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A study on the erosion hazard rate of Limboto Lake catchment area

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Abstract. Damages to the land resources, mainly those happening on the 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. As an attempt to analyze the problems, this study is undergone through field observation and documentation. This study covers aspects of socio-biogeophysical characteristics of the Alo drainage basin and analyzes the level of soil surface erosion and tolerable erosion rate. 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 is 98.79 hectares wide. This suggests that the inappropriate use of land is more likely to increase the erosion hazard rate.

1. Introduction

Preserving conservation 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. 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 (1) pressures from local people, (2) land conversions and working shifts, (3) forest degradation and land damages, and (4) 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 [1].

Damages to land resources in watersheds are the aftereffect of loss of soil surface by raindrops 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 on soil conservation principles. As reported by the 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 the pervasive spread of damaged catchment areas over Indonesia and nearly 4.2 percent of land conversion rates per year [2].



Limboto Lake is a natural lake located in Gorontalo regency. 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 [9]. Functioning as hydrological support, it acts as a catchment area for the five top rivers, also as 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 a tourism object. Such important roles Limboto Lake possesses, that government needs to sustain its existence.

Alo drainage basin is among the largest watersheds nearby the Limboto Lake catchment area, having an area of 48,828 hectares, covering 52 percent of the Limboto Lake catchment area, making it a benchmark when analyzing Limboto Lake catchment area entirely. One major quest needs to be solved by the tendency of a functional land shift by local people. Most of the locals are farmers. Thus they tend to explore the 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 Lihawa [3], there was a decrease in the size of forests in Alo watershed, from 5,587 hectares in 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 in 2003 to 30,338 hectares in 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 BPDAS-BB [4], Hidayat and Kakizawa [5], State Agency for Research and Development, and Control of Regional Environmental Impact [6], erosion level of Limboto Lake catchment area have 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. Subehi et al. [7] and Saleh et al. [8] 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 percent on average. The maximum rainfall with 24 rainy days is in December [2]. This evidence is enough as a proof of regency 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 the Limboto Lake catchment area.

2. Research Method

The research took place in the Alo drainage basin, Tibawa district, Gorontalo Regency, province of Gorontalo, precisely at the west of Limboto district. Tibawa district is at the longitude of 122° 46' 56" - 122° 53' 47" E and latitude of 0° 45' 51" - 0° 39' 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 and data analysis

2.1.1. Data collection. This study encompasses the 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 the 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.

2.1.2. Data analysis. A descriptive analysis is performed to break down and present data of environmental conditions 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 the environmental situation of the watershed, i.e., the condition of the hillside, soil, land use, socio-economy, and culture. The approach involves the following steps:

2.1.3. Level of erosion hazard. The impact of actual land use towards erosion and land degradation is measured by a 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 the 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. 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
	Erosiond (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

Source: Department Of Forestry (2004)

Description:

EL: extremely low

H: high

L: low

EH: extremely high

M: moderate

3. Research results and discussion

3.1. Erosion level

Arsyad [1] asserts that erosion is a process of movement of the soil or its parts from a place to another by natural media. There is a parametric model to predict the rate of erosion of a plot of land developed by Wischmeier and Smith [9] called Universal Soil Loss Equation (USLE). USLE enables planners to predict the 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.

3.2. Rain erosivity.

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 maximum daily rainfall collected from four mentioned stations.

