estimation method of 212,872.80 ha of total area of 214,092.20 ha area of research.

Estimation factors of erosion using USLE method had been obtained and calculated. The average erosion value obtained at 112.83 tons/year. The erosion value is the average erosion value that was obtained from 984 land units.

From the calculation of the TSL value, this research obtained eight types of TSL value, which ranged from 18.13 tons/ha/yr up to 45.56 tons/ha/yr. The average TSL value was amounted to 31.26 tons/ha/yr. TSL value that had been obtained is still smallercompared to TSL value contained in Tapung Kanan Sub-Watershed, Riau Islands Province, that described by Sutrisna (2014), the obtained data of TSL value in Tapung Kanan Sub-Watershed ranged from 14.40 tons / ha / yr up to 30.00 tons/ha/yr.

Comparison of the erosion prediction results using SDR and USLE showed a very different value, which amounted to 1: 1.93. This value indicates if the erosion prediction of each method are very different. Despite the differences shown in the results of erosion prediction value using USLE and SDR, but both the erosion prediction method showed higher value than the value of TSL. The statement indicates if the average erosion that occurred at research location above the TSL. The difference between the two methods shows there are some weaknesses in each method. To estimate the amount of sediment result by calculating the SDR amount of a catchment area will obtain less accurate result, remenbering that the total erosion that was determined by USLE does not count moat erosion and sediment in the cavities of soil surface between the source area of erosion and waterways that the result of sediment are assessed (Asdak, 2007). Weakness of erosion prediction using USLE method described by Wischmeier (1976, in Banuwa 2013) that one of the weaknesses of the erosion using USLE method is the wide-scale average value ofthe parameters in areas as diverse drainage will reduce the accuracy of the calculation. Thedetermining of CP factor in USLE method is very difficult to obtain, so it needs toconducta depth investigation (Pradhan et al., 2012).

3.2.3 Simulation of land improvement under Forestry Act No. 41/1999 Article 18, paragraph 2.

One of CP factor improvements that can be conducted one based on Forestry Act No. 41/1999 article 18. The law describes the minimum area of forest land of at least 30% of the watershed area. The forest area that was found in the study site is only about 4.46% from 9,558.33 ha of Waterhed area.

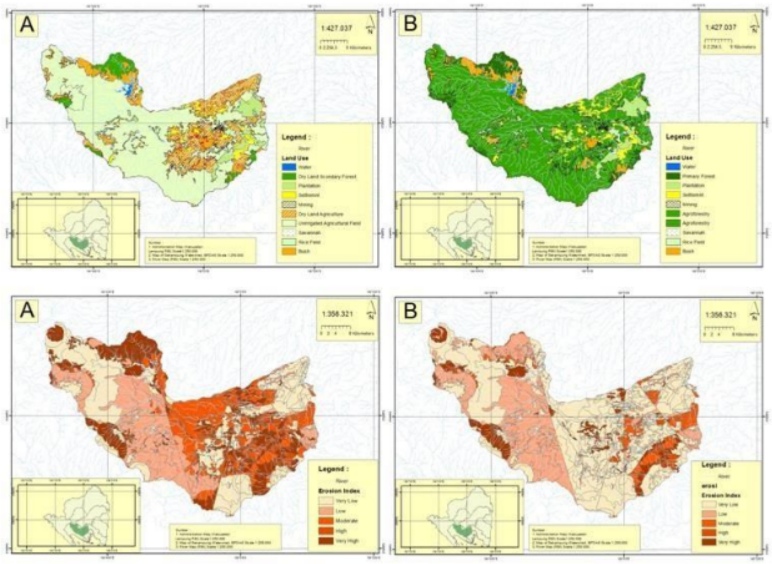

Figure 2. Top (A) Closure of vegetation prior to simulation, (B) Vegetation cover after the simulation, Down (A) Erosion Index before the simulation, (B) Erosion Index after the simulation.

Land improvements can be applied to the land that can be converted into agroforestry. Agricultural land that converted to forest (agroforestry) has an area of 75.81%. The total value of forest land by land improvement simulation of 80.28% of the area of research. Simulation of land improvement can be seen in Figure 2.

The average of the obtained fromn land improvement simulation were 32.02 ton/ha/th or decearse about 71.60% of the actual erosion before the simulation. A similar study conducted by Pradana (2015), The decrease of erosion in Dieng Pleteau by changing agricultural patterns into agroforestry decreased the erosion of 463.86 tonth be 115.96 tons/ha/yr.

The obtained Erosion index (IE) after land improvement simulation was much lower (IE value in Table 4). IE on the actual value is dominated by very high IE with a percentage of 50.30% and high IE by 1.21%, after the land improvement simulation was conducted, The obtained IE values for high and very high grade were 11.50% of the area of research.

4. Conclusions and Recommendations

4.1 Conclusions

The average value of erosion prediction using SDR (Sediment Delivery Ratio) at the study site in the Sekampung Watershed was 58.49 ton/ha/yr. Comparison of erosion value using SDR (Sediment Delivery Ratio)method with USLE (Universal Soil Loss Equation) method is 1: 1.93, USLE method has an average value of 112.86 tons/ha/yr, with TSL value of 31.26 tons/ha/yr. Simulation using USLE method is conducted by changing the land use of forest area from 4.46% to 80.28%, it can minimize the extent of Very High IE and minimize the erosion up to 71.60%.

4.2 Recommendation

Suggestion for this research is the need for further research related to erosion by various methods combined with ground checks, land improvement and perform simulations, and applying the results of the research.

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