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The Erosion Hazard Risk on Several Land Uses in the Rassasisi Sub-watershed of the Rongkong Watershed, North Luwu Regency, Indonesia

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Abstract The Rongkong watershed is an area in which most of the local community works as farmers in North Luwu Regency Indonesia. The use of the surrounding land by the local community is as agricultural land. This usage may give benefits to the local community. However, it is necessary to avoid the risk of land damage due to erosion. An intensive land use potentially increases the erosion of value if it does not heed to the conservation measures, so that the risks of land damage due to erosion, such as environmental pollution, floods, landslides and many more are likely to be occurred, therefore it is needed to know the value of erosion, a study was conducted on the index analysis of erosion hazard in the sub-watershed of the Rassasisi in the upstream of the Rongkong watershed. This study aims to analyze the tolerable soil loss (TSL) and to find out the *Erosion Hazard Index* (EHI) in various of land use types in the Rassasisi sub-watershed. This research was conducted in Rassasisi sub-watershed in the upstream of the Rongkong watershed in North Luwu Regency, Indonesia from July to September 2017. To determine the land units in the research location, several maps were used, they were: soil map, slope map and land use map. The data were overlaid by using the Arc GIS 9.3 program to obtain 54 units of land. The results showed that the tolerable soil loss (TSL) varies between the land use types. The highest tolerance value was found in primary forest with the score was 57.04 tons / ha / year, followed by mixed garden land (55.2 tons / ha / year), the shrub (49.68 tons / ha / year), and secondary forest was 49.68 tons / ha / year. The erosion hazard index was also varied among the land use types. The lowest value was found in primary forest with the score was 0.01 followed by secondary forest (0.33), mixed garden land (11.30), the shrub (36.43). Therefore, this study suggests that the land use type of mixed garden land was recommended for the local community because it have had a lower risk than the shrub.

Keywords Erosion, the tolerable soil loss, the Erosion Hazard Index, Sub-watershed, Land use, Land units

1. Introduction

The Rongkong Watershed is a watershed located in North Luwu Regency. This watershed is used for irrigation and other needs of the local community. The Rongkong watershed consists of primary forests that was 40.96%, secondary forests 10.88%, and mixed gardens 23.99% of the Rongkong watershed area. Agricultural land consisting of dryland and wetland (agriculture) was 10.25% (19,463.26 ha), mixed gardens covering 45,764.18 ha (23.99%), the inundated condition of Rongkong watershed reaches 11,695, 33 ha (6.13% of the area of Rongkong watershed). Other closures of the Rongkong watershed area were settlements, shrubs and open land [1].

If the intensive land use does not pay attention to conservations and its management, it will potentially cause the erosion hazard such as: environmental pollution, floods, landslides and siltation in the downstream area. An alternative that can be done to reduce the occurrence of erosion is the regulation of the land maintenance pattern by intercropping certain plants with mounds given organic fertilizer [2]. The treatment is significantly able to reduce the amount of erosion and surface runoff to be smaller than the other land maintenance techniques and be the most demanded technique by farmers.

The results of a study showed that the physical properties of soil were the dominant factors that determined the level of erosion in coffee-based farming land in Sumberjaya. Soils with the average porosity of >65% with macro pores >24%

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and soil permeability >9 cm^{-1} hour, the erosion that has occurred for 3 months reaches 37 t ha^{-1} [3]. In addition, disaster management efforts can also be carried out in a non-structural manner, meaning in the form of non-physical development, yet in the form of non-physical actions, for instance, making erosion hazard maps, demonstrating the early warning systems, public information and counseling, and spatial planning [4]. In line with that, it was suggested that watershed management can be viewed from a physical and institutional perspective, so that watershed management and policies are not only based on physical indicators, yet their success is strongly supported by the existence of coordination, integration, synchronization and synergy [5].

Therefore, it is important to know the level of erosion. Regarding to this issue, a study of erosion hazard analysis was carried out in the upstream of the Rassasisi sub - watershed of Rongkong watershed.

In Rongkong watershed, several problems were identified, namely critical land, erosion, sedimentation, land use outside the status of the area or outside its functions (land conversion), social problems, and institutions. Critical land reaches 34,206.39 ha with critical conditions covering the area of 30,424.52 ha and very critical conditions covering the area of 3,781.87 ha; and rather critical conditions covering the area of 74,294.21 ha and a critical potential conditions covering the area of 69,953.22 ha. Meanwhile, the conversion of land was 16,218.70 ha. [6].

