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Effectiveness Analysis of Sediment Control Building in the Alopohu River Flow

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***Abstract*— *Limboto Lake is the largest lake in Gorontalo Province. Administratively, this lake is located in Gorontalo Regency and Gorontalo City, is in the lowlands of ± 5 m above sea level and its position is on the outskirts of Gorontalo City. Watershed) Limboto with an area of 875.89 Km^2 and physiographically the landscape of the catchment area has various slopes. Lake Limboto, is a low basin or lagoon, which is the mouth of rivers, including: Ritenga, Alo Pohu, Marisa, Meluopo, Biyonga. Lake Limboto has a strategic role, namely; (i) ecological aspects as a natural reservoir for river water runoff that enters from its catchment area or flood control, (ii) provides important economic resources for fisheries (cultivation and capture). (iii) development of natural tourism, (iv) potential sources of clean water, (v) containing biodiversity for natural laboratories, and (vi) for agriculture. The silting of the lake has resulted in a narrowing of the lake area and has an impact on the decrease in the normal water level of the lake in the dry season and an increase in the normal water level in the rainy season. The decrease in capacity has resulted in flooding in almost every rainy season in the areas around the lake. Areas that are always flooded during the rainy season are around the lakes in the lower reaches of the Biyonga and Tapodu rivers, as well as areas along the Alopohu river. Among the main rivers and other rivers, the Alopohu River has the widest catchment area, namely the Alo Sub-watershed (76.00 Km^2), Molamahu Sub-watershed (131.22 Km^2), Pulubala Sub-watershed (105.78 km^2) and Batulayar Sub-watershed (153.09 Km^2), The total area is 466.10 Km^2 with rivers and their tributaries including the Alo River in the Alo Sub-watershed, the Molalahu River in the Molamahu Sub-watershed, the Pulubala River in the Pulubala Sub-watershed and the Pohu River in the Batu Layar Sub-watershed..*

***Keywords*— *Erosion, Sedimentation, Effectiveness of sediment control structures.*

I. Introduction

Limboto Lake is the largest lake in Gorontalo Province. Administratively, this lake is located in Gorontalo Regency and Gorontalo City, located in the lowlands of ± 5 m above sea level and its position is on the outskirts of Gorontalo City. (DAS) Limboto with an area of 875.89 Km^2 and physiographically the landscape of the catchment area has various slopes. Very steep 6.71%, steep 42.80%, slightly steep 3.03%, sloping 4.24% and flat 43.22 %. Lake Limboto is located in two areas, namely + 30% of the Gorontalo City area and + 70% in the Gorontalo Regency area which spans 7 sub-districts. Geographically, Lake Limboto is located in the central part of Gorontalo Province and astronomically, Lake Limboto is located at 122° 57' 40" – 123° 02' 14" East Longitude and 00° 31' 58" – 00° 34' 50" North Latitude

Changes in land cover and land use change in the Limboto Watershed (DAS) have an impact on the expansion of critical land which increases the risk of erosion (erosion risk) and erosion hazard (erosion hazard) and causes a larger volume of sediment transport loads in the area. rivers and tributaries that empties into Lake Limboto which ultimately resulted in Lake Limboto being in a critical condition due to siltation and shrinkage of the area. The rate of silting of the lake due to erosion from the rivers that flow into the lake is very large.

The silting of the lake has resulted in a narrowing of the lake area and has an impact on the decrease in the normal water level of the lake in the dry season and an increase in the normal water level in the rainy season. The decrease in capacity has resulted in flooding in almost every rainy season in the areas around the lake. Areas that are always inundated during the rainy season are around the lakes in the lower reaches of the Biyonga and Tapodu rivers, as well as areas along the Alopohu river.

II. Review of Literature

A. Universal Soil Loss Equation (USLE) Method

The Universal Soil Loss Equation (USLE) method developed by Wischmeir and Smith (1978) is the most commonly used method for estimating the magnitude of erosion. USLE allows prediction of the average erosion rate of a particular land on a slope with a certain rainfall pattern for each type of soil and land management applications. USLE is designed to predict long-term erosion from sheet erosion and channel erosion under certain conditions. The equation can also predict erosion on non-agricultural lands but cannot predict deposition and does not take into account sediment yields from erosion of ditches, riverbanks, and riverbeds. Suripin, 2002: 69 in (Solichin, 2012)

In the USLE formula, the factors that affect erosion are the erodibility factor of rainfall and runoff for a certain area (R), the soil erodibility factor for a certain soil horizon (K) and is the soil loss per unit area for a certain erosive index, the slope length factor that does not has units (L), gradient factor (different) slopes that do not have units (S), management factors and farming methods that do not have units (C) and mechanical soil conservation practice factors that do not have units (P). Estimation of erosion or the amount of soil loss per unit area of land (A) based on the USLE formula is described by the equation:

$$A = R\ K\ L\ S\ C\ P$$

B. Erosion and Deposition of Stream Power Based Erosion Deposition (USPED) Units

The Earth's surface, exposed to the forces of gravity, wind, water, and the action of ice, continues to evolve over a wide range of spatial and temporal scales. The erosional processes that shape the soil surface are complex, poorly understood, and

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difficult to predict quantitatively in large landscapes (Finlayson and Montgomery, 2003). Remote data that allows us to gain insight into the interactions between physical processes and environmental conditions that control erosion and landform evolution. Recent advances in mapping technology, such as Light Detection and Ranging (LiDAR), hyperspectral imaging, and ground-penetrating radar have dramatically improved the spatial and temporal resolution of Earth's surface and shallow subsurface monitoring. New, more detailed data suggest that fundamental changes in the theory underlying erosion processes may be needed to align them with new observations. Geospatial information science (GISc)-based analysis and modeling plays an important role in integrating observations and models, and improving understanding and predictability aimed at minimizing the negative impacts of erosion and sedimentation (Mitasova et al., 2013).

The advantage of USPED is the fact that it predicts the spatial distribution of erosion, as well as the rate of deposition under conditions of uniform runoff and high rainfall. Thus, this model can be applied in complex terrain where erosion is limited by the capacity of runoff to transport sediment. The topographic index represents the change in transport capacity from the flow direction, being positive for areas with topographic potential for deposition and negative for areas with erosion potential. The contribution area is used as a representation of water flow in a place or a grid of cells. (Hoffmann et al., 2013)

USPED developed a method of calculating topographic factors, both for the standard USLE and for a unit-flow power-based model suitable for complex terrain and applicable to large areas. Particular attention is paid to the precise representation of the terrain and the calculation of significant topographical parameters for erosion/deposition modeling. (Mitasova et al., 1996)

1. The modified 3D LS3D topographic factor (slope length), which represents the topographic potential for erosion at a point on the hillside, is a function of the area of the upslope contribution per unit width and slope angle, with the equation:
$$LS = (m + 1)\ (U/22.1)^m\ (\sin \beta/0.09)^n$$
2. Modify the LS3D factor to represent the topographical components of the sediment transport capacity of the ESG overland flow, with the equation:
$$LST = U^m.(\sin\beta)^n$$
and then the sediment flow T at the sediment transport capacity is estimated as
$$T = R.K.C.P.U^m.(\sin\beta)^n$$
3. Erosion/net deposition D is then calculated as sediment flow divergence (change in the 2D plane represents sediment flow in the direction of the elevation surface gradient)
$$D = \nabla \bullet (T\ s0) = \partial(T \cos \alpha)/\partial x + \partial(T \sin \alpha)/\partial y$$

To make the equations easy to implement in GIS with support for basic terrain analysis, the erosion/deposition equations can be rewritten using the following relationship between partial derivatives and surface β slope and α aspect
$$\partial z/\partial x = \tan \beta\ .\ \cos \alpha$$
$$\partial z/\partial y = \tan \beta\ .\ \sin \alpha$$

The exponents m, n control the relative effects of water rate and slope and reflect the effects of different types of flow. Typical ranges of values are m = 1.0 - 1.6, n = 1.0 - 1.3, with higher values reflecting the real erosion pattern that occurs with more turbulent flow when erosion increases markedly with the amount of water. Lower exponent values close to m = n = 1 better reflect the combined pattern of long-term impacts of rill and sheet erosion and average over the long-term sequence of major and minor events.

III. Research Methodology

A. *Study Area*

The study was conducted in Gorontalo Regency, Gorontalo Province, precisely in the catchment area of the Alopohu River which is one of the main rivers carrying sediment to Limboto Lake, which includes the Alo sub-watershed, Molamahu sub-watershed, Pulubala sub-watershed and Batulayar sub-watershed, as mapped. in Fig 1.

