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by Aang Panji Permana

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Abstract*:* Damages to the land resources, mainly those happening on drainage basin at Alo, Gorontalo occur in consequence of degradation of the ground surface layer as hit by raindrops and rainwater flow that carry soil surface. This issue becomes quite serious due to illegal logging and agricultural land conversion, mostly for maize fields as one of Gorontalo's top commodities. The purpose of this tudy is to determine the level of erosion hazard in the Limboto Lake catchment area. In order to achieve these objectives two methods are used namely the field survey and documentation. The research material used includes of socio-biogeophysical characteristics of Alo drainage basin and analyzes the level of soil surface erosion. The result shows that 98.75 percent of erosion hazard is classified into low-to-moderate, covering approximately 6,874.721 hectares. Meanwhile, 1.25 percent of the high-to-extreme level of erosion hazard are 98.79 hectares wide. This suggests that inappropriate use of land is more likely to increase the erosion hazard rate.

Key Words: Erosion Hazard, Limboto Lake, Alo, Gorontalo

1. Introduction

Preserving conservations sites from threats is quite a duty these days. The treats are from various illegal activities, such as logging, hunting, kinds of land conversion, mineral exploration and exploitation, or conflict of land use [1]. It is important to manage land resources in the context of development in Indonesia years ahead, as now more complex challenges begin to emerge. These challenges are pressures from local people, land conversions and working shifts, forest degradation and land damages, and environmental damages and natural disasters. Therefore, a sustainable concept of land resources management focusing on tackling the challenges needs to be designed and formulated on local, regional and national scale [2].

Damages to land resources in watersheds are the after effect of loss of soil surface by rain drops and rainwater's carrying capacity, eventually creating a critical land zone. It is caused by over exploitations of productive lands and careless activities towards environment preservation. Some of the main factors to damage the catchment area are deforestation and cultivation with less or no appliance of soil conservation principles. As reported by State Ministry of Environment and Forestry, in entire Indonesia, floods in 2006 only affected 124 districts in total. The number increased to 240 districts in 2007. This was aggravated by pervasive spread of damaged catchment areas over Indonesia and nearly 4.2 percents of land conversion rate per year [3].

Limboto Lake is a natural lake located in Gorontalo regency, Indonesia. Stretched approximately 3.000 hectares wide, it is the estuary of 5 main rivers, namely Bone Bolango, Alo, Daenaa, Bionga, and Molamahu River. As an icon of both Gorontalo regency and province, Limboto Lake possesses a significant role, either as an ecological and hydrological function, or socio-economical support to the locals [4]. Functioning as hydrological support, it acts as a catchment area for the five top rivers, also as a control of disaster and erosion handling. It also acts as a model of biodiversity, providing habitat for plants and animals. Limboto Lake supports the locals in the socio-economical sector, delivering commodities for the fish farmers. Furthermore, it also takes part as a medium of cultural development, education and research, and as tourism object. Such important roles Limboto Lake possesses, that government needs to sustain its existence. Research on Lake Limboto has been carried out mainly on microfacies and uplift rate of limestone. There are three limestone microfacies in the slope to toe of slope depositional environment. While the rate of uplift limestone 0.0669-0.0724 mm/year [5,6].

Alo drainage basin is among the largest watersheds nearby Limboto Lake catchment area, having an area of 48.828 hectares, covering 52 percents of Limboto Lake catchment area, making it a benchmark when analyzing Limboto Lake catchment area entirely. One major quest needs to be solved the tendency of land functional shift by local people. Most of the locals are farmers. Thus they tend to explore land in the upstream area of the watershed, resulting in gradual deforestation. The forest is cut down then replaced by farms (mainly maize fields), as an effort of industrial extensification, without scrutiny analysis on the watershed's environmental support capacity. There is not enough intensive management and technology used in maize farms located in a hilly area of the watershed. As mentioned in [7], there was a decrease in the size of forests in Alo watershed, from 5,587 hectares on 2003 to 4,478 hectares two years later. By that, Alo watershed has more dry farmland and wide open ground than other sub-watersheds, also, most lands have a slope of 49.3 percent. On the other hand, farmlands expanded significantly from 1,398 hectares on 2003 to 30,338 hectares on 2005. This might trigger an increase in surface flow rate in the rainy season, being very prone to erosion. Lihawa then asserted that erosions in Alo were categorized as heavy ones, rated 190.36 tons/hectares/year or 9,294,695.62 tons/year in total. Meanwhile, as claimed in [8-10], erosion level of Limboto.

Lake catchment area has met the number of 9,902,588.12 tons/year. As per 2006, the area of the lake has shrunk into less than 3,000 hectares, with an average depth of 2.5 meters. The shrinkage occurred as a result of illegal logging and agricultural land conversions to maize fields. [4,10] also blamed the existence of water hyacinth, causing lake sedimentation and also damaging ecosystems of the lake. With that in mind, there is a bigger probability that flood might happen in high rainfall. It is worsened by the high rate of air humidity in Gorontalo, having 80.17 percents on average. The maximum rainfall with 24 rainy days is in December [3]. This evidence is enough as a proof of urgency to conserve Limboto Lake to reduce the rate of lake degradation. Hence, one needs to conduct a study on the level of erosion hazard on Limboto Lake catchment area.