The next step is to interpolate the calculations result of every rain station by EI_{30} 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 ₂ IB	113000,00	76.36
2	D ₁ IIIB	53000,00	31.82
3	D ₁ IIIPc	190000,00	77.77
4	D ₁ IIIPt	420000,00	4.08
5	D ₁ IIPc	113000,00	154.83
6	D ₁ IIPt	190000,00	49.09
7	D ₂ Ipc	113000,00	486.63
8	D ₂ Ipm	420000,00	27.78
9	D ₂ Ipt	190000,00	301.32
10	D ₁ IVB	53000,00	252.30
11	D ₁ IVPc	392000,00	548.75
12	D ₁ IVPt	51000,00	30.99
13	D ₁ VB	198000,00	9.26

14	D ₁ VPc	1102000,00	35.36
15	F ₁ Ipk	48000,00	58.14
16	K ₂ IB	105000,00	59.19
17	K ₁ IIIB	165000,00	63.58
18	K ₁ IIIPc	165000,00	98.75
19	K ₂ Ipk	105000,00	52.00
20	K ₂ Ipm	186000,00	3.60
21	K ₁ IVB	165000,00	118.19
22	K ₁ IVPc	198000,00	101.36
23	S ₃ IB	303000,00	153.20
24	S ₁ IIIB	303000,00	231.61
25	S ₁ IIIB	303000,00	57.18
26	S ₁ IIIPc	303000,00	424.00
27	S ₁ IIIPt	420000,00	17.19
28	S ₁ IIIPc	282000,00	312.08
29	S ₃ Ipc	627000,00	1,010.54
30	S ₃ Ipm	190000,00	15.86
31	S ₃ Ipt	47000,00	165.24
32	S ₁ IVB	303000,00	6.83
33	S ₁ IVPc	282000,00	600.53
34	S ₁ IVPt	1102000,00	5.40
35	S ₁ IVB	303000,00	67.20
36	S ₁ VPc	399000,00	47.12
37	S ₄ IB	393000,00	255.00
38	S ₂ IIIB	520000,00	201.46
39	S ₂ IIIPc	190000,00	439.54
40	S ₄ Ipc	190000,00	126.55
41	S ₂ IVB	303000,00	24.73
42	S ₂ IVPc	303000,00	138.27
43	S ₂ VB	303000,00	32.91

Also, the 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 the contributing factors 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 rainy period in the ton-m ha-l cm-l rain, and I30 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-l cm-l. What differentiates between both kinds of land is on their use, shrubs in granite rocks, and karst hills for settlements. Following figure 2 shows the full spread of rain erosivity.

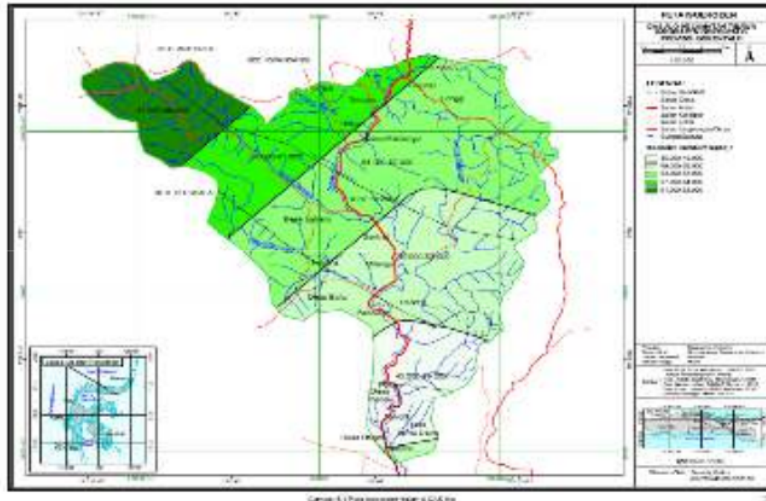


Figure 2. Spread of rain erosivity in Alo drainage basin

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, 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 of *Rencana Teknik Lapangan-Rehabilitasi Lahan dan Konservasi Tanah* (Field Technical Plan-Land Rehabilitation and Soil Conservation).