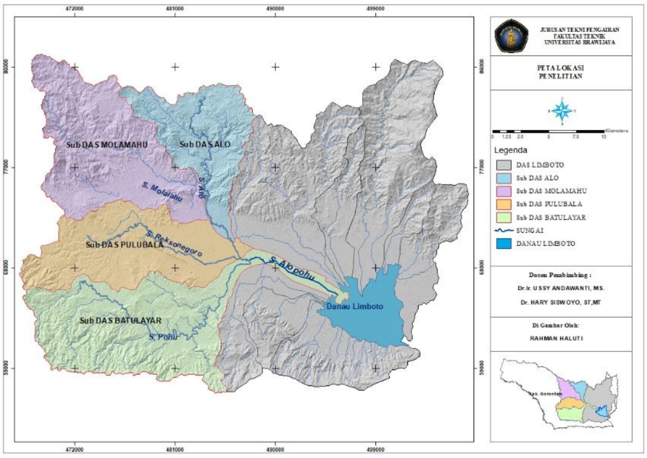

Fig. 1. Research Site Map

B. *Metode Analisis Data*

The data analysis method used is to calculate erosion and sediment originating from the Alo sub-watershed, Molamahu sub-watershed, Pulubala sub-watershed and Batulayar sub-watershed, which enter Limboto Lake through the Alopohu River by comparing the Universal Soil Loss Equation (USLE) modeling and Unit Stream Power-based Erosion Deposition (USPED). The stages of data processing carried out for the modeling are as follows

1. DEMNAS Data Processing

The National DEM was built using IFSAR data sources (5m resolution), TERRASAR-X (5m resolution) and ALOS PALSAR (11.25m resolution) and after adding the stereo-plotting Masspoint data. The spatial resolution of DEMNAS is 0.27-arcsecond at the 2008 EGM vertical datum.

DEMNAS data processing using ArcGis 10.3 software is data analysis to be able to create the following maps:

a. Map of Altitude and area of Catchment Area of research location
b. Precent_Rise and Degree . slope maps
c. Precent_Rise → for USLE modeling
d. Degree → for USPED modeling

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e. Slope direction map (*aspect)* → for USPED modeling
f. Identify flow (*stream*) → for USLE and USPED modeling
g. Hillshade Map → USLE and USPED

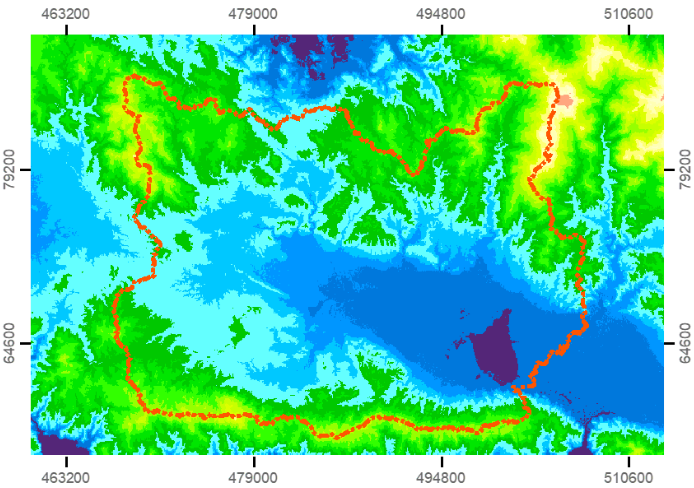

Fig. 2. Plotting of DEMNAS DAS Limboto

2. Rainfall Data Processing

Rainfall data processing is an analysis of rainfall distribution data to obtain the Rain Erosivity Index (Factor R). Before the monthly rainfall data in one year of observation at a rain station is used, the missing (incomplete) rainfall data is filled in based on the rainfall data of the nearest station that has a good correlation with the rain station whose rainfall data is incomplete.

Rain data used is annual rain. Annual rain is obtained from daily rainfall data which is cumulative to become the average monthly rain in the span of one year. The rain recording period available and used is from 2007 to 2020. Rain data is used to calculate the value of the rain erosivity factor (R) using the Wischmeier and Smith equation. After calculating the value of rain erosivity for each station, the next step is to make a rain erosivity map using the interpolation method. By considering the relatively low number of stations and not evenly distributed in the research area, the interpolation method used is the IDW (Inverse Distance Weigthing) method in the Arcgis 10.3 program.

The IDW method uses point input, namely the location of the station and the rainfall erosivity value of each station which is then weighted to produce an area based on the interpolation value. The resulting interpolation is interval data

3. Soil Map Processing and Soil Erodibility Value

Soil maps are secondary data obtained from the Geospatial Information Agency (BIG) which are ready for use. In this process, all that is done is to separate the soil map of the research area from the soil map of Gorontalo Regency and add attribute information regarding the erodibility value of the soil based on the literature for each soil type.

4. Making Slope and Aspect Maps

Slope and Aspect maps are obtained from the results of DEMNAS flowcart 3.1 data processing, the data processing used is in two ways, namely slope with precent_rise slope value for USLE modeling to obtain LS values (length and slope) while slope with slope degree and aspect for USPED modeling,

5. Land Cover Map

The land cover maps are sourced from KLHK data for 2007 and 2020 which are ready for use. In this process, what is done is only adding attribute information regarding the value of land cover and land management (CP) in the research area based on the literature for land factors

C. Flowchart

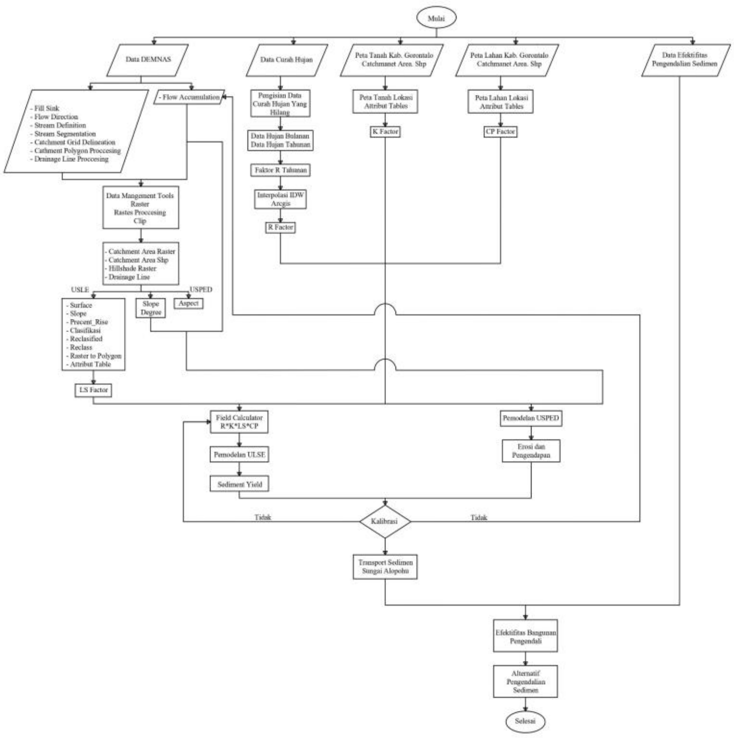

Fig. 3. Research Flowchart

IV. Result

A. *Alopohu River Sediment Load Analysis of the National Digital Elevation Model Map (DEMNAS)*

Based on the analysis of the National Digital Elevation Model (DEMNAS) map using the Arcgis 10.3 Software, the catchment area of the Alopohu River is mapped into 4 (four) sub-watersheds, namely the Alo sub-watershed, the Molamahu sub-watershed, the Pulubala sub-watershed and the Batu Layar sub-watershed.

Digital Elevation Model (DEM) data is used in the analysis and display of maps, especially those related to topography. Globally available elevation models are the SRTM DEM and ASTER GDEM, or ALOS PALSAR which have 1 arc-second (~30 meters) resolution each.

The National DEM is built from several data sources including IFSAR data (5m resolution), TERRASAR-X (5m resolution) and ALOS PALSAR (11.25m resolution), by adding the stereo-plotting Masspoint data. The spatial resolution of DEMNAS is 0.27-arcsecond, using the EGM2008 vertical datum.

This DEMNAS data processing method uses ArcaGis 10.3 software with the following steps:

1. Download DEMNAS data at http://tides.big.go.id/DEMNAS
2. Plotting of the Limboto watershed and sub-watershed polygons which are the Alopohu River Catchment Area (DTA) using ArcToolbox, with a computational process.

B. *Climate*

The climate in the study area is generally classified as a tropical area with irregular rainy and dry periods with temperatures > 18º in the coldest season.

Based on rainfall data from 4 (four) Limboto rain stations – Datahu, Limboto Pilolalenga, Limboto Tabango and Limboto Iloponu in 2007 – 2020, the Alopohu River catchment area has an average annual rainfall of 1491 mm with an average number of rainy days. 113 per year. The maximum monthly rainfall is 134.2 mm in 2016 and the minimum is 0.7 mm in September 2015. In general, the average daily rainfall in January to May is 9 mm and begins to decline from June to September and then increases again in October to December.

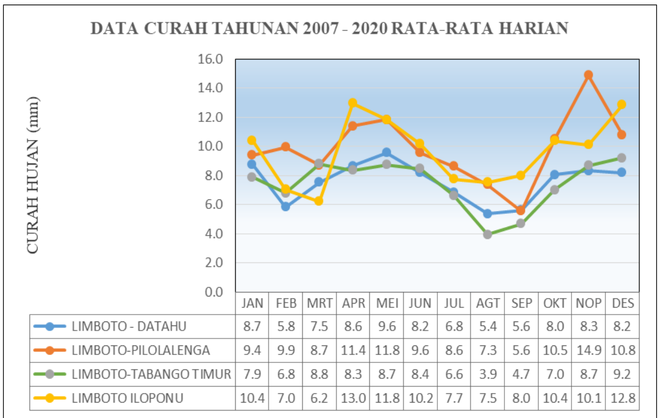

Fig. 4. Average daily rainfall patterns for 2007-2020

From the rainfall data, based on the calculation of the rain erosivity index using the Lenvain formula and the Wischmeier and Smith rain kinetic energy formula, the kinetic energy value of rainfall at each rain station is shown in the following table:

Rain Kinetic Energy In Metric Ton-Meters Per Hectare Per Cm Of Rain At Each Rain Station.