2. Research Method

The research took place in Alo drainage basin, Tibawa District, Gorontalo Regency, Gorontalo Province, precisely at the west of Limboto District. Tibawa District is at the longitude of 122º46'56" – 122º53'47"E and latitude of 00º45'51" – 00º39'14"N. Alo river is a river with most sediment deposits of 124.83 tons/hectares flowing to Limboto Lake. Alo drainage basin covers six villages, namely Datahu, Iloponu, Buhu, Isimu Utara, Labanu, and Motilango village, all under the administration of Tibawa District. This is shown in Figure 1 as follows:

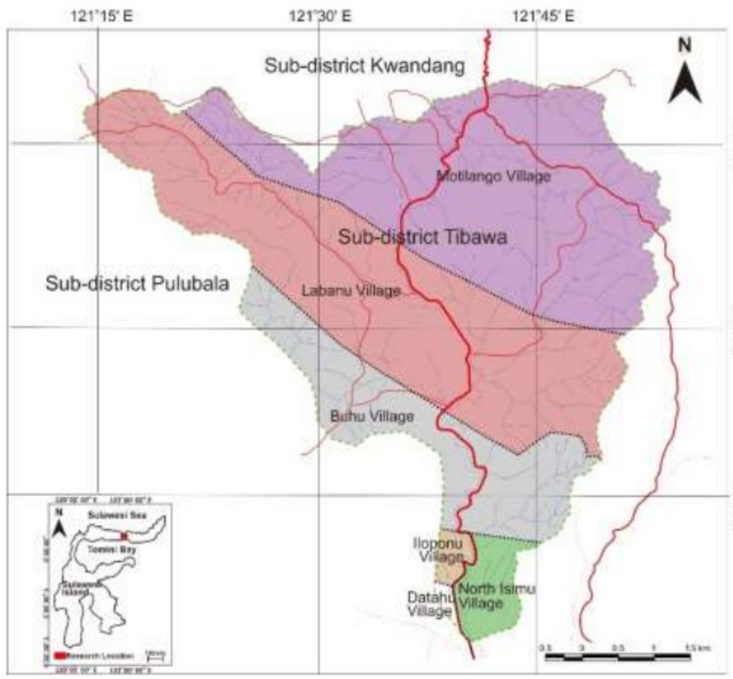

Figure 1. Map of Alo drainage basin

2.1 Data Collection

This study encompasses socio-biogeophysical characters of Alo watershed and involves the rate of surface erosion and tolerable erosion rate. Field observation and documentation were conducted to collect data of slope length and area, land use by the locals, varieties of plants, conservations completed, sufficient depth of soil, soil color and texture, land cover, and soil sampling.

The main climate data of the research are rainfall and air temperature. Data of rainfall are obtained from four rainfall stations, i.e., the meteorological station of Djalaluddin Airport, Alo station, Kwandang station, and Biyonga station. The obtained data then are converted into isohyetal map and rain erosivity map to acquire data of spatial rainfall and erosivity spread. The mock approach is preferred to extract data of the air temperature obtained from the meteorological station at Djalaludin Airport of Gorontalo.

2.2. Data Analysis

A descriptive analysis is performed to break down and present data of environmental condition of and land use in Alo watershed in forms of the table. The spatial and ecological approach is undergone by using Geographical Information System (GIS) to observe the spatial spread of environmental situation of the watershed, i.e., the condition of the hillside, soil, land use, socio-economy, and culture. The impact of actual land use towards erosion and land degradation is measured by comparison ratio of real soil erosion value (A) and tolerable soil erosion (T). Actual land use will not trigger land degradation if A < T, and vice versa. The impact is then classified into three categories, safe (A<), unsafe

(T<A<2T), and highly unsafe (A<2T).The data gathered is then set as a benchmark to measure erosion hazard rate. The parameters of measurement are the value of erosion rate and soil solum. The rate of erosion hazard is then arranged based on five criteria of level: extremely low, low, moderate, high, and extremely high [11]. The data is presented in Table 1.

Table 1. Measurement of erosion hazard rate

Erosion / Soil solum (cm)	Levels of erosion				
	I	II	III	IV	V
	Erosion (ton/ha/year)				
	< 15	15-60	60-180	180-480	> 480
Deep > 90	EL	L	M	H	EH
Moderate 60-90	L	M	H	EH	EH
Shallow 30-60	M	H	EH	EH	EH
Extremely Shallow < 30	H	EH	EH	EH	EH

Description:

EL: extremely low
L: low
M: moderate
H: high
EH: extremely high

3 Research Results and Discussion

3.1 Erosion Level

Erosion is a process of movement of the soil or its parts from a place to another by natural media [12]. There is a parametric model to predict the rate of erosion of a plot of a land developed by [13-14] called Universal Soil Loss Equation (USLE). USLE enables planners to predict average rate of erosion of a certain soil at a given slope steepness by a certain rain pattern for every kind of plantation and land conservation. It is an equation used to put various physical parameters and managements affecting erosion rate into six principal factors in which each value can be presented numerically.

Rain's kinetic energy plays a major role in determining erosion level as energy in a raindrop is responsible for the destruction of soil aggregates. Quantification of rain erosivity is based on data of average rainfall yearly, the number of rainy days and daily maximum rainfall collected from four mentioned stations. The next step is to interpolate calculations result of every rain station by EI30 to gather rain erosivity value of every land unit by ArcView 3.3 software, to be then overlapped by a map of a land unit. The result is in following Table 2.