The most visible phenomenon in Rongkong watershed is the frequent overflow of water in the central areas of human activity, which often has a negative impact on humans both directly and indirectly. Erosion brings a surface layer of soil that is generally most fertile, rich in organic material and nutrients, thus it causes the loss of nutrients for plants [7]. Regarding to this reason, in the context of development in Rongkong watershed, data and information is needed regarding the amount of total erosion, average erosion or the rate of erosion increase and the magnitude of the Erosion Hazard Index. This study aims to analyze the tolerable soil loss (TSL) and to find out the *Erosion Hazard Index* (EHI) in various of land use types in the Rassasisi sub-watershed.

2. Research Methods

2.1. Place and Time

This research was conducted in Rassasisi sub-watershed in the upstream of the Rongkong watershed in North Luwu Regency, which runs from July to September 2017.

2.2. Materials and Tools

The materials used in this study were watershed, soil, land use, and slope maps of each with a scale of 1: 100,000 obtained from the Watershed Management Center and rainfall data from the Meteorology and Geophysics Agency of South Sulawesi Province.

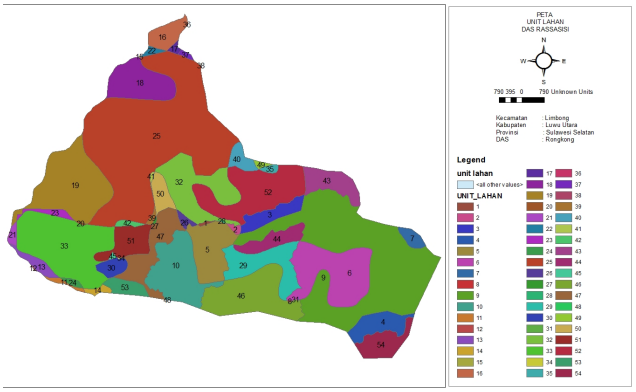

Figure 1. Land unit map of the Rassasisi watershed as the research location

The tools used in the research include soil drill, sample ring, hammer, machete, roller meter, camera, and stationery equipment.

2.2. Research Methods

2.2.1. Land Unit Determination

To determine the land units in the research location, several maps were used, they were: soil map, slope map and land use map. The data were overlaid by using the Arc GIS 9.3 program to obtain 54 units of land.

2.2.2. Determining Erosion Rate

The general equation that was used in this study to estimate the magnitude of erosion was the general equation of soil loss using Wichmeier Method (1978) or USLE [8].

A = R K L S C P

2.2.3. Rain Erosivity

Factors of Rainy Erosivity are obtained from the Lenvain equation [9]. These obtains a relationship between all 30 and annual rainfall (R) as follows:

$$R = \sum(Rm) = 2.21(R_{Jan} + R_{Feb} + ... + R_{Des})^{1.36} \quad (1)$$

Rm = Rain Erosivity Index

R_{jan} = Monthly Rainfall (cm)

In which: EI30 = Rainfall erosivity factor with a maximum rainfall intensity of 30 minutes.

2.2.4. Soil Erodibility

Soil erodibility factors, determination of soil erodibility value developed by [8] Wischmeier and Smith (1978) by using homographs which are based on soil properties influencing it, include the texture, soil structure, organic material content and soil permeability [10].

2.2.5. Topographic Conditions

Factors of length and slope, the determination of slope factors, namely the length of slope (L) and slope (S), were calculated together. The LS value of a land can be calculated

by the following equation [11]:

$$LS = \frac{\sqrt{\lambda}}{100}(1.38 + 0.965S + 0.138s)^2 \quad (2)$$

In which:
L: Length of slope (m)
S: Slope (%)

2.2.6. Land Management

Land or Plant Management Factors. This factor is determined by the value of plant factors and the management or pattern of plants in a year of planting.

2.2.7. Conservation Action

Soil Conservation Measures were based on P factor values for a variety of special soil conservation [11].