The erosivity zoning of each sub-watershed is obtained using the inverse distance weighted (IDW) interpolation method based on the interpolated kinetic energy value of the rain station value with the following results:

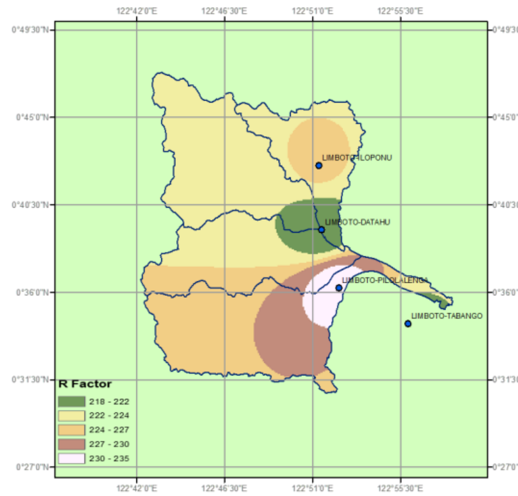

Fig. 5. IDW R Factor Sub-watershed

Furthermore, to get a uniform rainfall intensity value, the R value in each Sub-watershed is reclassified into 1 (one) class and the median value is taken, the results of the reclassification are as follows:

TABLE 1 Rain Kinetic Energy in Metric Ton-Meter Per Hectare Per Cm Rain In Sub-watershed Area

No	Area	Nilai R	Nilai Tengah Factor R
1	Sub DAS Alo	225 - 218	222
2	Sub DAS Molamahu	225 - 218	222
3	Sub DAS Pulubala	233 - 218	226
4	Sub DAS Batu Layar	235 - 222	229

C. *Soil Type*

Based on the Soil Type Map from the Geospatial Information Agency (BIG) in the study area, the soil types in each sub-watershed are classified in the following soil type maps and tables:

TABLE 2. Sub-watershed Soil Type Map

No	Tutupan Lahan	Luas (Ha)	Nilai CP
1	Hutan Lahan Kering Sekunder	1260.12	0.05
2	Pertanian Lahan Kering Bercampur Semak	8979.77	0.43
3	Pertanian Lahan Kering	4013.88	0.14
4	Semak / Belukar	327.61	0.10
5	Sawah	565.85	0.02
6	Permukiman	50.95	1.00
7	Danau	110.91	0.01

Sumber: Kementerian Lingkungan Hidup dan Kehutanan

Soil Type Alo Sub-watershed:

TABLE 3. Soil Types in Alo Sub-watershed

No	Kemiringan Lereng	Luas (ha)	Faktor Jenis Tanah (K)
1	Kambisol & Mediteran	3274.37	0.227
2	Latosol & Kambisol	206.71	0.186
3	Mediiteran & Molisol	295.27	0.16
4	Mediteran & Latosol	2358.55	0.123
5	Molisol & Latosol	1465.51	0.132

D. Topography

In this study, it is necessary to analyze topographic conditions, namely the length of the slope and the slope in the percentage size which is normalized using the LS table which is required in USLE modeling and the slope/slope (degree/degree) and aspect required in USPED modeling, the topographical conditions of the Sub-watershed are mapped. picture as follows:

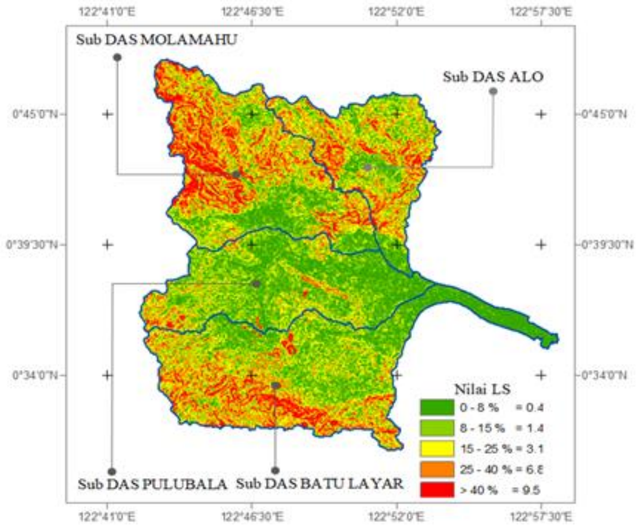

Fig. 6. Map of Slope Length and Slope (LS) of Sub-watershed

The length and slope of each sub-watershed are as follows:

Alo sub-watershed

Has a height of 19 – 550 masl, dominated by steep hilly land with 3446.41 hectares or 45% of the sub-watershed area, the classification of slopes is described in the following table:

Length and Slope Slope of Alo Sub-watershed:

TABLE 4. Length and Slope of Alo Sub-watershed

No	Kemiringan Lereng	Luas (ha)	Panjang Dan Kemiringan Lereng (LS)
1	Agak datar (0-8)	501.98	0.4
2	Bergelombang (8-15)	2358.55	1.4
3	Berbukit agak curam (15-25)	1155.95	3.1
4	Berbukit curam (25-40)	3446.41	6.8
5	Bergunung sangat curam (>40)	137.52	9.5

Sumber: Peta Digital Elevation Model Nasional (DEMNAS)

E. Land Cover

Land cover uses land maps of the Ministry of Environment and Forestry in 2007 and 2020 so no analysis is carried out but only digitizes entering the CP value according to the land map.

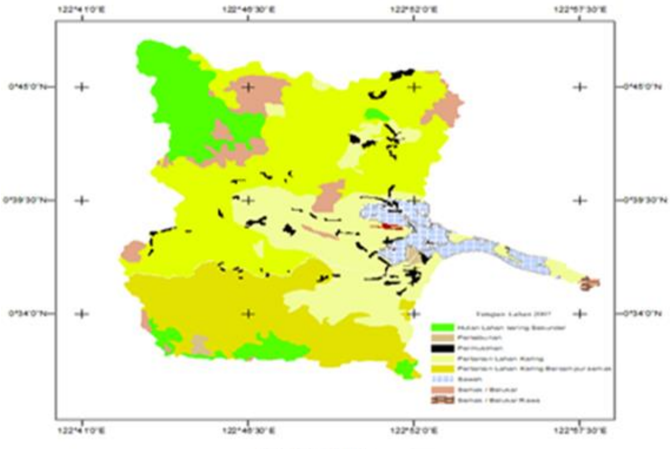

Fig. 7. Peta Tutupan Lahan Sub DAS 2007

2007 Land Cover

Alo sub-watershed

Based on the ploating area, the land cover in 2007 was dominated by dry land mixed with shrubs with an area of 5494.29 hectares or 72% of the sub-watershed area. Land cover classification is described in the following table:

2007 Alo Sub-watershed Land Cover

TABLE 5. Land Cover of Alo Sub-watershed in 2007

No	Tutupan Lahan	Luas (Ha)	Nilai CP
1	Hutan Lahan Kering Sekunder	112.27	0.05
2	Pertanian Lahan Kering Bercampur Semak	5494.29	0.43
3	Pertanian Lahan Kering	821.58	0.14
4	Semak / Belukar	582.78	0.10
5	Sawah	354.05	0.02
6	Permukiman	235.75	1.00

Sumber: Kementerian Lingkungan Hidup dan Kehutanan

2020 Land Cover

Alo sub-watershed

Based on the ploating area, the land cover in 2020 is dominated by Dry Land Mixed with Shrubs with an area of 5657.03 hectares or 74% of the sub-watershed area. The land cover classification is described in the following table:

TABLE 6. Land Cover of Alo Sub-watershed in 2020

No	Tutupan Lahan	Luas (Ha)	Nilai CP
1	Hutan Lahan Kering Sekunder	113.07	0.05
2	Pertanian Lahan Kering Bercampur Semak	5663.57	0.43
3	Pertanian Lahan Kering	954.07	0.14
4	Semak / Belukar	136.00	0.10
5	Sawah	265.34	0.02
6	Permukiman	468.37	1.00

Sumber: Kementerian Lingkungan Hidup dan Kehutanan

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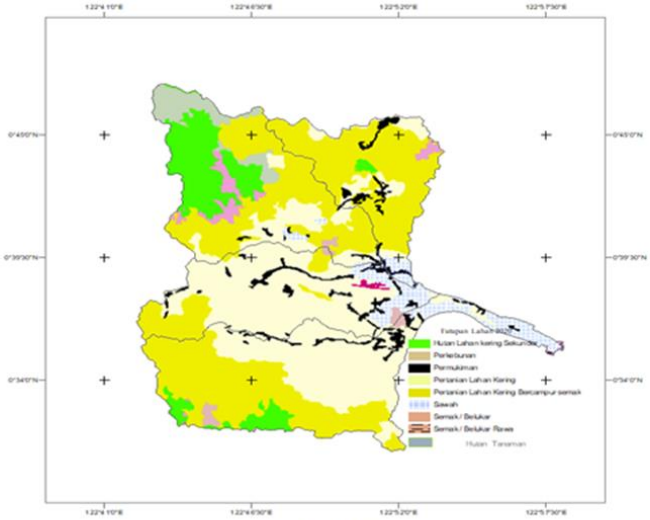