The value of soil erodibility is classified as a means of measuring soil susceptibility rates against erosion. Arsyad [10] denotes that there are six classifications of the rate, from very low to very high. The quantification result of the K value presented in Table 5.3 is classified based on K value to determine the susceptibility rate of soil on every land unit in the 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 is 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 factors, 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 patterns. 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 is less likely to increase since high permeability will trigger a 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. The 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 ₂ IB	76.36	68.19	2.95	2	5	0.07	Extremely Low
D ₁ IIIB	31.82	68.19	2.95	2	5	0.07	Extremely Low
D ₁ IIIPc	77.77	35.82	1.78	3	5	0.11	Low
D ₁ IIIPt	4.08	45.16	2.22	3	5	0.11	Low
D ₁ IIPc	154.83	68.19	2.95	2	5	0.07	Extremely Low
D ₁ IIPt	49.09	25.36	1.78	3	5	0.11	Low
D ₂ IPc	486.63	68.19	2.95	2	5	0.07	Extremely Low
D ₂ IPm	27.78	32.31	2.74	3	5	0.11	Low
D ₂ IPt	301.32	32.31	2.74	4	6	0.18	Low
D ₁ IVB	252.30	56.59	2.95	2	5	0.07	Extremely Low
D ₁ IVPc	548.75	32.31	2.74	4	6	0.18	Low
D ₁ IVPt	30.99	32.31	2.74	4	6	0.18	Low
D ₁ VB	9.26	68.19	3.19	2	5	0.07	Extremely Low
D ₁ VPc	35.36	32.31	2.74	3	5	0.11	Low
F ₁ IPk	58.14	68.19	3.19	2	5	0.07	Extremely Low
K ₂ IB	59.19	68.19	3.19	2	5	0.07	Extremely Low
K ₁ IIIB	63.58	32.31	2.95	3	2	0.01	Extremely Low
K ₁ IIIPc	98.75	32.31	2.95	3	2	0.01	Extremely Low
K ₂ IPk	52.00	32.31	2.74	2	5	0.07	Extremely Low
K ₂ IPm	3.60	32.31	2.74	3	2	0.01	Extremely Low
K ₁ IVB	118.19	32.31	2.74	3	2	0.01	Extremely Low
K ₁ IVPc	101.36	32.31	2.74	3	5	0.11	Low
S ₃ IB	153.20	35.82	1.78	3	6	0.14	Low
S ₁ IIB	231.61	35.82	1.78	3	6	0.14	Low
S ₁ IIIB	57.18	35.82	1.78	3	6	0.14	Low
S ₁ IIIPc	424.00	35.82	1.78	3	6	0.14	Low
S ₁ IIIPt	17.19	32.31	2.74	3	5	0.11	Low
S ₁ IIPc	312.08	32.31	2.74	3	5	0.11	Low
S ₃ IPc	1,010.54	25.36	1.78	3	3	0.04	Extremely Low
S ₃ IPm	15.86	40.90	0.88	3	5	0.11	Low
S ₃ IPt	16524	40.90	0.88	3	5	0.11	Low
S ₁ IVB	6.83	38.44	2.69	3	6	0.14	Low
S ₁ IVPc	600.53	38.44	3.60	3	5	0.11	Low
S ₁ IVPt	5.40	38.44	2.69	3	5	0.11	Low
S ₁ VB	67.20	35.82	1.78	3	6	0.14	Low
S ₁ VPc	47.12	25.36	1.78	3	3	0.04	Extremely Low
S ₄ IB	255.00	32.31	2.74	3	5	0.11	Low
S ₂ IIIB	201.46	32.31	2.74	3	5	0.11	Low
S ₂ IIIPc	439.54	32.31	2.74	3	5	0.11	Low
S ₄ IPc	126.55	32.31	2.74	3	5	0.11	Low
S ₂ IVB	24.73	35.82	1.78	3	6	0.14	Low
S ₂ IVPc	138.27	35.82	1.78	3	6	0.14	Low
S ₂ VB	32.91	35.82	1.78	3	6	0.14	Low

From table 3, it can be concluded that the 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 the 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 circumstances. The unit measured when analyzing erosion rate on a plot of 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 3.