Table 2. Erosivity calculation of every land unit in Alo drainage basin

No	Land unit	R	width (ha)
1	D_2IB	113000	76.36
2	D_1IIIB	53000	31.82
3	D_1IIIPc	190000	77.77
4	D_1IIIPt	420000	4.08
5	D_1IIPc	113000	154.83
6	D_1IIPt	190000	49.09
7	D_2Ipc	113000	486.63
8	D_2Ipm	420000	27.78

9	D_2Ipt	190000	301.32
10	D_1IVB	53000	252.30
11	D_1IVPc	392000	548.75
12	D_1IVPt	51000	30.99
13	D_1VB	198000	9.26
14	D_1VPc	1102000	35.36
15	F_1Ipk	48000	58.14
16	K_2IB	105000	59.19
17	K_1IIIB	165000	63.58
18	K_1IIIPc	165000	98.75
19	K_2Ipk	105000	52.00
20	K_2Ipm	186000	3.60
21	K_1IVB	165000	118.19
22	K_1IVPc	198000	101.36
23	S_3IB	303000	153.20
24	S_1IIB	303000	231.61
25	S_1IIIB	303000	57.18
26	S_1IIIPc	303000	424.00
27	S_1IIIPt	420000	17.19
28	S_1IIPc	282000	312.08
29	S_3Ipc	627000	1,010.54
30	S_3Ipm	190000	15.86
31	S_3Ipt	47000	165.24
32	S_1IVB	303000	6.83
33	S_1IVPc	282000	600.53
34	S_1IVPt	1102000	5.40
35	S_1VB	303000	67.20
36	S_1VPc	399000	47.12
37	S_4IB	393000	255.00
38	S_2IIIB	520000	201.46
39	S_2IIIPc	190000	439.54
40	S_4Ipc	190000	126.55
41	S_2IVB	303000	24.73
42	S_2IVPc	303000	138.27
43	S_2VB	303000	32.91

Alo watershed has C, D, and E climate type with rain intensity of 1,100-1,400 mm/year. It determines the power of raindrops toward the ground, a number of raindrops, rain spread area, and rate of soil erodibility. One of contributing factor of erosion rate is rain erosivity (R) presented in EI30; energy interaction with maximum rain intensity during 30 minutes; E stands for kinetic energy during a rain period in the ton- m ha-l cm-l rain, and 130 stands for maximum rain intensity during 30 minutes in cm/hour. The highest rate of erosivity in Alo watershed is 1,102,000 tons-m ha-l cm-l occurring on a land unit of structural hills of granite rocks (S1IVPt) with an area of 5.4 hectares, with class IV slope steepness and land use of shrubs. A similar rate of erosivity also occurred in D1VPc with an area of 35.36 hectares. Concurrently, the lowest rate of erosivity, 47,000 tons-m ha-l cm-l, took place on unit S1IPt with an area of 165.24 hectares. On karst hills, the highest rate of erosivity took place on unit K1IVPc and K21Pm, both with an area of 101.36 hectares and 3.6 hectares respectively, at a rate of 198.000 tons-m ha-1cm-1. What differentiates between both kinds of land is on their use, shrubs in granite rocks, and karst hills for settlements.

3.3. Soil Erodibility

Soil erodibility is the value of soil resistance against water erosion (infiltration and percolation). The rate of soil erodibility factor value (K) is determined by soil texture, structure, its permeability, and organic matter contained. Soil structure is observed at the place during field sampling, while other factors are seen by using soil core sampler. Furthermore, the data of each factor are classified based on the operational guide Field Technical Plan-Land Rehabilitation and Soil Conservation.

The value of soil erodibility is classified as a mean of measuring soil susceptibility rate against erosion. There are six classifications of the rate, from very low to very high [11]. The quantification result of K value presented in Table 4 is classified based on K value, to determine susceptibility rate of soil on every land unit in Alo drainage basin.

The four previous factors are critical in determining soil erodibility. When analyzing soil texture, one needs to observe the ratio of soil particle size and portion, forming three textures of soil: sand, silt, and clay. A bond between soil particles of clay-dominant soil texture is strong, making it more resistant to erosion. A soil texture dominated by sand has low susceptibility to erosion since the infiltration rate is high that it can minimize runoff water. Au contraire, silt-dominated soil texture are more likely to erode for it consists of a particle of soft sand and a little portion of organic matter.

Furthermore, elements of the C-organic matter by some means tends to restructure soil and increase its permeability, carrying capacity to absorb soil water, and its fertility. Accumulated organic elements on the ground surface can decrease the likelihood of erosion. Regarding soil structure factor, secondary soil particles can be formed apart from the primary soil particles. However, it is rare for them to be formed, in a profile in a given circumstance the particles can present unique pattern. These auxiliary units are sorted into classes, types, and levels. In conclusion, soil structure has an impact on how the soil can absorb water. Granular and loose soil structure can free the runoff water, decreasing surface water simultaneously.

Soil permeability is of how capable soil is to release the runoff water. It is also influenced by soil structure and texture, and organic matter. Consequently, the higher the permeability is, the rate of surface water flow are less likely to increase, since high permeability will trigger high infiltration rate. On the contrary, the water is more potential to turn into surface water flow when soil permeability is low. Nomograph and calculation formula are two methods used in computing soil erodibility (K value). By nomograph, some parameters need to be observed: a) soil texture (in a fraction of silt, very soft sand, and sand); b) amount of organic matter contained; c) soil structure, and d) soil permeability. The result shows that the smallest K value, 0.01, is on land units K1IIIB, K1IVB, and K1IIIPc. Meanwhile, the largest K value is in D1IPt, D1IVPc, and D1IVPt counted 0,118. Measurement result of soil erodibility by formula 8 is in the following Table 3.