Sub DAS 2020

Fig. 8. Land cover map Sub-watershed 2020

Table

POTENSI EROSI Sub DAS ALO 2007

FID	LAHAN	R	K_Fac	LS	CP	Nilai Pot_Erosi	TBE	Luas Bidang	Pot_Eros_Lahan
0	Permukiman	222	0.123	9.5	1	259.407	Berat	0.00445	1.153293
1	Permukiman	222	0.123	3.1	1	84.6486	Sedang	0.00849	0.718942
2	Permukiman	222	0.123	3.1	1	84.6486	Sedang	0.00019	0.015843
3	Permukiman	222	0.123	3.1	1	84.6486	Sedang	0.04294	3.634506
4	Permukiman	222	0.123	1.4	1	38.2284	Ringan	0.00117	0.044553
5	Permukiman	222	0.123	3.1	1	84.6486	Sedang	0.02312	1.957493
6	Permukiman	222	0.123	1.4	1	38.2284	Ringan	0.00014	0.005396
7	Permukiman	222	0.123	9.5	1	259.407	Berat	0.00307	0.796903
8	Permukiman	222	0.123	3.1	1	84.6486	Sedang	0.00685	0.580177
9	Permukiman	222	0.123	1.4	1	38.2284	Ringan	0.01144	0.437367

(0 out of 74377 Selected)

Fig. 9. Attribute Table of Erosion Potential of Alo Sub-watershed 2007

Land Cover Change 2007 – 2020

In the span of ± 13 years, changes occur in the land cover of the Sub-watershed, the changes that occur are described in the following matrix:

TABLE 7. Alo Sub-watershed Land Cover Change Matrix

No	Tutupan Lahan	2007		2020	
		Luas (Ha)	Luas %	Luas (Ha)	Luas %
1	Hutan Lahan Kering Sekunder	112.27	1.49	113.07	1.49
2	Pertanian Lahan Kering Bercampur Semak	5494.29	72.29	5663.57	74.52
3	Pertanian Lahan Kering	821.58	10.81	954.07	12.55
4	Semak / Belukar	582.78	7.67	136.00	1.79
5	Sawah	354.05	4.66	265.34	3.49
6	Permukiman	235.75	3.09	468.37	6.16
	Jumlah	7600.41	100.00	7600.41	100.00

Sumber: Hasil Analisis

F. *Universal Soil Loss Equation (USLE) Prediction*

Alo sub-watershed

- 2007 Erosion and Sediment Load Prediction

Erosion prediction in 2007, Alo sub-watershed with an area of 7,600.41 Ha based on the criteria for erosion hazard level (TBE) has the potential for erosion on average to land cover of 827,973.30 tons/year, erosion predictions and sediment load are described in the following table:

TABLE 8. Erosion Rate Based on Alo Sub-watershed Land in 2007

Tingkat Erosi	Luas (Ha)	Erosi Lahan (Ha)	Prosentase (%)
Berat			
Pertanian Lahan Kering Bercampur Semak	971,78	1.022,53	13,45
Pemukiman	50,75		
Sedang			
Pertanian Lahan Kering Bercampur Semak	2.751,20	2.840,61	37,37
Pemukiman	56,87		
Pertanian Lahan Kering	32,53		
Ringan			
Pertanian Lahan Kering Bercampur Semak	1.394,30	2.144,91	28,22
Pemukiman	67,13		
Pertanian Lahan Kering	146,34		
Hutan Lahan Kering Sekunder	93,67		
Semak / Belukar	443,48		
Sangat Ringan			
Pertanian Lahan Kering Bercampur Semak	377,01	1.592,37	20,95
Pemukiman	60,01		
Pertanian Lahan Kering	642,71		
Hutan Lahan Kering Sekunder	19,30		
Semak / Belukar	139,30		
Sawah	354,05		
TOTAL		7.600,41	100,00

Sumber: Hasil Perhitungan

TABLE 9. Erosion Hazard Level of Al0 Sub-watershed

No	Kriteria	Erosi Ton/Ha/Thn	Luas Ha	Prosentase %
1	Erosi Sangat Berat	> 480	-	-
2	Erosi Berat	180 - 480	1,022.53	13.45
3	Sedang	60 - 180	2,840.61	37.37
4	Ringan	15 - 60	2,144.91	28.22
5	Sangat Ringan	< 15	1,592.37	20.95
6	Stabil	-	-	-
	Jumlah		7,600.41	100.00

Sumber: Hasil Perhitungan

TABLE 10. Analysis of Land Cover Erosion Potential for Alo Sub-watershed in 2007

	Potensi Erosi Ton/Thn		Luas Ha		Potensi Erosi Ton/Ha/Thn			Rata-rata Erosi Lahan Ton/Thn
Tingkat Bahaya Erosi (TBE)	Nilai Potensi Erosi (Ton)	Rata-rata Nilai Potensi Erosi	Nilai Luas Sub Bidang (Ha)	Total Luas Sub Bidang	Potensi Erosi	Potensi Erosi terhadap Luas Sub Bidang	Rata-rata Potensi Erosi	Rata-rata Erosi Lahan (Ton/Thn)
1	2	3	4	5	6	7	8	9
						(4 : 6)		(4 x 8)
Hutan Lahan Kering Sekunder								
Ringan	6577,68	5.171,17	93,67	112,970	2.078,98	22,19	14,03	1.585,27
Sangat Ringan	3764,65		19,30		113,30	5,87		
Pertanian Lahan Kering Bercampur Semak								
Berat	230.150,91	694.453,08	971,78	5.494,29	199.843,82	205,65	87,30	479.639,65
Sedang	1.779.301,06		2.751,20		300.008,34	109,05		
Ringan	717.566,84		1.394,30		40.258,50	28,87		
Sangat Ringan	50.793,50		377,01		2.120,33	5,62		
Pertanian Lahan Kering								
Sedang	4.892,75	28.490,50	32,53	821,58	2.180,51	67,02	34,79	28.581,15
Ringan	44.117,48		146,34		4.759,98	32,53		
Sangat Ringan	36.461,27		642,71		3.093,24	4,81		
Semak / Belukar								
Ringan	62.020,07	40.914,26	443,47825	582,778	14.552,34	32,81	19,34	11.269,32
Sangat Ringan	19.808,44		139,3006		816,346	5,86		
Sawah								
Ringan	4.842,71	4.842,71	354,05	354,05	298,79	0,84	0,84	298,79
Pemukiman								
Berat	99.710,52	54.101,59	50,75	234,75	11.660,72	229,75	91,68	21.520,82
Sedang	72.265,88		56,87		4.993,69	87,81		
Ringan	39.086,70		67,13		2.548,40	37,96		
Sangat Ringan	5.343,27		60,01		670,93	11,18		

Sumber: Hasil Perhitungan

TABLE 11. Erosion and Sediment Potential of Alo . Sub-watershed

No	Jenis Lahan	Potensi Erosi Ton/Thn	Luas Ha	Rata-rata Potensi Erosi Ton/Ha/Thn	Rata-rata Erosi Lahan Ton/Thn	Rata-rata Erosi Lahan M3/Thn	Rata-rata Erosi Lahan Mm/Thn
1	Hutan Lahan Kering Sekunder	5,171.17	112.97	14.03	1,585.27	707.08	0.63
2	Pertanian Lahan Kering Bercampur Semak	694,453.08	5,494.29	87.30	479,639.65	213,933.83	3.89
3	Pertanian Lahan Kering	28,490.50	821.58	34.79	28,581.15	12,748.06	1.55
4	Semak / Belukar	40,914.26	582.78	19.33	11,269.32	5,026.46	0.86
5	Sawah	4,842.71	354.05	0.84	298.79	133.27	0.04
6	Permukiman	54,101.59	234.75	91.68	21,520.82	9,598.94	4.09
	Total Erosi	**827,973.30**	**7,600.41**	**41.33**	**90,482.50**	**40,357.94**	**1.84**
	SDR/Sedimen Delivery Ratio (%)		13.96		12,631.34		
	Rata-rata kehilangan tanah tahunan dalam ton (USLE)			2.242		5,631.34 M3	

Sumber: Hasil Perhitungan

The determination of the criteria and the value of erosion is determined based on the Classification of Erosion Hazard Levels (Name, A., Andawayanti, A., & Suhartanto 2016) with an area based on the summation of the erosion hazard level in the land cover.

The potential for erosion and sediment of the 2007 Alo sub-watershed is obtained by the following calculation method:

1. Erosion Potential
   TBE = Erosion hazard level based on classification
   Area = Area TBE
   Land Erosion Potential = Erosion potential value x field area.
2. Erosion Potential Ton/yr = Total soil erosion potential on average according to TBE
3. Area = Total area according to TBE
4. Average erosion potential Ton/ha/yr = Average amount of land erosion potential according to TBE / Area.
5. Average land erosion Ton/ha/yr = Average erosion potential ton/ha/yr x Area of erosion hazard level.
6. Total erosion = Average land erosion Ton/ha/yr
7. The value of SDR/Sediment Delivery Ratio (%) is determined based on the table of the relationship between the area of the watershed and the ratio of sediment delivery.
8. Specific gravity value is the average annual soil loss in USLE standard tons.