Table 4. The 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 ₂ IB	76.36	113000	0.068	0.400	0.010	0.350	0.004	10.698	0.140
D ₁ IIIB	31.82	53000	0.068	3.100	0.010	0.350	0.004	38.841	1.221
D ₁ IIIPc	77.77	190000	0.108	0.400	0.000	0.000	0.020	164.024	2.109
D ₁ IIIPt	4.08	420000	0.109	0.400	0.000	0.000	0.020	365.114	89.599
D ₁ IIPc	154.83	113000	0.068	0.400	0.010	0.350	0.004	10.698	0.069
D ₁ IIPt	49.09	190000	0.108	0.400	0.000	0.000	0.020	164.024	3.341
D ₂ Ipc	486.63	113000	0.068	0.400	0.010	0.350	0.004	10.698	0.022
D ₂ Ipm	27.78	420000	0.109	0.400	0.000	0.000	0.020	365.114	13.144
D ₂ Ipt	301.32	190000	0.182	0.400	0.010	0.150	0.002	20.771	0.069
D ₁ IVB	252.30	53000	0.068	3.100	0.010	0.350	0.004	38.841	0.154
D ₁ IVPc	548.75	392000	0.183	1.400	0.010	0.350	0.004	351.420	0.640
D ₁ IVPt	30.99	51000	0.182	3.100	0.010	0.350	0.004	100.821	3.253
D ₁ VB	9.26	198000	0.068	3.100	0.010	0.350	0.004	145.105	15.679
D ₁ VPc	35.36	1102000	0.108	3.100	0.010	0.150	0.002	553.680	15.657
F ₁ Ipk	58.14	48000	0.067	0.400	0.000	0.000	0.020	25.745	0.443
K ₂ IB	59.19	105000	0.068	0.400	0.010	1.500	0.015	42.604	0.720
K ₁ IIIB	63.58	165000	0.011	3.100	0.010	0.350	0.004	19.490	0.307
K ₁ IIIPc	98.75	165000	0.011	3.100	0.010	0.350	0.004	19.490	0.197
K ₂ Ipk	52.00	105000	0.068	0.400	0.010	1.500	0.015	42.604	0.819
K ₂ IPm	3.60	186000	0.011	0.400	0.010	0.350	0.004	2.835	0.788
K ₁ IVB	118.19	165000	0.011	3.100	0.010	0.350	0.004	19.490	0.165
K ₁ IVPc	101.36	198000	0.108	3.100	0.010	0.350	0.004	231.824	2.287
S ₃ IB	153.20	303000	0.141	3.100	0.010	0.350	0.004	461.999	3.016
S ₁ IIIB	231.61	303000	0.141	3.100	0.010	0.350	0.004	461.999	1.995
S ₁ IIIPc	57.18	303000	0.141	3.100	0.010	0.350	0.004	461.999	8.080
S ₁ IIIPt	424.00	303000	0.141	3.100	0.010	0.350	0.004	461.999	1.090

