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EROSION HAZARD ANALYSIS IN THE LIMBOTO LAKE CATCHEMENT AREA, GORONTALO PROVINCE, INDONESIA

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.

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]. 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.

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 122°46'56" – 122°53'47"E and latitude of 00°45'51" – 00°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

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.

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].

Research Results and Discussion. 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). 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.

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. The highest rate of erosivity in Alo watershed is 1,102,000 tons-m ha^{-1} cm^{-1} 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. 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.

Prediction of Soil Surface Erosion. here 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. All land units of karst hills have a value below 10 ton/hectare/year. The erosion rate is low, owing to low rate of rain erosivity.

Measurement of Tolerable Erosion Rate (T) and Erosion Hazard Rate (EHR). The result of which is presented in table 1. According to table 1, 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), 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).

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 2. 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 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 2 displays spread map of EHR in Alo drainage basin.

Table 1 – 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	1,906,223	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

Table 2 – Erosion hazard rate at Alo watershed

Land unit	Soil solum	EHL
D2IB	95	Extremely Low
D1IIIB	95	Extremely Low
D1IIIPc	75	Extremely Low
D1IIIPt	100	High
D1IIPc	100	Extremely Low
D1IIPt	30	Extremely Low
D2IPc	100	Extremely Low
D2IPm	45	Low
D2IPt	100	Extremely Low
D1IVB	90	Extremely Low
D1IVPc	60	Low
D1IVPt	80	Low
D1VB	75	Moderate
D1VPc	95	High
F1IPk	85	Extremely Low
K2IB	80	Extremely Low
K1IIIB	45	Moderate
K1IIIPc	70	Moderate
K2IPk	90	Extremely Low
K2IPm	90	Extremely Low
K1IVB	100	Moderate
K1IVPc	35	Moderate
S1IB	100	Low
S1IIB	60	Low
S1IIIB	75	Low
S1IIIPc	75	Low
S1IIIPt	75	Moderate
S1IIPc	55	Extremely Low
S3IPc	65	Moderate
S3IPm	60	Low
S3IPt	60	Low
S1IVB	30	High
S1IVPc	40	Extremely Low
S1IVPt	45	Extremely High
S1VB	75	Low
S1VPc	35	High
S4IB	40	Moderate
S2IIIB	45	Moderate
S2IIIPc	85	Low
S4IPc	85	Low
S2IVB	75	Moderate
S2IVPc	75	Low
S2VB	75	Low

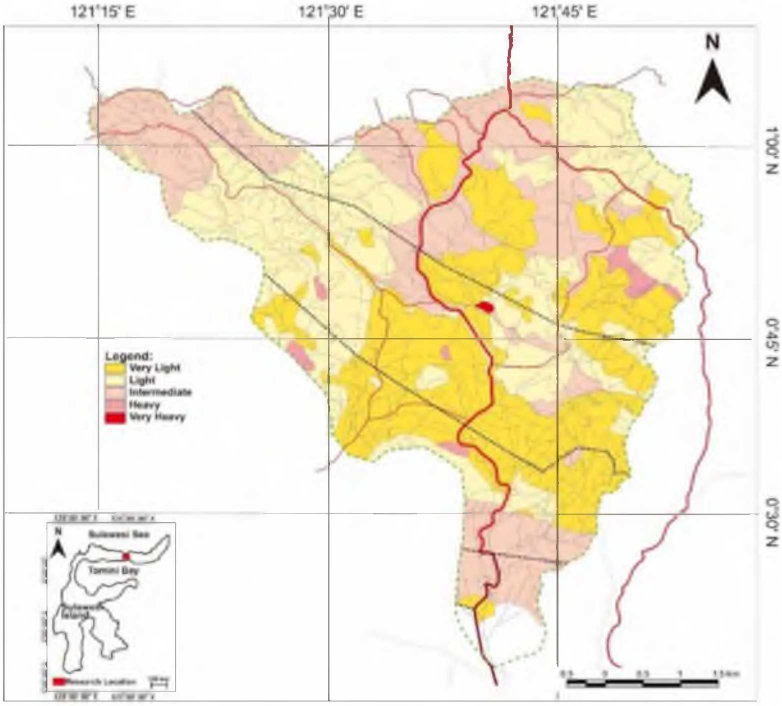

Figure 2 – Map of Erosion Hazard Rate in Alo drainage basin

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. 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.