Table 3. Calculation of soil erodibility rate in Alo watershed

Land unit	Area (hectares)	M	A	b (Soil structure)	c	K	Soil erodibility rate
D_2IB	76.36	68.19	2.95	2	5	0.07	Extremely Low
D_1IIIB	31.82	68.19	2.95	2	5	0.07	Extremely Low
D_1IIIPc	77.77	35.82	1.78	3	5	0.11	Low
D_1IIIPt	4.08	45.16	2.22	3	5	0.11	Low
D_1IIPc	154.83	68.19	2.95	2	5	0.07	Extremely Low
D_1IIPt	49.09	25.36	1.78	3	5	0.11	Low
D_2IPc	486.63	68.19	2.95	2	5	0.07	Extremely Low
D_2IPm	27.78	32.31	2.74	3	5	0.11	Low
D_2IPt	301.32	32.31	2.74	4	6	0.18	Low
D_1IVB	252.30	56.59	2.95	2	5	0.07	Extremely Low
D_1IVPc	548.75	32.31	2.74	4	6	0.18	Low
D_1IVPt	30.99	32.31	2.74	4	6	0.18	Low
D_1VB	9.26.	68.19	3.19	2	5	0.07	Extremely Low
D_1VPc	35.36	32.31	2.74	3	5	0.11	Low
F_1IPk	58.14	68.19	3.19	2	5	0.07	Extremely Low
K_2IB	59.19	68.19	3.19	2	5	0.07	Extremely Low
K_1IIIB	63.58	32.31	2.95	3	2	0.01	Extremely Low
K_1IIIPc	98.75	32.31	2.95	3	2	0.01	Extremely Low
K_2IPk	52.00	32.31	2.74	2	5	0.07	Extremely Low
K_2IPm	3.60	32.31	2.74	3	2	0.01	Extremely Low
K_1IVB	118.19	32.31	2.74	3	2	0.01	Extremely Low
K_1IVPc	101.36	32.31	2.74	3	5	0.11	Low
S_3IB	153.20	35.82	1.78	3	6	0.14	Low
S_1IIB	231.61	35.82	1.78	3	6	0.14	Low
S_1IIIB	57.18	35.82	1.78	3	6	0.14	Low
S_1IIIPc	424.00	35.82	1.78	3	6	0.14	Low
S_1IIIPt	17.19	32.31	2.74	3	5	0.11	Low
S_1IIPc	312.08	32.31	2.74	3	5	0.11	Low
S_3IPc	1,010.54	25.36	1.78	3	3	0.04	Extremely Low
S_3IPm	15.86	40.90	0.88	3	5	0.11	Low
S_3IPt	165.24	40.90	0.88	3	5	0.11	Low
S_1IVB	6.83	38.44	2.69	3	6	0.14	Low

S_1IVPc	600.53	38.44	3.60	3	5	0.11	Low
S_1IVPt	5.40	38.44	2.69	3	5	0.11	Low
S_1VB	67.20	35,82	1,78	3	6	0.14	Low
S_1VPc	47.12	25.36	1.78	3	3	0.04	Extremely Low
S_4IB	255.00	32.31	2.74	3	5	0.11	Low
S_2IIIB	201.46	32.31	2.74	3	5	0.11	Low
S_2IIIPc	439.54	32.31	2.74	3	5	0.11	Low
S_4IPc	126.55	32.31	2.74	3	5	0.11	Low
S_2IVB	24.73	35.82	1.78	3	6	0.14	Low
S_2IVPc	138.27	35.82	1.78	3	6	0.14	Low
S_2VB	32.91	35.82	1.78	3	6	0.14	Low

From Table 3, it can be concluded that K value of 0.04 spread on land units S1IPc and S1VPc, both having 1,010.54 and 47.12 hectares of area respectively. The difference between the two units lies on the structural hills of granite rocks with slope steepness of 0-8% and 25-40% respectively. Both land units are used as mixed dry farmland.

3.4 Prediction of Soil Surface Erosion

USLE (Universal Soil Loss Equation) formula is used to predict surface erosion in Alo drainage basin. This is a parametrical model developed by Wischmeier and Smith to predict the erosion of a land plot. The equation involves six factors influencing erosion rate, namely: rain erosivity (R), Soil erodibility (K), slope length (L), slope steepness (S), covering vegetations (C), and special treatment of soil conservation (P). The result of erosion rate is a prediction of average long-term erosion rate from erosion pattern under certain circumstance. The unit measured when analyzing erosion rate on a plot of a land is a land unit formed from overlapping result map of the landscape, slope steepness, land, and its use. The following Table 4 presents the quantification result of erosion rate in Alo watershed and its spread map as shown in Figure 2.