S ₁ IIIpt	17.19	420000	0.109	0.400	0.000	0.000	0.020	365.114	21.244
S ₁ IIPc	312.08	282000	0.108	1.400	0.010	0.350	0.004	149.705	0.480
S ₃ Ipc	1.010.54	627000	0.044	3.100	0.000	0.000	0.020	1700.510	1.683
S ₃ Ipm	15.86	190000	0.108	1.400	0.010	0.350	0.004	100.865	6.360
S ₃ Ipt	165.24	47000	0.109	1.400	0.010	1.500	0.015	107.252	0.649
S ₁ IVB	6.83	303000	0.141	3.100	0.010	0.350	0.004	461.999	67.652
S ₁ IVPc	600.53	282000	0.108	1.400	0.010	0.350	0.004	149.705	0.249
S ₁ IVPt	5.40	1102000	0.108	3.100	0.010	0.150	0.002	554.494	102.608
S ₁ VB	67.20	303000	0.141	3.100	0.010	0.350	0.004	461.999	6.875
S ₁ VPC	47.12	399000	0.044	3.100	0.100	0.350	0.035	1906.223	40.456
S ₄ IB	255.00	393000	0.108	3.100	0.010	0.350	0.004	460.730	1.807
S ₂ IIIB	201.46	520000	0.108	3.100	0.010	0.350	0.004	610.514	3.031
S ₂ IIIPc	439.54	190000	0.108	1.400	0.010	0.350	0.004	100.865	0.229
S ₄ Ipc	126.55	190000	0.108	1.400	0.010	0.350	0.004	100.865	0.797
S ₂ IVB	24.73	303000	0.141	3.100	0.010	0.350	0.004	461.999	18.682
S ₂ IVPc	138.27	303000	0.141	3.100	0.010	0.350	0.004	461.999	3.341
S ₂ VB	32.91	303000	0.141	3.100	0.010	0.350	0.004	461.999	14.037



Figure 3. Map of soil surface erosion (A) of Alo watershed

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, beside 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), D₁IIIPt (0.069 ton/ha/year), D₁IIIPt (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), D₁IIIPt (0.069 ton/ha/year), D₁IIIPt (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). The erosion rate of these units is quite low attributable to the 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.

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 the 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 the extremely unsafe category, by reason of A value more than T value those are: D₁IIIPt (89.599 tons/ha/year), S₁IIIPt (21,244 tons/ha/year), S₁IVB (67.652 tons/ha/year), S₁IVPt (102.608 tons/ha/year), and S₁VPc (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 for Conservation
D ₂ IB	76.36	10.698	0.475	0.140	Conservation not needed
D ₁ IIIB	31.82	38.841	0.19	1.221	Conservation needed
D ₁ IIIPc	77.77	164.024	0.15	2.109	Conservation needed
D ₁ IIIPt	4.08	365.114	0.2	89.599	Conservation needed
D ₁ IIPc	154.83	10.698	0.3	0.069	Conservation not needed
D ₁ IIPt	49.09	164.024	0.09	3.341	Conservation needed
D ₂ Ipc	486.63	10.698	0.5	0.022	Conservation not needed
D ₂ Ipm	27.78	365.114	0.09	13.144	Conservation needed
D ₂ Ipt	301.32	20.771	0.5	0.069	Conservation not needed
D ₁ IVB	252.30	38.841	0.45	0.154	Conservation not needed
D ₁ IVPc	548.75	351.420	0.5	0.640	Conservation needed
D ₁ IVPt	30.99	100.821	0.4	3.253	Conservation not needed
D ₁ VB	9.26	145.105	0.225	15.679	Conservation needed
D ₁ VPc	35.36	553.680	0.285	15.657	Conservation needed
F ₁ Ipk	58.14	25.745	0.255	0.443	Conservation needed
K ₂ IB	59.19	42.604	0.24	0.720	Conservation needed
K ₁ IIIB	63.58	19.490	0.045	0.307	Conservation needed