2.2.8. Tolerable Erosion

Tolerable Soil Loss (TSL) model or erosion that can be tolerated was determined by using the equation as follows [12].

$$TSL = \frac{Effective\ depht\ (mm) x Value\ of\ the\ depth\ factor}{Age\ of\ land\ use}$$
$$Ton / ha / year = mm / year x BD(gr / cc) x 10 \quad (3)$$

2.2.9. Erosion Hazard Index

Calculating the magnitude of the Erosion Hazard Index used the equation as follows [13].

$$EHI = \frac{The\ amount\ of\ soil\ erosion\ (ton / ha / year)}{TSL\ (ton / ha / year)} \quad (4)$$

3. Results and Discussion

3.1. Land Unit Analysis

Based on the overly results of land use map, slope map and soil map in Rassasisi sub-watershed in the upstream of Rongkong watershed, there were 54 units of land as in Figure 1. The classification of land units based on land use is presented in Table 1, while erosion value of each land unit is presented in Table 2.

3.2. Tolerable Erosion

The value of Tolerable Soil Loss (TSL) or the tolerable erosion rate was calculated according to the Hammer method [14]. This value was traced based on the effective depth (mm) of the soil suborder, the value of the depth factor and the age of land use. Tolerable erosion rate values and various land uses are presented in Table 3.

Table 1. Land Unit Map of Rassasisi Watershed as the Research Location

No	Land Use	Symbol	Area (ha)	Land Unit
1	Shrub	S	483.76	1,2,3,4,5,14,15,21,22,34,35,36, 37,38,51,52,53,54
2	Primary Forest	PF	35.87	16,17,23,39
3	Secondary Forest	SF	668.85	12,13,18,20,19,24,25,26,27,40,41,42,43,44
4	Mixed Garden	MG	899.58	6,7,8,9,10,11,28,29,30,31,32,33,45,46,47,48,49,50
Total			2,088.05	54

Table 2. Value of erosion occurring in each land unit in the Rassasisi sub-watershed

Land Unit	Symbol	Area (ha)	R	K	LS	CP	Erosion (ton/ha/year)
1	S	1.029	2516	0.32	6.8	0.3	1642.44
2	S	2.690	2516	0.32	6.8	0.3	1642.44
3	S	26.587	2516	0.32	9.5	0.3	2294.59
4	S	33.998	2516	0.32	9.5	0.3	2294.59
5	S	62.190	2516	0.32	6.8	0.3	1642.44
6	MG	109.726	2516	0.32	6.8	0.1	547.48
7	MG	10.149	2516	0.32	6.8	0.1	547.48
8	MG	0.149	2516	0.32	9.5	0.1	717.06
9	MG	320.778	2516	0.32	9.5	0.1	717.06
10	MG	87.922	2516	0.32	9.5	0.1	717.06
11	MG	3.582	2516	0.32	1.4	0.1	112.71
12	SF	0.202	2516	0.32	1.4	0.005	5.63
13	SF	12.095	2516	0.32	1.4	0.005	5.63
14	S	4.516	2516	0.32	1.4	0.3	338.15
15	S	0.070	2516	0.32	3.1	0.3	748.76
16	PF	23.381	2516	0.32	3.1	0.001	2.49

Land Unit	Symbol	Area (ha)	R	K	LS	CP	Erosion (ton/ha/year)
17	PF	2.670	2516	0.32	3.1	0.001	2.49
18	SF	62.145	2516	0.32	3.1	0.005	12.47
19	SF	126.650	2516	0.32	3.1	0.005	12.47
20	SF	0.528	2516	0.32	3.1	0.005	12.47
21	S	4.845	2516	0.32	6.8	0.3	1642.44
22	S	3.589	2516	0.32	6.8	0.3	1642.44
23	PF	7.724	2516	0.32	6.8	0.001	5.47
24	SF	3.502	2516	0.32	6.8	0.005	27.37
25	SF	2.393	2516	0.32	6.8	0.005	27.37
26	SF	409.971	2516	0.32	6.8	0.005	27.37
27	SF	4.489	2516	0.32	6.8	0.005	27.37
28	MG	0.409	2516	0.32	6.8	0.1	547.48
29	MG	0.382	2516	0.32	6.8	0.1	547.48
30	MG	59.504	2516	0.32	6.8	0.1	547.48
31	MG	13.240	2516	0.32	6.8	0.1	547.48
32	MG	0.105	2516	0.32	6.8	0.1	547.48
33	MG	84.723	2516	0.32	6.8	0.1	547.48
34	S	2.290	2516	0.32	6.8	0.3	1642.44
35	S	144.272	2516	0.32	6.8	0.3	1642.44
36	S	0.149	2516	0.32	6.8	0.3	1642.44
37	S	3.446	2516	0.32	9.5	0.3	2294.59
38	S	0.027	2516	0.32	9.5	0.3	2294.59
39	PF	2.091	2516	0.32	9.5	0.001	7.64
40	SF	0.010	2516	0.32	9.5	0.005	38.24
41	SF	1.241	2516	0.32	9.5	0.005	38.24
42	SF	4.008	2516	0.32	9.5	0.005	38.24
43	SF	13.919	2516	0.32	9.5	0.005	38.24
44	SF	27.697	2516	0.32	9.5	0.005	38.28
45	MG	0.908	2516	0.32	9.5	0.1	764.86
46	MG	36.095	2516	0.32	9.5	0.1	764.86
47	MG	54.486	2516	0.32	9.5	0.1	764.86
48	MG	0.000	2516	0.32	9.5	0.1	764.86
49	MG	99.805	2516	0.32	9.5	0.1	764.86
50	MG	17.618	2516	0.32	9.5	0.1	764.86
51	S	35.950	2516	0.32	9.5	0.3	2294.59
52	S	108.795	2516	0.32	9.5	0.3	2294.59
53	S	16.117	2516	0.32	9.5	0.3	2294.59
54	S	33.196	2516	0.32	9.5	0.3	2294.59