Prediction of Erosion and Sediment Load in 2020

Erosion prediction in 2020, Alo sub-watershed with an area of 7,600.41 Ha based on the criteria for erosion hazard level (TBE) has the potential for average erosion to land cover of 883.739.30 tons/year, erosion predictions and sediment load are described in the following table:

TABLE 12. Erosion Rate Based on Alo Sub-watershed Land in 2020

Tingkat Erosi	Luas Ha	Erosi Lahan (Ha)	Prosentase %
Berat			
Pertanian Lahan Kering Bercampur Semak	1,121.29	1,197.98	15.76
Pemukiman	76.69		
Sedang			
Pertanian Lahan Kering Bercampur Semak	2,847.28	2,973.77	39.13
Pemukiman	100.27		
Pertanian Lahan Kering	26.21		
Ringan			
Pertanian Lahan Kering Bercampur Semak	1,317.99	1,879.75	24.73
Pemukiman	142.49		
Pertanian Lahan Kering	242.72		
Hutan Lahan Kering Sekunder	90.87		
Semak / Belukar	85.67		
Sangat Ringan			
Pertanian Lahan Kering Bercampur Semak	377.00	1,548.92	20.38
Pemukiman	148.92		
Pertanian Lahan Kering	685.14		
Hutan Lahan Kering Sekunder	22.20		
Semak / Belukar	50.33		
Sawah	265.34		
Total		7,600.41	100.00

Sumber: Hasil Perhitungan

TABLE 13. Alo Erosion Hazard Level Sub-watershed

No	Kriteria	Erosi Ton/Ha/Thn	Luas Ha	Prosentase %
1	Erosi Sangat Berat	> 480	-	-
2	Erosi Berat	180 - 480	1,197.98	15.76
3	Sedang	60 - 180	2,973.77	39.13
4	Ringan	15 - 60	1,879.75	24.73
5	Sangat Ringan	< 15	1,548.92	20.38
6	Stabil	-	-	-
	Jumlah		7,600.41	100.00

Sumber: Hasil Perhitungan

TABLE 14. Analysis of Potential Erosion of Land Cover in Alo Sub-watershed in 2020

	Potensi Erosi Ton/Thn		Luas Ha		Potensi Erosi Ton/Ha/Thn			Rata -rata Erosi Lahan Ton/Ha/Thn
Tingkat Bahaya Erosi (TBE)	Nilai Potensi Erosi Ton/Thn	Rata-rata Nilai Potensi Erosi Ton/Thn	Nilai Luas Sub Bidang Ha	Total Luas Sub Bidang Ha	Potensi Erosi Ton/Ha/Thn	Potensi Erosi terhadap Luas Sub Bidang Ton/Ha/Thn	Rata-rata Potensi Erosi	Rata-rata Erosi Lahan Ton/Ha/Thn
1	2	3	4	5	6	7	8	9
						(4:6)		(4 x 8)
Hutan Lahan Kering Sekunder								
Ringan	6224.93	5,076.23	90.87	113.07	2,016.58	22.19	13.81	1,561.21
Sangat Ringan	3927.53		22.20		120.39	5.42		
Pertanian Lahan Kering Bercampur Semak								
Berat	254,236.48	733,546.69	1.121,29	5,663.57	229.980,51	205,10	87.40	495,020.14
Sedang	1,915.,54.92		2.847,28		313.421,61	110,08		
Ringan	712.937.48		1.317,99		37.890,15	28,75		
Sangat Ringan	50,793.50		377,00		2.144,53	5,69		
Pertanian Lahan Kering								
Sedang	5.361,92	36,336.36	26,21	954.07	1.756,53	67,02	34.46	32,879.87
Ringan	55.256,60		242,72		7.475,18	30,80		
Sangat Ringan	48.390,55		685,14		3.814,05	5,57		
Semak / Belukar								
Ringan	12.687,72	10,177.89	443.47825	136.00	14,552.34	32.81	15.29	2,079.97
Sangat Ringan	7.668,05		139.31		816.35	5.86		
Sawah								
Ringan	3.724,66	3,724.66	265.34	265.34	227.82	0.82	0.82	227.82
Pemukiman								
Berat	136,625.30	94,877.47	76,69	468.38	17,732.50	231.22	93.39	43,742.60
Sedang	139,063.71		100,27		9,126.26	91.01		
Ringan	92,115.79		142,49		5,601.68	39.31		
Sangat Ringan	11,705.08		148,92		1,790.08	12.02		

Sumber: Hasil Perhitungan

TABLE 15. Erosion and Sediment Potential of Alo Sub-watershed

No	Jenis Lahan	Potensi Erosi	Luas	Rata-rata Potensi Erosi	Rata-rata Erosi Lahan	Rata-rata Erosi Lahan	Rata-rata Erosi Lahan
		Ton/Thn	Ha	Ton/Ha/Thn	Ton/Thn	M3/Thn	Mm/Thn
1	Hutan Lahan Kering Sekunder	5,076.23	113.07	13.81	1,561.21	696.35	0.62
2	Pertanian Lahan Kering Bercampur Semak	733,546.69	5,663.57	87.40	496,020.14	220,794.00	3.90
3	Pertanian Lahan Kering	36,336.36	954.07	34.46	32,879.87	14,665.42	1.54
4	Semak / Belukar	10,177.89	136.00	15.29	2,079.97	927.73	0.68
5	Sawah	3,724.66	265.34	0.86	227.82	101.62	0.04
6	Permukiman	94,877.47	468.37	93.39	43,741.66	19,510.11	4.17
	Total Erosi	**883,739.30**	**7,600.41**	**40.87**	**95,918.45**	**42,782.54**	**1.82**
SDR/Sediment Delivery Rasio (%)			**13.96**		**13,390.20**		
Rata-rata kehilangan tanah tahunan dalam ton (USLE)				**2.242**		**5,972.44 M3**	

Sumber: Hasil Perhitungan

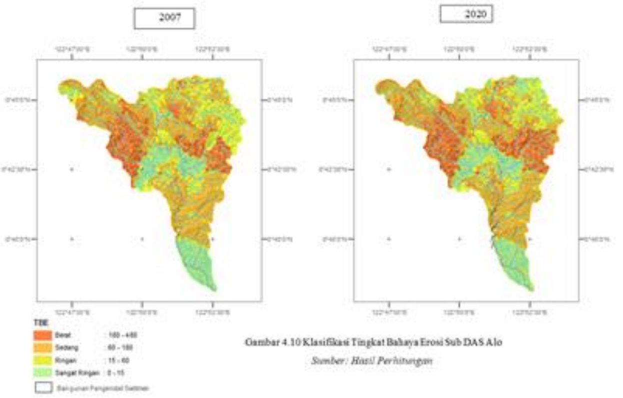

Fig. 10. Classification of Erosion Hazard Sub-watershed Alo

- 2007-2020 Sediment Load

With the increase in the level of erosion hazard that occurs, the sediment load of the Alo sub-watershed increases from the original 12,631.34 tons/ha/year to 13,390.20 tons/ha/year.

G. Validation of Sediment Yield Analysis

Validation of Sediment Yield Analysis was carried out on the USLE erosion and sediment model using multiple linear regression analysis which is an analytical method to test research hypotheses to determine whether there is an influence between 2 (two) or more independent variables (X) on the dependent variable (Y) which can be expressed in the form of a regression equation.

TABLE 16. Hypothesis of Sediment Yield (Sediment Yield) Sub-watershed

Tahun	X1 Erosi (Ton/Ha/Thn)	X2 Sdr (%)	Y Hasil Sedimen (Ton/Ha/Thn)
2007	90,482.50	13.96	12,631.34
	91,934.43	12.38	11,377.43
	83,975.01	12.88	10,819.61
	130,931.03	11.94	15,630.79
2020	95,918.45	13.96	13,390.20
	80,839.75	12.38	10,004.40
	70,834.58	12.88	9,126.61
	120,325.72	11.94	14,364.71

Sumber: Hasil Perhitungan

with the following hypothesis:

- H1 = There is an effect of variable X1 on variable Y
- H2= There is an effect of variable X2 on variable Y
- H3= There is an effect of variables X1 and X2 simultaneously or together on variable Y
- 95% confidence level, α= 0.05

The steps for testing the multiple linear regression hypothesis are:

1. Normality Test

   The normality test is carried out to determine whether the Unstandardized Residual is normal or not, the results of the normality test are as follows:

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		8
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	53.96072085
Most Extreme Differences	Absolute	.197
	Positive	.131
	Negative	-.197
Test Statistic		.197
Asymp. Sig. (2-tailed)		.200[c,d]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

From the normality test data of the One-Sample Kolmogorov-Smirnov Test, the asymp value is obtained. sig. (2-tailed) unstandardized residual is 0.200c,d where 0.200> from 0.05, it can be concluded that the residual data is normally distributed.

2. Regression Test

Descriptive Statistics

	Mean	Std. Deviation	N
Sedimen	12145.1875	2308.14402	8
Erosi	95465.1763	20761.47953	8
SDR	12.7900	.80491	8

The descriptive statistics table data shows the Mean, Std Deviation and N values which are the number of samples of the variables, with the Mean > Std Deviation value indicating that there is no outlier data.

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	SDR, Erosi[b]	.	Enter

a. Dependent Variable: Sediment
b. All requested variables entered.