K ₁ IIIPc	98.75	19.490	0.21	0.197	Conservation needed
K ₂ lpk	52.00	42.604	0.27	0.819	Conservation needed
K ₂ lpm	3.60	2.835	0.27	0.788	Conservation needed
K ₁ IVB	118.19	19.490	0.5	0.165	Conservation not needed
K ₁ IVPc	101.36	231.824	0.105	2.287	Conservation needed
S ₃ IB	153.20	461.999	0.2	3.016	Conservation needed
S ₁ IIB	231.61	461.999	0.18	1.995	Conservation needed
S ₁ IIIB	57.18	461.999	0.33	8.080	Conservation needed
S ₁ IIIPc	424.00	461.999	0.11	1.090	Conservation needed
S ₁ IIIPt	17.19	365.114	0.225	21.244	Conservation needed
S ₁ IIPc	312.08	149.705	0.11	0.480	Conservation needed
S ₃ Ipc	1,010.54	1,700.510	0.195	1.683	Conservation needed
S ₃ lpm	15.86	100.865	0.12	6.360	Conservation needed
S ₃ lpt	165.24	107.252	0.18	0.649	Conservation not needed
S ₁ IVB	6.83	461.999	0.06	67.652	Conservation needed
S ₁ IVPc	600.53	149.705	0.08	0.249	Conservation needed
S ₁ IVPt	5.40	554.494	0.09	102.608	Conservation needed
S ₁ VB	67.20	461.999	0.075	6.875	Conservation needed
S ₁ VPc	47.12	1.906.223	0.035	40.456	Conservation needed
S ₄ IB	255.00	460.730	0.2	1.807	Conservation needed
S ₂ IIIB	201.46	610.514	0.135	3.031	Conservation needed
S ₂ IIIPc	439.54	100.865	0.255	0.229	Conservation not needed
S ₄ Ipc	126.55	100.865	0.425	0.797	Conservation needed
S ₂ IVB	24.73	461.999	0.15	18.682	Conservation needed
S ₂ IVPc	138.27	461.999	0.15	3.341	Conservation needed
S ₂ VB	32.91	461.999	0.075	14.037	Conservation needed

Based on the previous table, denudational hills of granite rocks D₁IIIB (1.221 ton/hectare/year), D₁IIIPc (2.109 ton/hectare/year), D₁IIIPt 89.599 (ton/hectare/year), D₁IIPt (3.341 ton/hectare/year), D₁IPm (13.144 ton/hectare/year), D₁IVPc (0.640 ton/hectare/year), D₁VB (15.679 ton/hectare/year), and D₁VPc (15.657 ton/hectare/year) have $A > T$, henceforth are extremely unsafe and need an immediate conservation. It is on account of the length and steepness factors of the slope. Further, the computation result of the erosion rate is next applied to count erosion hazard rate with the outcome of Table 5 as reference.

As a way to figure out the value of erosion hazard rate, erosion rate, and soil solum is 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
D ₂ IB	76.36	10.698	0.140	95	Extremely Low
D ₁ IIIB	31.82	38.841	1.221	95	Extremely Low
D ₁ IIIPc	77.77	164.024	2.109	75	Extremely Low

D ₁ IIIPt	4.08	365.114	89.599	100	High
D ₁ IIPc	154.83	10.698	0.069	100	Extremely Low
D ₁ IIPt	49.09	164.024	3.341	30	Extremely Low
D ₂ IIPc	486.63	10.698	0.022	100	Extremely Low
D ₂ IIPm	27.78	365.114	13.144	45	Low
D ₂ IIPt	301.32	20.771	0.069	100	Extremely Low
D ₁ IVB	252.30	38.841	0.154	90	Extremely Low
D ₁ IVPc	548.75	351.420	0.640	60	Low
D ₁ IVPt	30.99	100.821	3.253	80	Low
D ₁ VB	9.26	145.105	15.679	75	Moderate
D ₁ VPc	35.36	553.680	15.657	95	High
F ₁ IIPk	58.14	25.745	0.443	85	Extremely Low
K ₂ IB	59.19	42.604	0.720	80	Extremely Low
K ₁ IIIB	63.58	19.490	0.307	45	Moderate
K ₁ IIIPc	98.75	19.490	0.197	70	Moderate
K ₂ IIPk	52.00	42.604	0.819	90	Extremely Low
K ₂ IIPm	3.60	2.835	0.788	90	Extremely Low
K ₁ IVB	118.19	19.490	0.165	100	Moderate
K ₁ IVPc	101.36	231.824	2.287	35	Moderate
S ₁ IB	153.20	461.999	3.016	100	Low
S ₁ IIIB	231.61	461.999	1.995	60	Low
S ₁ IIIB	57.18	461.999	8.080	75	Low
S ₁ IIIPc	424.00	461.999	1.090	75	Low
S ₁ IIIPt	17.19	365.114	21.244	75	Moderate
S ₁ IIPc	312.08	149.705	0.480	55	Extremely Low
S ₃ IIPc	1,010.54	1700.510	1.683	65	Moderate
S ₃ IIPm	15.86	100.865	6.360	60	Low
S ₃ IIPt	165.24	107.252	0.649	60	Low
S ₁ IVB	6.83	461.999	67.652	30	High
S ₁ IVPc	600.53	149.705	0.249	40	Extremely Low
S ₁ IVPt	5.40	554.494	102.608	45	Extremely High
S ₁ VB	67.20	461.999	6.875	75	Low
S ₁ VPc	47.12	1,906.223	40.456	35	High
S ₄ IB	255.00	460.730	1.807	40	Moderate
S ₂ IIIB	201.46	610.514	3.031	45	Moderate