Note: S = Shrub, MG = Mixed Garden, SF = Secondary Forest, PF = Primary Forest

Table 3. Tolerable Soil Loss values (TSL) in each land unit of Rassasisi watershed

Land Unit	Area (ha)	ED (mm)	DF	LUA	BD (g/cc)	TSL (ton/ha/year)
1	1.03	2700	0.80	400	0.92	49.68
2	2.69	2700	0.80	400	0.92	49.68
3	26.59	2700	0.80	400	0.92	49.68
4	34.00	2700	0.80	400	0.92	49.68
5	62.19	2700	0.80	400	0.92	49.68
14	4.52	2700	0.80	400	0.92	49.68
15	0.07	2700	0.80	400	0.92	49.68

Land Unit	Area (ha)	ED (mm)	DF	LUA	BD (g/cc)	TSL (ton/ha/year)
21	4.85	2700	0.80	400	0.92	49.68
22	3.59	2700	0.80	400	0.92	49.68
34	2.29	2700	0.80	400	0.92	49.68
35	144.25	2700	0.80	400	0.92	49.68
36	0.15	2700	0.80	400	0.92	49.68
37	3.45	2700	0.80	400	0.92	49.68
38	0.03	2700	0.80	400	0.92	49.68
51	35.95	2700	0.80	400	0.92	49.68
52	108.80	2700	0.80	400	0.92	49.68
53	16.12	2700	0.80	400	0.92	49.68
54	33.20	2700	0.80	400	0.92	49.68
39	2.09	3100	0.80	400	0.92	57.04
23	7.72	3100	0.80	400	0.92	57.04
16	23.38	3100	0.80	400	0.92	57.04
17	2.67	3100	0.80	400	0.92	57.04
40	0.01	2700	0.80	400	0.92	49.68
41	1.24	2700	0.80	400	0.92	49.68
42	4.01	2700	0.80	400	0.92	49.68
20	0.53	2700	0.80	400	0.92	49.68
24	3.50	2700	0.80	400	0.92	49.68
25	2.39	2700	0.80	400	0.92	49.68
26	409.95	2700	0.80	400	0.92	49.68
27	4.49	2700	0.80	400	0.92	49.68
12	0.20	2700	0.80	400	0.92	49.68
13	12.10	2700	0.80	400	0.92	49.68
18	62.15	2700	0.80	400	0.92	49.68
43	126.65	2700	0.80	400	0.92	49.68
44	13.92	2700	0.80	400	0.92	49.68
6	27.70	3000	0.80	400	0.92	55.20
7	109.73	3000	0.80	400	0.92	55.20
8	10.15	3000	0.80	400	0.92	55.20
9	0.15	3000	0.80	400	0.92	55.20
10	320.76	3000	0.80	400	0.92	55.20
11	87.92	3000	0.80	400	0.92	55.20
19	3.58	3000	0.80	400	0.92	55.20
28	0.41	3000	0.80	400	0.92	55.20
29	0.38	3000	0.80	400	0.92	55.20
30	59.50	3000	0.80	400	0.92	55.20
31	13.24	3000	0.80	400	0.92	55.20
32	0.11	3000	0.80	400	0.92	55.20
33	84.72	3000	0.80	400	0.92	55.20
45	0.91	3000	0.80	400	0.92	55.20
46	36.10	3000	0.80	400	0.92	55.20
47	54.49	3000	0.80	400	0.92	55.20
48	0.00	3000	0.80	400	0.92	55.20
49	99.81	3000	0.80	400	0.92	55.20
50	17.62	3000	0.80	400	0.92	55.20