The data from the Variables Entered/Removeda table shows that an analysis test has been carried out on all variables using the enter method.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
					Change Statistics				
1	1.000[a]	.999	.999	63.84719	.999	4571.649	2	5	.000

a. Predictors: (Constant), SDR, Erosi

3. T test

   The t test aims to determine whether or not there is a partial (own) effect of the independent variable (X) on the dependent variable (Y), the results of the t test are as follows:

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-11973.484	495.144		-24.182	.000
	Erosi	.123	.001	1.102	94.567	.000
	SDR	971.280	33.417	.339	29.066	.000

a. Dependent Variable: Sedimen

Multiple linear regression equation Y = -11973.484+0.123X1+971.280X2

4. F test

The t-test aims to determine whether or not there is a simultaneous (together) effect of the independent variable (X) on the dependent variable (Y), the results of the F test are as follows:

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3727231 9.269	2	1863615 9.635	4571 .649	.00
	Residual	20382.31 6	5	4076.463		
	Total	3729270 1.585	7			

a. Dependent Variable: Sedimen
b. Predictors: (Constant), SDR, Erosi

H. Erosion and Sediment Unit Stream Power Based Erosion Deposition (USPED)

Erosion and sediment prediction The Unit Stream Power Based Erosion Deposition (USPED) method combines the Universal Soil Loss Equation (USLE) parameter and the contribution of the upslope area to estimate and map erosion and deposition flows, calculated as changes in erosion and sediment flow towards the slope. steepest, using arcgis software 10.3

Alo sub-watershed

Prediction of land potential for erosion and estimated sediment flow (settlement) that will occur in 2007 and 2020 are as follows:

TABLE 17. Comparison of Erosion Flow Potential and Land Sediment Sub-watershed Alo

No	Kriteria Tingkat Bahaya Erosi Dan Penilaian Muatan Sedimen	Prediksi Erosi dan Sedimen Ton/Ha/Tahun	Tahun 2007	Tahun 2020
			Luas	
			Ha	Ha
1	Erosi Sangat Berat	>480	117.02	108.03
2	Erosi Berat	180 - 480	90.59	86.47
3	Erosi Sedang	60 - 180	186.50	170.58
4	Erosi Ringan	15 - 60	450.76	412.98
5	Erosi Sangat Ringan	1 - 15	2,525.70	2,457.16
6	Stabil	0 - 1	1,863.15	2,012.08
7	Sedimen Sangat Rendah	1 - 5	937.38	1,017.35
8	Sedimen Rendah	5 - 10	420.73	397.31
9	Sedimen Sedang	10 - 15	192.02	179.52
10	Sedimen Tinggi	15 - 20	111.51	99.68
11	Sedimen Sangat Tinggi	>20	705.06	659.24
	Total		7,600.41	7600.41

Sumber: Hasil Perhitungan

The table is a comparison of the potential for erosion and sediment flow (settlement) which is mapped based on the level of erosion hazard and the assessment of the sediment load that occurs due to changes in land cover.

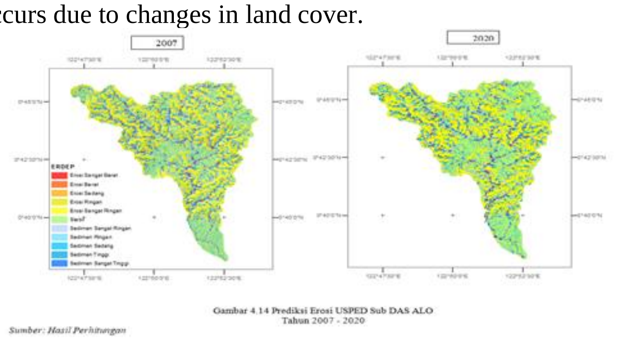

Fig. 11. USPED Erosion Prediction for ALO Sub-watershed in 2007 - 2020

I. Comparison of USLE and USPED . Erosion and Sediment Prediction Models

Based on the analysis results of the Universal Soil Loss Equation (USLE) erosion prediction model and the erosion and sediment predictions of the Unit Stream Power Based Erosion Deposition model (USPED) in the Alopohu River catchment area in the 2007-2020 period are as follows:

Alo sub-watershed

- 2007
  A. Erosion Hazard Level

TABLE 18. USLE and USPED Sub-watershed Erosion Hazard Levels 2007

No	Kriteria	Erosi	USLE Luas	USLE Prosentase	USPED Luas	USPED Prosentase
		Ton/Ha/Thn	Ha	%	Ha	%
1	Erosi Sangat Berat	> 480	-	-	117.02	0.71
2	Erosi Berat	180 - 480	1,197.98	15.76	90.59	0.86
3	Sedang	60 - 180	2,973.77	39.13	186.50	1.39
4	Ringan	15 - 60	1,879.75	24.73	450.76	2.52
5	Sangat Ringan	< 15	1,548.92	20.38	2,525.70	16.30
	Total Erosi		7 ,600.41	100.00	3,370.56	44.35
6	Stabil	-	-	-	1,863.15	24.51

Sumber: Hasil Perhitungan

TABLE 19. USLE and USPED Sub-watershed Model Sediment Loads 2007

No	Kualifikasi	Nilai Muatan Sedimen	USLE Sedimen	USLE SDR	USPED Luas	USPED Prosentase
		Ton/Ha/Thn	Ton/Ha/Thn	%	Ha	%
1	Erosi Sangat Rendah	1 - 5	-	-	937.38	7.15
2	Erosi Rendah	5 - 10	-	-	420.73	2.29
3	Sedang	10 - 15	-	-	192.02	1.05
4	Tinggi	15 - 20	-	-	111.51	0.65
5	Sangat Tinggi	< 20	-	-	705.06	4.77
	Total Sedimen		12,631.34	13.96	2,366.70	31.14
6	Stabil	1 - 1	-	-	1,863.15	24.51

Sumber: Hasil Perhitungan

I. Comparison of the results of the analysis of the level of erosion hazard are:
   1) In the prediction of the USLE model of the erosion hazard level, there is no very heavy erosion found on the land.
   2) In the prediction of the USPED model based on the spatial distribution of the erosion hazard level, there is very heavy erosion towards the steepest slope.
   3) The prediction results of the USPED model show that there is a spatial distribution of the level of erosion hazard towards the steepest slope with an area of 44.35% of the total area of land that is eroded as predicted by the USLE model..
   4) The Stable Criteria are not classified in the USLE model but in the USPED there is a stable condition which means that the distribution of erosion and sediment is equal (1:1).

II. The comparison of the results of the sediment load analysis is:
   1) In the prediction of the USLE model the sediment load is determined by the SDR (Sediment Delivery Ratio) value so that it cannot estimate and map the sediment flow that occurs.
   2) In the prediction of the USPED model the landscape potential for erosion and soil deposition towards the steepest slope can be estimated and mapped.
   3) The prediction results of the USPED model show that there is a spatial distribution of sediment transport towards the steepest slope with a deposit area of 31.14% of the average land erosion.

   Then the results of the USPED model sediment = ((Average potential erosion / USLE average soil loss) x USPED Sediment Percentage)

Rahman Haluti, Ussy Andawayanti, and Hari Siswoyo, “Effectiveness Analysis of Sediment Control Building in the Alopohu River Flow,” *International Research Journal of Advanced Engineering and Science*, Volume 7, Issue 3, pp. 234-245, 2022.

((90,482.5 /2.242) * 31.14%) = 12,567.46 Tons/ha/yr: 2,242 = 5,605.47 M3/ha/yr

4) Sediment yield (USLE – USPED) = 5,631.34 ~ 5,605.47 = Average 5,618.40 M3/ha/yr

- Year 2020

A. Erosion Hazard Level 2020

TABLE 20. USLE and USPED Sub-watershed Erosion Hazard Levels in 2020

No	Kriteria	Erosi	USLE		USPED	
			Luas	Prosentase	Luas	Prosentase
		Ton/Ha/Thn	Ha	%	Ha	%
1	Erosi Sangat Berat	> 480	-	-	108.03	1.42
2	Erosi Berat	180 - 480	1,197.98	15.76	86.47	1.14
3	Sedang	60 - 180	2,973.77	39.13	170.58	2.24
4	Ringan	15 - 60	1,879.75	24.73	412.98	5.43
5	Sangat Ringan	< 15	1,548.92	20.38	2,457.16	32.33
	Total Erosi		7 ,600.41	100.00	3,235.23	42.57
6	Stabil	-	-	-	2,012.08	26.47

Sumber: Hasil Perhitungan

B. Sediment Load 2020

I. The comparison of the results of the analysis of the level of erosion hazard are:

1) In the prediction of the USLE model of the erosion hazard level, there is no very heavy erosion found on the land.
2) In the prediction of the USPED model based on the spatial distribution of the erosion hazard level, there is very heavy erosion towards the steepest slope.
3) The prediction results of the USPED model show that there is a spatial distribution of the level of erosion hazard towards the steepest slope with an area of 42.57% of the total area of land that is eroded as predicted by the USLE model.
4) Stable criteria are not classified in the USLE model but in the USPED there is a stable condition which means that the distribution of erosion and sediment is equal (1:1).

II. The comparison of the results of the sediment load analysis are:

1) There was an increase in sediment mutants from the original 12,631.34 tons/ha/year in 2007 to 13,390.20 tons/ha/year in 2020.
2) In the prediction of the USLE model, the sediment load is determined by the SDR (Sediment Delivery Ratio) value so that it cannot estimate and map the sediment flow that occurs.
3) In the prediction of the USPED model the landscape potential for erosion and soil deposition towards the steepest slope can be estimated and mapped.
4) The prediction results of the USPED model show that there is a spatial distribution of erosion and sediment hazard levels towards the steepest slope with a sediment area of 30.96% of the average land erosion.