Table 4. Spread of soil surface erosion sorted by land units in Alo watershed

Land unit	Area (hectares)	R	K	LS	C	P	CP	Erosion rate (ton/year)	ton/ha/year
D_2IB	76,36	113000	0,068	0,400	0,010	0,350	0,004	10.698	0,140
D_1IIIB	31,82	53000	0,068	3,100	0,010	0,350	0,004	38.841	1,221
D_1IIIPc	77,77	190000	0,108	0,400	0,000	0,000	0,020	164.024	2,109
D_1IIIPt	4,08	420000	0,109	0,400	0,000	0,000	0,020	365.114	89,599
D_1IIPc	154,83	113000	0,068	0,400	0,010	0,350	0,004	10.698	0,069
D_1IIPt	49,09	190000	0,108	0,400	0,000	0,000	0,020	164.024	3,341
D_2Ipc	486,63	113000	0,068	0,400	0,010	0,350	0,004	10.698	0,022
D_2Ipm	27,78	420000	0,109	0,400	0,000	0,000	0,020	365.114	13,144
D_2Ipt	301,32	190000	0,182	0,400	0,010	0,150	0,002	20.771	0,069
D_1IVB	252,30	53000	0,068	3,100	0,010	0,350	0,004	38.841	0,154
D_1IVPc	548,75	392000	0,183	1,400	0,010	0,350	0,004	351.420	0,640
D_1IVPt	30,99	51000	0,182	3,100	0,010	0,350	0,004	100.821	3,253

D_1VB	9,26	198000	0,068	3,100	0,010	0,350	0,004	145.105	15,679
D_1VPc	35,36	1102000	0,108	3,100	0,010	0,150	0,002	553.680	15,657
F_1Ipk	58,14	48000	0,067	0,400	0,000	0,000	0,020	25.745	0,443
K_2IB	59,19	105000	0,068	0,400	0,010	1,500	0,015	42.604	0,720
K_1IIIB	63,58	165000	0,011	3,100	0,010	0,350	0,004	19.490	0,307
K_1IIIPc	98,75	165000	0,011	3,100	0,010	0,350	0,004	19.490	0,197
K_2Ipk	52,00	105000	0,068	0,400	0,010	1,500	0,015	42.604	0,819
K_2IPm	3,60	186000	0,011	0,400	0,010	0,350	0,004	2.835	0,788
K_1IVB	118,19	165000	0,011	3,100	0,010	0,350	0,004	19.490	0,165
K_1IVPc	101,36	198000	0,108	3,100	0,010	0,350	0,004	231.824	2,287
S_3IB	153,20	303000	0,141	3,100	0,010	0,350	0,004	461.999	3,016
S_1IIB	231,61	303000	0,141	3,100	0,010	0,350	0,004	461.999	1,995
S_1IIIB	57,18	303000	0,141	3,100	0,010	0,350	0,004	461.999	8,080
S_1IIIPc	424,00	303000	0,141	3,100	0,010	0,350	0,004	461.999	1,090
S_1IIIPt	17,19	420000	0,109	0,400	0,000	0,000	0,020	365.114	21,244
S_1IIPc	312,08	282000	0,108	1,400	0,010	0,350	0,004	149.705	0,480
S_3Ipc	1,010,54	627000	0,044	3,100	0,000	0,000	0,020	170.510	1,683
S_3Ipm	15,86	190000	0,108	1,400	0,010	0,350	0,004	100.865	6,360
S_3Ipt	165,24	47000	0,109	1,400	0,010	1,500	0,015	107.252	0,649
S_1IVB	6,83	303000	0,141	3,100	0,010	0,350	0,004	461.999	67,652
S_1IVPc	600,53	282000	0,108	1,400	0,010	0,350	0,004	149.705	0,249
S_1IVPt	5,40	1102000	0,108	3,100	0,010	0,150	0,002	554.494	102,608
S_1VB	67,20	303000	0,141	3,100	0,010	0,350	0,004	461.999	6,875
S_1VPc	47,12	399000	0,044	3,100	0,100	0,350	0,035	1906.223	40,456
S_4IB	255,00	393000	0,108	3,100	0,010	0,350	0,004	460,730	1,807
S_2IIIB	201,46	520000	0,108	3,100	0,010	0,350	0,004	610.514	3,031
S_2IIIPc	439,54	190000	0,108	1,400	0,010	0,350	0,004	100.865	0,229
S_4Ipc	126,55	190000	0,108	1,400	0,010	0,350	0,004	100.865	0,797
S_2IVB	24,73	303000	0,141	3,100	0,010	0,350	0,004	461.999	18,682
S_2IVPc	138,27	303000	0,141	3,100	0,010	0,350	0,004	461.999	3,341
S_2VB	32,91	303000	0,141	3,100	0,010	0,350	0,004	461.999	14,037

Table 4 elucidates that there are three groups of erosion rate; group I with A value more than 100 tons/hectare/year, group II having A value of 10-100 tons/hectare/year, and group III with less than 100 tons/hectare/year of value. Land unit S1IVPt (5.40 hectares) is included in the first panel, with A value of 102,608 tons/hectare/year, making it the largest A value of all units. It is due to the factors of slope length and steepness. It has average soil loss of 0.06 mm/year, being smaller compared to average soil loss of entire Alo watershed, losing 3.10 mm soil annually.

Group II consists of 9 land units, i.e.,: D1IIIPt (89.599 tons/ha/year), D2IPm (13.144 ton/ha/year), D1VB (15.679 ton/ha/year), D1VPc (15.657 ton/ha/year), S1IIIPt (21.244 ton/ha/year), S1IVB (67.652 ton/ha/year), S1VPc (40.456 ton/ha/year), S2IVB (18.682 ton/ha/year), and S2VB (14.037 ton/ha/year). In contrast to group I, rain erosivity and soil erodibility also partake in determining A value of this group, besides slope length and steepness, with soil erodibility becoming the most influencing factor.