S ₂ IIIPc	439.54	100.865	0.229	85	Low
S ₄ IPc	126.55	100.865	0.797	85	Low
S ₂ IVB	24.73	461.999	18.682	75	Moderate
S ₂ IVPc	138.27	461.999	3.341	75	Low
S ₂ VB	32.91	461.999	14.037	75	Low

The table shows that four land units, D₁IIIPt (89.599 ton/ha/year), D₁VPC (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 a CP value of 0.007. Besides, soil solum of the unit is shallow, only 35 cm, by that, the actual erosion exceeds the tolerable erosion rate. Further, figure 6 displays the spread map of EHR in the Alo drainage basin.



Figure 4. Map of Erosion Hazard Rate in Alo drainage basin

It shows that 98.75 percent of land units (a total of 6,874.21 hectares) in Alo Watershed are classified as extremely low to moderate. The remaining 1.25 percents are at a high – extremely high rate. The maximum erosion hazard rate of the 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, units 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), S₁IVPc (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 to 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 the analysis asserts that improper land use is more likely to trigger an increase in the erosion level hazard.

References

- [1] Worosuprojo S 2002 Studi erosi parit dan longsor dengan pendekatan geomorfologis di Daerah Aliran Sungai Oyo di Daerah Istimewa Yogyakarta
- [2] BAPPEDA 2009 *Rencana Tata Ruang Wilayah Provinsi Gorontalo 2008 – 2015* (Gorontalo)
- [3] Lihawa F 2009 Pengaruh kondisi lingkungan DAS dan penggunaan lahan terhadap hasil sedimen pada DAS Alo-Pohu Provinsi Gorontalo
- [4] BPDAS-BB 2004 *Technical Planning for Land Rehabilitation and Soil Conservation for Limboto Watershed (Book 1)* (Gorontalo)
- [5] Hidayat G G and Kakizawa H 2014 Development Process of Watershed Partnership: a Case Study of Limboto Watershed-Gorontalo, Indonesia *Indones. J. For. Res.* **1** 9–20
- [6] BALITBANGPEDALDA 2006 *Regional Environmental Status, Gorontalo Province Year 2005 (p. 7)*. (Gorontalo)
- [7] Subehi L, Wibowo H and Jung K 2016 Characteristics of Rainfall-Discharge and Water Quality at Limboto Lake, Gorontalo, Indonesia *J. Eng. Technol. Sci.* **48** 288–300
- [8] Saleh S E, Baiquni M and Yunus H S Determinants of Socio-Demography and Household Livelihood (A Study in Iluta and Limehe Timur Village, Gorontalo Regency) *Age (Omaha)*. **15** 19
- [9] Wischmeier W H, Johnson C B and Cross B V 1971 Soil erodibility nomograph for farmland and construction sites *J. soil water Conserv.*
- [10] Arsyad 2010 *Konservasi Tanah dan Air* (Bogor: IPB Press)

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