Then the results of the USPED model sediment = ((Average potential erosion / USLE average soil loss) x USPED Sediment Percentage)

((95,918.45/2,242) * 30.96%) = 13,245.47Ton/ha/yr : 2,242 = 5,907.88M3/ha/yr

4) Sediment yield (USLE ~ USPED) = 5,989.16 ~ 5,907.88 = Average 5,948.52 M3/ha/yr.

J. Alopohu River Sediment Control Efforts

The ineffectiveness of the sediment control building is due to the non-operation of maintenance and rehabilitation of the sediment control building.

Based on this, the efforts that need to be made are:

1. Carry out maintenance operations and rehabilitation of sediment control buildings. In accordance with Circular Number: 05/SE/D/2016 Director General of Natural Resources, Ministry of Public Works concerning Guidelines for Operation and Maintenance of River Infrastructure and River Maintenance, in this case optimizing the utilization of river infrastructure, therefore to streamline the function of sediment control buildings it is necessary to dredge sediment in reservoirs , especially sediment that accumulates in front of the inlet (upstream) and outlet (downstream) gates is carried out at least 1 (one) time in 5 (five) years.

ALO sub-watershed

TABLE 21. Sediment Control Building Storage Volume (Chekdam) Alo River-Alo Sub-Watershed After Dredging

No	Nama BPS (Chekdam)	Thn	Inflow Sedimen	Volume Sedimen Dikendalikan	Outflow	Umur Layanan	Ket
		ke	(m^3)	(m^3)	(m^3)	(Tahun)	
1	ALO1 (2012)	1-2	5,779.94	6,781.95	1,002.01	1.17	Pengerukan
2	ALO2 (2012)	2-1	4,776.93	6,781.95	2,004.02	2.35	Pengerukan
3	ALO3 (2007)		-	-	-	-	
4	ALO4 (2012)	3-4	3,773.92	6,781.95	3,006.03	3.52	Pengerukan
5	ALO5 (2012)	4-5	2,773.90	3,600.03	826.10	4.14	Pengerukan
6	Alternatif BPS	5	4,953.84	4,953.84	-	5.00	Tambahan BPS Hulu
			22,061.53	28,899.63	(6,838.16)	5.00	

Sumber: Hasil Perhitungan

From the table, sediment control in the Alo Sub-watershed will be more effective if dredging is carried out and by adding alternative sediment control buildings, the operation and maintenance of river infrastructure and river maintenance on a regular basis once in 5 (years) can be fulfilled.

K. Sediment Control Building Effectiveness

Sediment handling in the form of chekdam construction/sediment control buildings on rivers in the research area has been widely carried out as an effort to reduce sediment transport from the Alopohu River to Limboto Lake.

TABLE 22. Sediment Control Building Storage Volume (Chekdam) Sungai Alo-Sub DAS Alo

No	Nama BPS (Chekdam)	Panjang Aliran	Volume Tampungan Sedimen			Ket
			Volume Sedimen Dikendalikan	Tampungan Tetap	Tampungan Sementara	
		(m)	(m^3)	(m^3)	(m^3)	
1	ALO1 (2012)	753.55	6,781.95	2,260.65	4,521.30	Penuh
2	ALO2 (2012)	753.55	6,781.95	2,260.65	4,521.30	Penuh
3	ALO3 (2007)	-	-	-	-	Rusak
4	ALO4 (2012)	753.55	6,781.95	2,260.65	4,521.30	Penuh
5	ALO5 (2012)	400.00	3,600.00	2,260.65	1,339.35	Penuh
			23,945.85	9,042.60	14,903.25	

Sumber: Hasil Perhitungan

TABLE 23. Storage Volume of Sediment Control Building (Chekdam) Molalahu River-Molamahu Sub-watershed

No	Nama BPS (Chekdam)	Panjang Aliran	Volume Tampungan Sedimen			Ket
			Volume Sedimen Dikendalikan	Tampungan Tetap	Tampungan Sementara	
		(m)	(m³)	(m³)	(m³)	
1	MOLAMAHU (2010)	312	3,743.54	1,247.85	2,495.69	Penuh
2	TALOLODO (2009)	-	-	-	-	Rusak
			3,743.54	1,247.85	2,495.69	

Sumber: Hasil Perhitungan

TABLE 24. Storage Volume of Sediment Control Building (Chekdam) Pulubala River CS - Pulubala Sub-watershed

No	Nama BPS (Chekdam)	Panjang Aliran	Volume Tampungan Sedimen			Ket
			Volume Sedimen Dikendalikan	Tampungan Tetap	Tampungan Sementara	
		(m)	(m³)	(m³)	(m³)	
1	WANGATA (2009)	-	-	-	-	Rusak
2	PULUBALA 1 (2007)	-	-	-	-	Rusak
3	PULUBALA 2 (2007)	-	-	-	-	Rusak
4	PULUBALA 3 (2007)	-	-	-	-	Rusak
5	REKSO 1 (2019)	500.68	4,005.48	1,335.16	2,670.32	Berfungsi
6	REKSO 2 (2014)	500.68	4,696.00	1,335.16	3,360.84	Penuh
7	REKSO 3 (2007)	-	-	-	-	Rusak
8	REKSO 4 (2019)	500.68	5,006.85	1,668.95	3,337.90	Berfungsi
			13,708.34	4,339.27	9,369.06	

Sumber: Hasil Perhitungan

TABLE 25. Sediment Control Building Storage Volume (Check Dam) Pihu River - Batu Layar Sub-watershed

No	Nama BPS (Chekdam)	Panjang Aliran	Volume Tampungan Sedimen			Ket
			Volume Sedimen Dikendalikan	Tampungan Tetap	Tampungan Sementara	
		(m)	(m³)	(m³)	(m³)	
1	POHU 1 (2017)	633.36	3,800.18	1,266.73	2,533.45	Penuh
2	POHU 2 (2017)	316.68	1,187.56	395.85	791.70	Penuh
3	POHU 3 (2013)	633.36	4,750.23	1,583.41	3,166.82	Penuh
4	POHU 4 (2012)	760.04	7,752.37	2,584.12	5,168.25	Penuh
5	POHU 5 (2014)	633.36	5,383.59	1,794.53	3,589	Penuh
6	POHU 6 (2012)	760.04	4,284.00	2,584.12	1,699.88	Penuh
7	POHU 7 (2012)	760.04	7,752.37	2,584.12	5,168.25	Penuh
			34,910.29	12,792.89	22,117.40	

Sumber: Hasil Perhitungan

The level of reduction of sediment control buildings / checkdams that have been built in each sub-watershed is based on the capacity of the storage volume with the following calculation results:

TABLE 26. Total Volume of Sediment Control Building Storage (Chekdam) Alopohu River

No	Nama Sub Das	Bangunan Pengendali Sedimen Eksisting								Total Volume Setiap Sub Das
1	ALO	ALO 1 (2012)	ALO 2 (2012)	ALO 3 (2007)	ALO 4 (2012)	ALO 5 (2012)				23,945.85
	Volume Sedimen	6,781.95	6,781.95	-	6,781.95	3,600.00	-			
2	MOLAMAHU	MOLALAHU (2010)	TOLOLODO (2009)							3,743.54
	Volume Sedimen	3,743.54	-	-	-	-	-			
3	PULUBALA	WANGATA (2009)	PULUBALA 1 (2007)	PULUBALA 2 (2007)	PULUBALA 3 (2007)	REKSO 1 (2019)	REKSO 2 (2014)	REKSO 3 (2007)	REKSO 4 (2019)	13,708.34
	Volume Sedimen	-	-	-	-	4,005.48	4,696.00	-	5,006.85	
4	BATULAYAR	POHU 1 (2017)	POHU 2 (2017)	POHU 3 (2013)	POHU 4 (2012)	POHU 5 (2014)	POHU 6 (2012)	POHU 7 (2012)		34,910.29
	Volume Sedimen	3,800.18	1,187.56	4,750.23	7,752.37	5,383.59	4,284.00	7,752.37	-	
Total Volume Tampungan (M3)										76,308.02

Sumber: Hasil Perhitungan

Calculation of the average sediment yield (sediment yield) for the USLE and USPED sub-watershed methods with the following calculation results:

TABLE 27. Total Alopohu River Sediment Load

No	Nama Sub Das	Erosi & Sedimen USLE		Erosi & Sedimen USPED		Rata - rata Erosi & Sedimen (USLE - USPED)		Rata - rata Sedimen (USLE - USPED) 2007 s/d 2020	Rata-rata Sedimen dalam 5 Tahun (USLE - USPED)
		2007	2020	2007	2020	2007	2020		
1	ALO	5,633.96	5,972.44	5,605.47	5,907.88	5,619.72	5,940.16	5,779.94	28,899.69
2	MOLAMAHU	5,074.68	4,462.27	2,909.89	2,603.76	3,992.29	3,533.01	3,762.65	18,813.25
3	PULUBALA	4,825.90	4,070.74	2,404.03	1,975.71	3,614.96	3,023.22	3,319.09	16,595.47
4	BATULAYAR	6,971.81	6,407.09	6,889.65	6,530.28	6,930.73	6,468.68	6,699.71	33,498.53
Total Muatan Sedimen Sungai Alopohu (M3)									97,806.940

Based on the calculation between the total storage volume of the existing sediment control building by comparing the total sediment load in 5 years, the service life for effectiveness is described in the calculation as follows:

Service Life of Sediment Control Building (Chekdam)

The effectiveness of the sediment control buildings / checkdams that have been built in each sub-watershed at the time of the research are as follows:

ALO sub-watershed

The condition of the Alo Sub-watershed sediment control building located on the Alo River at the time of this research was unable to contain the sediment rate because of the 5 (five) chekdam buildings there was 1 (one) chekdam built in 2009 in a damaged condition and 4 (four) buildings The chekdam, which was built in 2012, has a full reservoir.