Group III has 20 remaining land units, i.e., D2IB (0.140 ton/ha/year), D1IIIB (1.221 ton/ha/year), D1IIIPc (2.109 ton/ha/year), D1IIPc (0.069 ton/ha/year), D1IIPt (3.341 ton/ha/year), D2IPc (0.022 ton/ha/year), D2IPt (0.069 ton/ha/year), D1IVB (0.154 ton/ha/year), D1IVPc (0.640 ton/ha/year), D1IVPt (3.253 ton/ha/year), D2IB (0.140 ton/ha/year), D1IIIB (1.221 ton/ha/year), D1IIIPc (2.109 ton/ha/year), D1IIPc (0.069 ton/ha/year), D1IIPt (3.341 ton/ha/year), D2IPc (0.022 ton/ha/year), D2IPt (0.069 ton/ha/year), D1IVB (0.154 ton/ha/year), D1IVPc (0.640 ton/ha/year), and D1IVPt (3.253 ton/ha/year). Erosion rate of these units is quite small attributable to area of each unit, ergo, the average of soil loss in Alo watershed is classified as small with the loss of 3,1 mm soil annually.

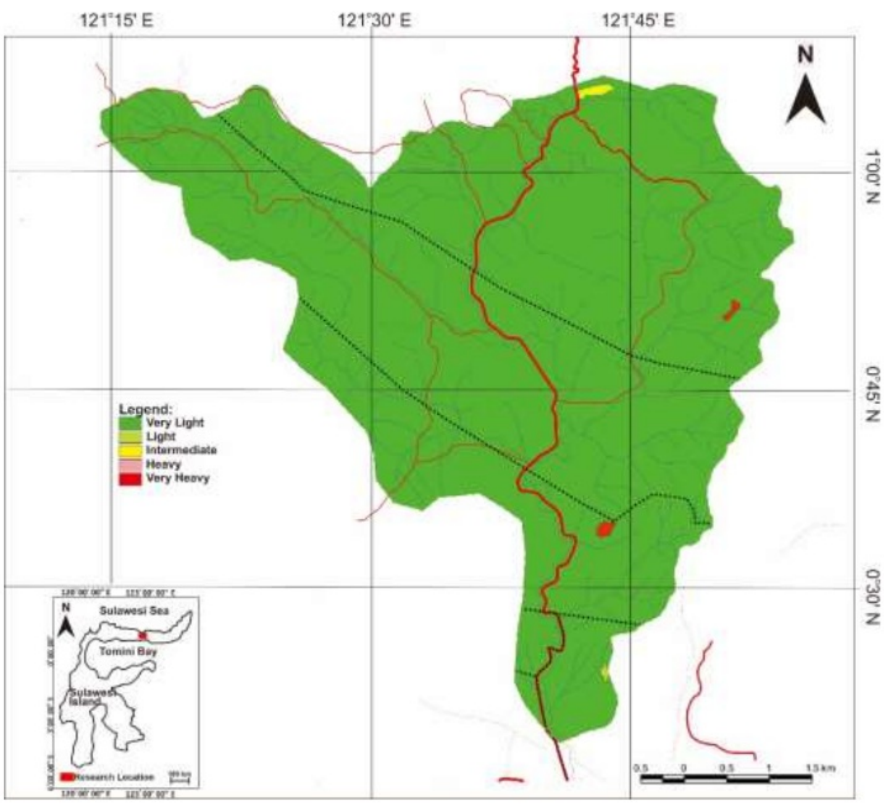

Figure 2. Map of soil surface erosion (A) of Alo watershed

Additionally, all land units of karst hills have a value below 10 ton/hectare/year, those are: K2IB (0.720 ton/ha/year), K1IIIB (0.307 ton/ha/year), K1IIIPc (0.197 ton/ha/year), K2IPk (0.819 ton/ha/year), K2IPm (0.788 ton/ha/year), K1IVB (0.165 ton/ha/year), and K1IVPc (2.287 ton/ha/year). The erosion rate is low, owing to low rate of rain erosivity.

3.5. Measurement of Tolerable Erosion Rate (T) and Erosion Hazard Rate (EHR)

It is substantial to measure the maximum limit of tolerable erosion rate as a reference when making decisions in the planning of land conservation. It is meant to preserve soil depth enough for the vegetations to live. T value is determined by some factors, i.e., the effective depth of soil, T value guideline, and weight of soil volume. T value of every land unit is measured up to the value of erosion rate (A). If $A < T$, actual erosion is less likely to cause land degradation. Otherwise, it is more likely for land degradation to happen if A

> T. This research then sorts impact of land use towards land degradation into three categories, explicitly, safe (A<T), unsafe (T<A<2T), and extremely unsafe (A<2T). The result of which is presented in Table 5. According to Table 5, five land units are included in extremely unsafe category, by reason of A value more than T value those are: D1IIIPt (89.599 tons/ha/year), S_1IIIPt (21.244 tons/ha/year), S_1IVB (67.652 tons/ha/year), S_1IVPt (102.608 tons/ha/year), and S_1VPc (40.456 tons/ha/year).