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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ЛИМБОТО КӨЛІ, ҒОРОНТАЛО, ИНДОНЕЗИЯ АЙМАҒЫНДАҒЫ ЭРОЗИЯ ҚАУПІН ТАЛДАУ

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АНАЛИЗ ОПАСНОСТИ ЭРОЗИИ В ОБЛАСТИ ОЗЕРА ЛИМБОТО, ҒОРОНТАЛО, НДОНЕЗИЯ

Аннотация. Повреждения земельных ресурсов, в основном те, которые происходят в водосборном бассейне в Ало, Горонтало, происходят в результате деградации поверхностного слоя грунта в результате попадания дождевых капель и потока дождевой воды, несущейся по поверхности почвы. Эта проблема становится довольно серьезной из-за незаконных рубок деревьев и переустройства сельскохозяйственных земель, в основном для кукурузных полей, как одного из главных товарных продуктов Горонтало.

Целью данного исследования является определение уровня эрозионной опасности в водосборном бассейне озера Лимбото. Для достижения этих целей используются два метода, а именно полевое обследование и документация. Используемые материалы исследования включают социально-биогеофизические характеристики водосборного бассейна Ало и анализ уровня эрозии поверхности почвы. Результат показывает, что 98,75% опасности эрозии классифицируется как от слабой до умеренной, охватывая приблизительно 6 874 721 га. В то же время, 1,25 процента от высокой до крайней степени эрозионной опасности имеют ширину 98,79 га. Это говорит о том, что ненадлежащее использование земли с большей вероятностью увеличивает риск эрозии.

Ключевые слова: опасность эрозии, озеро Лимбото, Ало, Горонтало.

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REFERENCES

[1] Nitibaskara (2005) Resource Conservation Management Policy. Aula State Agency for Regional Development, Teluk Bintuni Regency, Research Institute of Trisakti University, Jakarta.

[2] Worosuprojo S. (2002) Trench and Avalanche Erosion Study Using Geomorphological Approach in Oyo River Basin, Yogyakarta Special Province, Dissertation at the Faculty of Geography, Universitas Gadjah Mada.

[3] State Agency for Regional Development Gorontalo Province (2009) Gorontalo Food Print Blue Print Final Survey Report.

[4] Subehi L., Wibowo H., Jung K. (2016) Characteristics of Rainfall-Discharge and Water Quality at Limboto Lake, Gorontalo, Indonesia. J. Eng. Technol. Sci. Vol. 48. P. 288-300.

[5] Permana A.P., Pramumijoyo S., Akmaluddin (2019) Analysis of Microfacies and Depositional Environment of Limestone in Yosonegoro Area, Gorontalo Province, Indonesia. Bulletin of the Iraq Natural History Museum. Vol. 15 (4): 443-454. DOI: https://doi.org/10.26842/binhm.7.2019.15.4.0443.

[6] Permana A.P., Pramumijoyo S., Akmaluddin (2019) Uplift Rate of Gorontalo Limestone (Indonesia) Based on Biostratigraphy Analysis. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. Vol. 6 (438): 6-11. DOI: https://doi.org/10.32014/2019.2518-170X.150.

[7] Lihawa F. (2009) Effect of Watershed Environmental Conditions and Land Use on Sediment Results in Gorontalo Province's Alo-Pohu Watershed. Dissertation at Postgraduate School, Universitas Gadjah Mada.

[8] BPDAS-BB (2004) Technical Planning for Land Rehabilitation and Soil Conservation for Limboto Watershed (Book 1). BPDAS-BB, Gorontalo.

[9] Hidayat G.G., Kakizawa H. (2014) Development Process of Watershed Partnership: A Case Study of Limboto Watershed - Gorontalo, Indonesia // Journal of Forestry Research. Vol. 1. P. 9-20.

[8] Balitbangpedalda (2006) Regional Environmental Status, Gorontalo Province Year 2005 (7 p.). Balitbangpedalda Gorontalo Province.

[10] Saleh S.E., Baiquni M., Yunus H.S. (2016) Determinants of Socio-Demography and Household Livelihood (A Study in Iluta and Limehe Timur Village, Gorontalo Regency). International Journal of Scientific and Research Publications. Vol 6. P. 627-633.

[11] Ministry of Forestry Republic of Indonesia (2004) Technical Guidelines for Implementing a Field Plan for Land Rehabilitation and Conservation. Director general of reforestation and land rehabilitation, Jakarta.

[12] Arsyad S. (2010) Soil and Water Conservation. IPB Press, Bogor.

[13] Wischmeier W.H., Smith D.D. (1965) Predicting Rainfall-Erosion Losses From Cropland East of The Rocky Mountains. A guide for selection of practices for soil and water conservation. USDA-Agr. Handbk. Vol. 282.

[14] Wischmeier W.H., Smith D.D. (1978) Predicting Rainfall Erosion Losses. A guide to conservation planning. USDA-Agr. Handb. Vol. 537.