Based on these conditions, the calculation of the effectiveness of the sediment control building for the last 8 (eight) years is as follows:

TABLE 28. Sediment Control Building Service Life (Chekdam)

No	Nama Sub DAS	Jumlah Bangunan	Volume Tampungan	Rata-rata Hasil Sedimen Dalam 5 Tahun (USLE - USPED)	Umur Layanan	Volume Tidak Terkendali
		Bh	M3	M3	Thn	M3
1	ALO	4	23,945.85	28,899.69	4.14	4,953.84
2	MOLAMAHU	1	3,743.54	18,813.25	0.99	15,069.71
3	PULUBALA	3	13,708.34	16,595.47	4.13	2,887.13
4	BATU LAYAR	7	34,910.29	33,498.53	5.21	(1,411.76)
	Total	15	76,308.02	97,806.94		21,498.92
Persentase Umur Layanan 72.39 %						

Sumber: Hasil Perhitungan

Effectiveness = Total sediment storage volume / (Average sediment yield x time) = 23,945.85 M3 / (5,779.94 m3 X 8 years) = 23,945.85 / 46,239.50

= 51.79%

Thus in the last 8 (eight) years excess sediment of 48.21% or 22,293.65 M3 is still transported downstream.

V. Conclusion

1. Based on the analysis results of the Universal Soil Loss Equation (USLE) erosion prediction model and the erosion and sediment prediction model of the Unit Stream Power Based Erosion Deposition model (USPED) in the Alopohu River catchment area (DTA) in the 2007-2020 period, they are as follows:
   - Alo sub-watershed

   Between the two models of erosion distribution on sediment yields, there are differences in the erosion values, namely:
     - 2007 = 11,377.43 ~ 6,523.98 Tons/ha/yr.
     - 2020 = 10.004.40 ~ 5,837.63 Tons/ha/yr

   Based on the average value of USLE and USPED, there was a decrease in sediment yield of 1,029.69 Tons/ha/yr: 14 years = 73.55 Tons/ha/yr.

   Comparison of land cover changes that affect the increase in erosion of the Alo sub-watershed in 2007 and 2020 is the increase in land area that has a high CP value, namely, settlements covering an area of 235.29 hectares (3.08%), agriculture of dry land mixed with shrubs 165.82 hectares (2.18%), agriculture Dry Land 135.34 Hectare (1.78%) and the decreasing area of land that has a low CP value, namely Shrubs decreased by 447.64 Hectare (5.89), Rice Fields 88.25 Hectare (1.16%) while Secondary Dry Land Forest although there is an increase in area but not significant is only 0.46 hectares (0.01%).
2. The results of the evaluation of sediment control efforts that must be carried out in the Alopohu River catchment area by adding sediment control buildings in rivers in the Sub-watershed area and dredging the existing (existing) sediment control structures.

   The results of the calculation of efficiency between the addition of new buildings to the service life of 5 (five) years are more efficient than carrying out Operation and Maintenance every year for 5 (five) years.

   Problems that occur in efforts to control erosion and sediment are:
     - Operations and maintenance of sediment control buildings are not carried out properly so that many buildings have been damaged and sediment storage is over capacity.
     - There is no change in land management in reducing the impact of erosion and sediment, especially in dry land agricultural areas in the Alo sub-watershed and in the Batu Layar sub-watershed, causing the level of erosion and sediment in the two sub-watersheds to tend to rise.
3. From the results of the Universal Soil Loss Equation (USLE) analysis and modeling using the Stream Power Based Erosion Deposition (USPED) Unit, the distribution of erosion potential and sediment/deposition can be estimated and mapped so that the placement of the Sediment Control Building location can be more effective in controlling the transport of sediment that occurs. occurs, the simulation results with the USPED model are as follows:
     - ALO Sub-watershed

   The placement of the sediment control buildings in the Alo Sub-watershed that has been built is in the downstream area of the Alo River which was built in a series of 5 (five) buildings, 1 (one) was damaged, 4 (four) in good condition were able to reduce sediment by 51.79% with a service life the reservoir is 4.14 years but the current condition of the building is no longer effective because the reservoir is full and unable to withstand and control the rate of sediment transport downstream.

References

[1] Alfianto Ardian, Cecilia Shandy, Ridwan Banata. 2020. Pemodelan Potensi Erosi Dan Sedimentasi Hulu Danau Limboto Dengan Watem/Sedem. Jurnal Teknik Hidraulik Vol. 11 No. 2

[2] Asdak Chay. 1995. Hidrologi dan Pengelolaan Daerah Aliran Sungai. Yogyakarta: Gadjah Mada University Press.

[3] Asdak, C. 2002. Hidrologi dan pengelolaan daerah aliran sungai. Gadjah Mada University Press. Yogyakarta

[4] Auliyani Diah, Wijaya Wahyu Wisnu. 2017. Perbandingan Prediksi Hasil Sedimen Menggunakan Pendekatan Model Universal Soil Loss Equation Dengan Pengukuran Langsung. Jurnal Penelitian Pengelolaan Daerah Aliran Sungai, Vol. 1 No. 61-71

[5] Bols PL. 1978. The Iso-eredent Map of Java and Madura. Report of the Belgian Technical Assistance Project ATA 105-Soil Research Institute, Bogor, Indonesia.

[6] Hardiyatmo, H.C. 2006. Mekanika Tanah I. Gadjah Mada University Press, Yogyakarta

[7] Hoffmann Anna, Aparecida Mayesse, Leandro Marx, Curi Nilton, Klinke Gustavo, Antonio Diego. 2013. Development of Topographic Factor Modeling for Application in Soil Erosion Models. Soil Processes and Current Trends in Quality Assessment

[8] Indarto. 2013. Variabilitas Spasial Hujan Harian di Jawa Timur. Jurnal Teknik Sipil, ISSN 0853-2982

[9] Kironoto, B.A. dan Yulistiyanto B., (2000), Diktat Kuliah Hidraulika Transpor Sedimen, PPS-Teknik Sipil,Yogyakarta.

[10] Lihawa Fitryane. 2009. The Effect Of Watershed Environmental Conditions And Land Use On Sediment Yield In Alo-Po Hu Watershed. lndonesian Journal of Geography IJG Vol. 41. No. 2.

[11] Mitasova Helena, Hofierka Jaroslav, Zlocha Maros, Iverson Louis. 2007. Modelling topographic potential for erosion and deposition using GIS. International Journal of Geographical Information Systems, Vol. 10, No. 5, 629-641.

[12] Peraturan Menteri Kehutanan Republik Indonesia, Nomor: P. 60 /Menhut-II/2014

[13] Prasetyo Dani, Dermawan Very, Primantyo Andre. 2015. Kajian Penanganan Sedimentasi Sungai Banjir Kanal Barat Kota Semarang. Jurnal Teknik Pengairan, Volume 6, Nomor 1, Mei 2015, hlm

[14] Rahman Faisal, Andawayanti Ussy, Limantara Lily. 2017. Analisa Nilai Erodibilitas Tanah Terhadap Laju Kehilangan Tanah Dengan Rainfall Simulator.

[15] Sandi Dwi, Mulyanto Djoko, Arbiwati Dyah. 2019. Kajian Erodibilitas Tanah Pada Beberapa Sub Group Tanah Di Kecamatan Semin. Jurnal Tanah dan Air, ISSN: 1411-5719(p): 2655-500X (e),

[16] Subardja Djadj, Ritung Sofyan, Anda Markus, Sukarman, Suryani Erna, Subandiono Rudi. 2016. Klasifikasi Tanah Nasional. Balai Besar Litbang Sumberdaya Lahan Pertanian Badan Penelitian dan Pengembangan Pertanian. Bogor

[17] Suripin. 2002. Pelestarian Sumber Daya Tanah dan Air. Yogyakarta: PenerbitAndi.

[18] Umar Indriani, Marsoyo Agam, Setiawan Bakti. 2018. Analisis Perubahan Penggunaan Lahan Sekitar Danau Limboto Di Kabupaten Gorontalo. Jurnal Tata Kota dan Daerah Volume 10, Nomor 2

[19] Weise Ryan. 2018. 1-Dimensional Hydraulic and Sediment Transport Modelling of an Emergency Spillway. Electronic Thesis and Dissertation Repository. 5551.

[20] I Made Yuliara, 2016. Modul Regresi Linier Berganda, Universitas Udayana, Bali

[21] Surat Edaran Direktorat Jenderal Sumber Daya Air, Kementerian PUPR Nomor 05/SE/D/2016, Tentang Pedoman Penyelenggaraan Kegiatan Operasi dan Pemeliharaan Prasarana Sungai Serta Pemeliharaan Sungai.