Table 5. Calculation of tolerable erosion rate and conservation need

Land unit	Area (hectare)	Erosion rate (ton/year)	T (ton/ha/year)	A (ton/ha/year)	Need of Conservation
D2IB	76,36	10,698	0,475	0,140	Conservation not needed
D1IIIB	31,82	38,841	0,19	1,221	Conservation needed
D1IIIPc	77,77	164,024	0,15	2,109	Conservation needed
D1IIIPt	4,08	365,114	0,2	89,599	Conservation needed
D1IIPc	154,83	10,698	0,3	0,069	Conservation not needed
D1IIPt	49,09	164,024	0,09	3,341	Conservation needed
D2Ipc	486,63	10,698	0,5	0,022	Conservation not needed
D2Ipm	27,78	365,114	0,09	13,144	Conservation needed
D2Ipt	301,32	20,771	0,5	0,069	Conservation not needed
D1IVB	252,30	38,841	0,45	0,154	Conservation not needed
D1IVPc	548,75	351,420	0,5	0,640	Conservation needed
D1IVPt	30,99	100,821	0,4	3,253	Conservation not needed
D1VB	9,26	145,105	0,225	15,679	Conservation needed
D1VPc	35,36	553,680	0,285	15,657	Conservation needed
F1Ipk	58,14	25,745	0,255	0,443	Conservation needed
K2IB	59,19	42,604	0,24	0,720	Conservation needed
K1IIIB	63,58	19,490	0,045	0,307	Conservation needed
K1IIIPc	98,75	19,490	0,21	0,197	Conservation needed
K2Ipk	52,00	42,604	0,27	0,819	Conservation needed
K2Ipm	3,60	2,835	0,27	0,788	Conservation needed
K1IVB	118,19	19,490	0,5	0,165	Conservation not needed
K1IVPc	101,36	231,824	0,105	2,287	Conservation needed
S3IB	153,20	461,999	0,2	3,016	Conservation needed
S1IIB	231,61	461,999	0,18	1,995	Conservation needed
S1IIIB	57,18	461,999	0,33	8,080	Conservation needed
S1IIIPc	424,00	461,999	0,11	1,090	Conservation needed
S1IIIPt	17,19	365,114	0,225	21,244	Conservation needed
S1IIPc	312,08	149,705	0,11	0,480	Conservation needed
S3Ipc	1,010,54	1700,510	0,195	1,683	Conservation needed
S3Ipm	15,86	100,865	0,12	6,360	Conservation needed
S3Ipt	165,24	107,252	0,18	0,649	Conservation not needed
S1IVB	6,83	461,999	0,06	67,652	Conservation needed
S1IVPc	600,53	149,705	0,08	0,249	Conservation needed
S1IVPt	5,40	554,494	0,09	102,608	Conservation needed
S1VB	67,20	461,999	0,075	6,875	Conservation needed
S1VPc	47,12	1906,223	0,035	40,456	Conservation needed
S4IB	255,00	460,730	0,2	1,807	Conservation needed
S2IIIB	201,46	610,514	0,135	3,031	Conservation needed

S2IIIPc	439,54	100,865	0,255	0,229	Conservation not needed
S4Ipc	126,55	100,865	0,425	0,797	Conservation needed
S2IVB	24,73	461,999	0,15	18,682	Conservation needed
S2IVPc	138,27	461,999	0,15	3,341	Conservation needed
S2VB	32,91	461,999	0,075	14,037	Conservation needed

Based on the previous table, denudational hills of granite rocks D_1IIIB (1,221 ton/hectare/year), D_1IIIPc (2,109 ton/hectare/year), D_1IIIPt 89,599 (ton/hectare/year),D_1IIPt (3,341 ton/hectare/year), D_1IPm (13,144 ton/hectare/year), D_1IVPc (0,640 ton/hectare/year), D_1VB (15,679 ton/hectare/year), and D_1VPc (15,657 ton/hectare/year) have A > T, henceforth are extremely unsafe and need an immediate conservation. It is on account of length and steepness factors of the slope. Further, the computation result of erosion rate is next applied to count erosion hazard rate with outcome of Table 5 as reference. As a way to figure out the value of erosion hazard rate, erosion rate, and soil solum are used as parameters. The parameters can help when determining five levels of erosion hazard; extremely low, low, moderate, high, and extremely high. The result is shown in Table 6.

Table 6. Erosion hazard rate at Alo watershed

Land unit	Area (ha)	Erosion rate (ton/th)	A (ton/ha/year)	Soil solum	EHL
K_1IVB	118.19	19.490	0,165	100	Moderate
K_1IVPc	101.36	231.824	2,287	35	Moderate
S_1IB	153.20	461.999	3,016	100	Low
S_1IIB	231.61	461.999	1,995	60	Low
S_1IIIB	57.18	461.999	8,080	75	Low
S_1IIIPc	424.00	461.999	1,090	75	Low
S_1IIIPt	17.19	365.114	21,244	75	Moderate
S_1IIPc	312.08	149.705	0,480	55	Extremely Low
S_3IPc	1.010.54	1700.510	1,683	65	Moderate
S_3IPm	15.86	100.865	6,360	60	Low
S_3IPt	165.24	107.252	0,649	60	Low
S_1IVB	6.83	461.999	67,652	30	High
S_1IVPc	600.53	149.705	0,249	40	Extremely Low
S_1IVPt	5.40	554.494	102,608	45	Extremely High
S_1VB	67.20	461.999	6,875	75	Low
S_1VPc	47.12	1906.223	40,456	35	High
S_4IB	255.00	460.730	1,807	40	Moderate
S_2IIIB	201.46	610.514	3,031	45	Moderate
S_2IIIPc	439.54	100.865	0,229	85	Low
S_4IPc	126.55	100.865	0,797	85	Low
S_2IVB	24.73	461.999	18,682	75	Moderate
S_2IVPc	138.27	461.999	3,341	75	Low
S_2VB	32.91	461.999	14,037	75	Low