Note : ED = Efective Depth LUA = Land Use Age DF = Depth Factor BD = Bulk Density (g/cc)

Based on the calculation of the erosion rate that can be tolerated in shrub land units in Rassasisi watershed, 18 units of land (1, 2, 3, 4, 5, 14, 15, 21, 22, 34, 35, 36, 37, 38, 51, 52, 53, and 54) show that the erosion which could be tolerated was 49.68 tons / ha / year with the average erosion rate of 1118.41 tons / ha / year. Tolerable erosion in the use of primary forest in 4 land units (16, 17, 23 and 39) was 57.04 tons / ha / year with an average erosion rate of 18.09 tons / ha / year. Tolerable erosion of secondary forest land use in 14 land units (12, 13, 18, 19, 20, 24, 25, 26, 27.40, 41, 42.43, and 44) was 24.95 tons / ha / year with an average erosion rate of 311.11 tons / ha / year. Tolerable erosion of the land use of mixed garden in 18 land units (7, 8, 9, 10, 11, 28, 29, 30, 31, 32, 33, 45, 46, 47, 48, 49 and 50) was 55.2 tons / ha / year with an average erosion rate of 11232.83 tons / ha / year.

3.3. Erosion Hazard Index

Based on tolerable erosion and erosion values, the erosion hazard index criteria were calculated according to the Hammer method [12]. The criteria were traced based on the tolerable erosion and erosion values of various land uses in Rassasisi watershed, the criteria for the average of the erosion hazard index and the calculations are presented in Table 4, and the erosion hazard index map is presented in Figure 2.

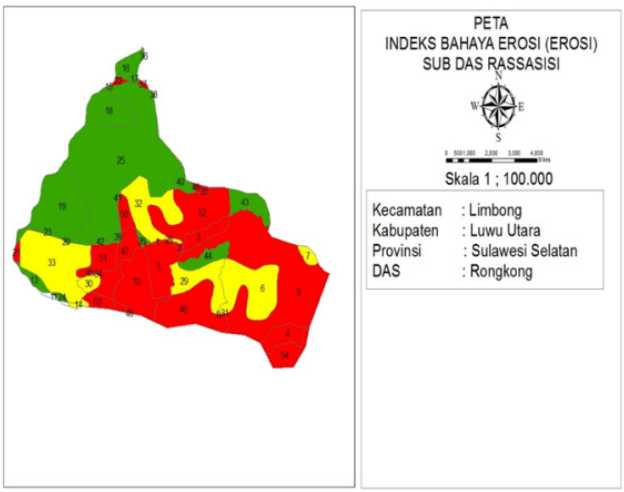

Figure 2. Erosion hazard index map of in rassasisi sub-watershed

Table 4. Erosion Hazard Index (EHI) for each Land Unit in the Rassasisi sub-watershed

Unit	Area (ha)	Erosion (ton/ha/year)	TSL (ton/ha/year)	Erosion Hazard Index Value	Criteria/ Level of Erosion Hazard Index
1	1.03	1642.44	49.68	33.06	very high
2	2.69	1642.44	49.68	33.06	very high
3	26.59	2294.59	49.68	46.18	very high
4	34	2294.59	49.68	46.18	very high
5	62.19	1642.44	49.68	33.06	very high
14	4.52	338.15	49.68	6.80	high
15	0.07	748.76	49.68	15.07	very high
21	4.85	1642.44	49.68	33.06	very high
22	3.59	1642.44	49.68	33.06	very high
34	2.29	1642.44	49.68	33.06	very high
35	144.25	1642.44	49.68	33.06	very high
36	0.15	1642.44	49.68	33.06	very high
37	3.45	2294.59	49.68	46.18	very high
38	0.03	2294.59	49.68	46.18	very high
51	35.95	2294.59	49.68	46.18	very high
52	108.80	2294.59	49.68	46.18	very high
53	16.12	2294.59	49.68	46.18	very high
54	33.20	2294.59	49.68	46.18	very high
39	2.09	7.64	57.04	0.13	low
23	7.72	5.47	57.04	0.09	low
16	23.38	2.49	57.04	0.04	low
17	2.67	2.49	57.04	0.04	low
40	0.01	38.24	49.68	0.76	low
41	1.24	38.24	49.68	0.76	low
42	4.01	38.24	49.68	0.76	low
20	0.53	12.47	49.68	0.25	low
24	3.50	27.37	49.68	0.55	low
25	2.39	27.37	49.68	0.55	low