The table shows that four land units, D_1IIIPt (89,599 ton/ha/year), D_1VPc (15.657 ton/ha/year), S1IVB (67.652 ton/ha/year), and S1IVPt (102.608 ton/ha/year) are in the critical zone. These units are scoring high to extremely high EHR value. This results from the slope steepness and CP value as the key factors. In particular, land unit D1IVPt is in class IV steepness. However, its use as dry farmland makes it under bad caretaking and accordingly has CP value of 0,007. Besides, soil solum of the unit is shallow, only 35 cm, by that, the actual erosion exceeds tolerable erosion rate. Further, Figure 3 displays spread map of EHR in Alo drainage basin.

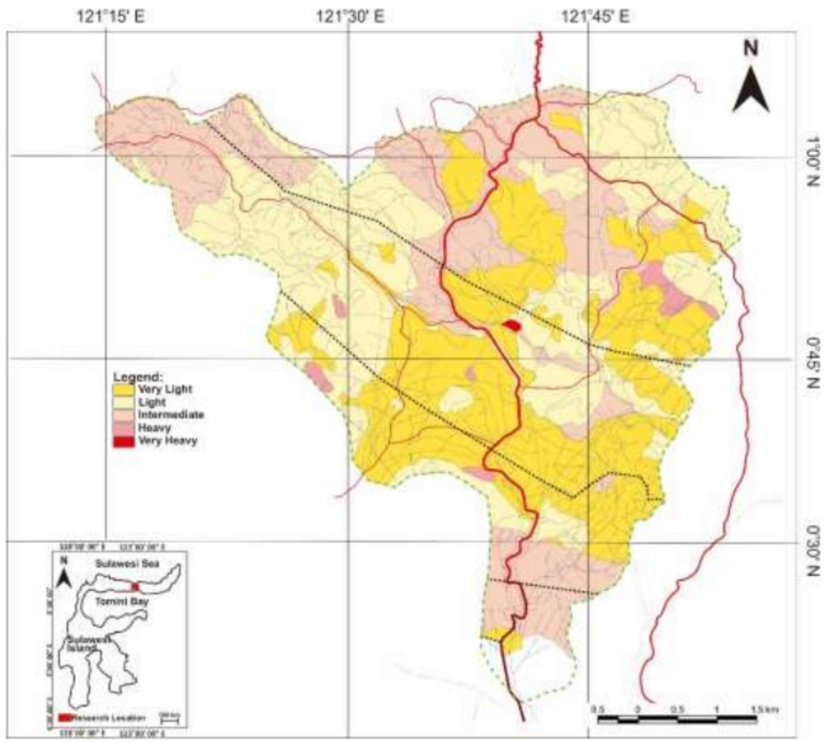

Figure 3. Map of Erosion Hazard Rate in Alo drainage basin

It shows that 98.75 percents of land units (a total of 6.874,21 hectares) in Alo watershed are in classified as extremely low to moderate. The remaining 1.25 percents are in high – extremely high rate. The maximum erosion hazard rate of Alo basin takes place in some land units. The units involved are D1IVPc (16.88 hectares) in Buhu Village, unit D1IVPc (7.71 hectares) in Labanu Village, two units; S1IVPc and S1IVB in Motilango Village (having area of 6.83 and 47.11 hectares respectively), and one unit in downstream of Alo basin, S1IVPt, with an area of 5.4 hectares. In total, land units categorized in extremely low hazard rate have accumulated area of 2.200,53 ha, those in the low category have a total of 2.776,64 ha, unit in the moderate class have 1.896,99 hectares, units in high and extremely high have a total area of 93.86 and 5.50 hectares in order. The analysis of erosion hazard spread points out that inappropriate land use in Alo watershed has brought the land capacity to the limit, if not taken care of, it will eventually increase the hazard rate.

Further, of 43 land units, there are 32 units to be taken action immediately, since the A value of the units exceed tolerable erosion rate. Most units are on structural hills with class III, IV, and V slope steepness. Those are: S2IVB (18.682 ton/ha/year), S2IVPc (3.341 ton/ha/year), S2VB (14.037 ton/ha/year), S1VPc (40.456 ton/ha/year), S1IVPt (102.608 ton/ha/year), and S1IVB (67.652 ton/ha/year). In conclusion, conservation is needed in most land units in Alo watershed to minimize the rate of soil surface erosion.

4. Conclusion

Slope length and its steepness are the key factors to contribute the value of erosion rate on a given land unit. 32 of 43 units of lands in Alo watershed have a value that exceeds tolerable erosion rate, by that, such actions of land conservation are needed. It mostly occurred on structural hills with class III, IV, and V slope steepness. The land units categorized in extremely low hazard rate have an overall area of 2.200,53 ha, while those in the low category are 2.776,64 hectares in total. Also, land units in the moderate class have a total of 1.896,99 ha, and units included in high and extremely high are of 93.86 and 5.50 hectares in order. The result of analysis asserts that improper land use is more likely to trigger an increase of the erosion level hazard.

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