Unit	Area (ha)	Erosion (ton/ha/year)	TSL (ton/ha/year)	Erosion Hazard Index Value	Criteria/ Level of Erosion Hazard Index
26	409.95	27.37	49.68	0.55	low
27	4.49	27.37	49.68	0.55	low
12	0.20	5.63	49.68	0.11	low
13	12.10	5.63	49.68	0.11	low
18	62.15	12.47	49.68	0.25	low
19	126.65	12.47	49.68	0.25	low
43	13.92	38.24	49.68	0.76	low
44	27.70	38.24	49.68	0.76	low
6	109.73	547.48	55.20	9.91	high
7	10.15	547.48	55.20	9,91	high
8	0.15	717.06	55.20	12.99	very high
9	320.76	717.06	55.20	12.99	very high
10	87.92	717.06	55.20	12.99	very high
11	3.58	112.71	55.20	2.04	moderate
28	0.41	547.48	55.20	9.91	high
29	0.38	547.48	55.20	9.91	high
30	59.50	547.48	55.20	9.91	high
31	13.24	547.48	55.20	9.91	high
32	0.11	547.48	55.20	9.91	high
33	84.72	547.48	55.20	9.91	high
45	0.91	764.86	55.20	13.85	very high
46	36.10	764.86	55.20	13.85	very high
47	54.49	764.86	55.20	13.85	very high
48	0.00	764.86	55.20	13.85	very high
49	99.81	764.86	55.20	13.85	very high
50	17.62	764.86	55.20	13.85	very high

The erosion hazard index occuring in each land unit (in 54 land units) of Rassasisi sub-watershed was divided into 4 levels, namely L (low), M (medium), H (high), and VH (very high).

The Erosion Hazard Index with a low level occurred on land units 12, 13, 16, 17, 18, 19, 20, 23, 24, 25, 26, 27, 39, 40, 41, 42, 43, 44 with the land area of 704, 72 ha. Low erosion hazard index in each land unit occurred in primary and secondary forests. The affecting factors were the presence of conservation factors in the form of a tight / good cover of the vegetation, so that if there was rain it would not cause the raindrops directly hit the soil particles. Moderate value Erosion Hazard Index occurred in 11 land units with land use in the form of mixed gardens, with an area of 3.58 ha.

The Erosion Hazard Index with a high value occurs in land units of 6, 7, 14, 28, 29, 30, 31, 32, and 33 with the land area of 282.75 ha. The erosion hazard index with a higher value occurs in the land of mixed garden and shrub. The affecting factors were the steep slope factors, the land use factors that do not apply soil and water conservation measures, the vegetation cover was rather opened so that there was space for raindrops to hit directly on the ground surface which will cause erosion.

The Erosion Hazard Index with a very high level occurs in land units 1, 2, 3, 4, 5, 8, 9, 10, 15, 21, 22, 34, 35, 36, 37, 38, 45, 46, 47, 48, 49, 50 51, 52, 53, and 54 with the land area of 1097.00. The erosion hazard index with a very high level occurs in mixed garden and shrub. The affecting factors were the opened land cover factor where the plant density was very low, the slope was very steep and did not apply the soil and water conservation measures.

4. Conclusions

The highest tolerance value was found in primary forest with the score was 57.04 tons / ha / year, followed by mixed garden land (55.2 tons / ha / year), the shrub (49.68 tons / ha / year), and secondary forest was 49.68 tons / ha / year. The erosion hazard index was also varied among the land use types. The lowest value was found in primary forest with the score was 0.01 followed by secondary forest (0.33), mixed garden land (11.30), the shrub (36.43).

5. Suggestion

The management of mixed garden should practice the soil conservation techniques such as planting crops, according to contour directions and making terraces or replacing them with forest plants such as *sengon* (*Albizia chinensis*) and teak. Shrub land management is used as reforestation land, while protecting secondary and primary forests should be a conservation priority.

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