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THE EFFECT OF WATERSHED ENVIRONMENTAL CONDITIONS AND LANDUSE ON SEDIMENT YIELD IN ALO-POHU WATERSHED

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ABSTRACT

The research carried out in alo-pohu watershed gorontalo province aims at identifying the effect of watershed conditions and land use on the amount sheet erosion, sediment yield and sediment delivery ratio. It is also intended to develop them in a spatio-temporal distribution, and give recommendation for management of environmental condition and land use in alo-pohu watershed to prevent damage erosion and sediment. Data on environmental condition and land use were collected by interpreting landsat images and topography map. Data on surface erosion were obtained by means of direct measurement using 10 erosion plots placed in the land units. Data on sediment were obtained by collecting water samples from the upper course, middle course, and lower course of the rivers. Data on sheet erosion and sediment yield were analyzed in a spatio-temporal manner using geographic information systems (gis) and effect of watershed conditions and land utilization on sheet erosion, sediment yield, and sediment delivery ratio are tested using double regression analysis. The research results suggest significant effect of watershed conditions and land use on sheet erosion. the largest amount of erosion very likely occurred in wasteland (bero land) with steep slopes whereas the least amount of erosion was found in undergrowth with flat slope (0-8%). the amount of sheet erosion was 122.24 ton/ha/year. sediment yield in alo-pohu was affected to a large extent by runoff rate, the width of watershed, percentage of wasteland, and drainage density.

Keywords: watershed, environmental conditions, land use, sheet erosion, sediment yield

INTRODUCTION

Utilization of land for agriculture has been increasing. The total plantation area in Alo-Pohu Watershed extended from 1,398 ha in 2003 to 30,338 ha in 2005. Such extension consequently narrowed the forest area in Alo-Pohu Watershed. The forest covered an area of 5,587 ha in 2003 and decreased to 4,478 ha in 2005 (interpretation of Land sat, 2003 and 2005).

Damage of a watershed area prevents it from fulfilling its function, affecting the hydrological system. Rainfall catchments, infiltration, water storage capacities will deteriorate as water drains in a wasteful way. This may result in flood during rainy season and correspondingly short of water supply during dry season. In addition, the increasing overland water flow will increase the sediment carrying capacity, resulting in the increase in sediment yield.

Various studies on the effects of land use on erosion and sediment results have been conducted among others by [*Suripin,* 1998; *Sulastriningsih,* 2001; Ismail, 2002; *Fuller, et al ,* 2003], [*Yves Le Chaplot and Bissonnais,* 2003; *Laflen, et al,* 2004]. From the studies the factors influencing the results of sediment on a watershed basin varied from one watershed to another, they were influenced by the physical condition of watersheds, land use and conservation techniques applied to these watersheds.

It is essential to understand sediment deposits formed, characteristics of sediment, as well as the effect of watershed conditions and land utilization on sheet erosion rates and sediment yield to devise watershed management plan. Therefore, a research is deemed necessary to study the effect of watershed conditions and land use on erosion and sediment yield as well as its spatio-temporal distribution on which the formulation of policy on the management of priority watersheds is based. In line with the statement of problem, the research aims at (1) identifying the effect of watershed environmental conditions and land use on sheet erosion rates as well as developing it in the spatio-temporal distribution as sediment deposits, (2) identifying the effect of watershed environmental conditions and land use on sediment yield and sediment delivery ratio as well as developing it in the spatio-temporal distribution, (3) recommending management of environmental condition and land use in Alo-Pohu Watershed to prevent damage, erosion and sediment. Hypotheses to be tested in the research are as follows (1) spatio-temporal distribution of sheet erosion rates has a strong correlation with watershed environmental conditions and land use, (2) the watershed environmental conditions and land use significantly affect sediment yield and Sediment Delivery Ratio.

THE METHODS

Material applied in this research were Landsat images 2003 and 2005, Shuttle Radar Topographic Mission (SRTM) 2004 resolutions 90 x 90 m^2, Topography Map of 1991 scales 1:50000 Gorontalo Sheets, Limboto Sheets, Kwandang Sheets, Tengah Sheets and Molombulahe Sheets, Land Unit Map of Limboto Watershed 2004 scales 1: 50000, Land Use Map of Limboto Watershed 2004 scales 1:50000, Soil Map of Limboto Watershed 2004 scales 1:50000, Slope Map 2004 scales 1:50000, and climate data.

Equipment of the research consisted of a set of computer, printer and scanner, software Arc View, Sediment sampler type USDH 48, float, Automatic Water Level Recorder (AWLR), Automatic Rainfall Recorder (ARR).
The variables of the research were as follows:

1. Independent variable: environmental condition and land use of watershed. Environmental condition parameters analyzed are area of watershed (A), shape of watershed, drainage density (Dd), stream frequency, bifurcation ratio (Rb), rainfall, discharge (Q). Land use parameters analyzed are primary forest percentage, secondary forest percentage, dry land percentage, and coppice percentage.
2. Dependent variables: sheet erosion that is level of soil loss (tons/sq. km) and sediment yield that is volume or sediment weight per set of water capture area (tons/sq km).

The observation site covers the entire area of Alo-Pohu Watershed, stretching 488.28 sq km. it is divided into five sub watersheds, i.e. Pohu, Pliable, Molamahu, Alo, and Buhiya sub watersheds. The sheet erosion rate as well as its spatial distribution serving as a source of sediment was analyzed using land unit approach. The land unit was classified according to its types, i.e. slope, soil, and land use.

The samples of sediment were collected from the rivers within the area of Alo-Pohu sub watershed, namely Pohu, Pulubala, Alo, Buhiya, and Molamahu rivers which fulfill the criteria as they are situated in the main river, unaffected by back water, and have characteristic of the upper course, middle course, and lower course.

Main data in this research were level of sheet erosion, sediment, land use, slope, morphometry of watershed (area of watershed, drainage density, bifurcation ratio, stream frequency, total stream length). Primary data collecting technique was adopted using direct measurement and observation in the field. In addition, the data were also collected through interpretation of Landsat images and Shuttle Radar Topographic Mission (SRTM). Measurement of erosion was done at ten locations with different land unit characteristics. Plot system with form of length square was employed in the measurement. Check measured 2 m wide, 5 m long and 20 cm high above soil ground surface. Measurement of discharge was performed using surface float method; while integration method of depth by the way of Equal-Width-Increment (EWI) was implemented in sediment sampling. Measurement of watershed morphometry was executed through interpretation of Topography Map, scale 1:50000 and determination base of stream order applied according to Strahler.

Data on sheet erosion as source of sediment was analyzed in spatial and temporal manner. Spatial analysis was done with Geographical Information System (SIG) to see level of sheet erosion variation at land unit in Alo-Pohu Watershed. Temporal analysis aimed to see various time level of erosion happened in Alo-Pohu Watershed. Steps of analysis in the sediment study started with laboratory analysis to determine concentration of sediment and grain size followed by analysis to calculate how big the charged sediment is.

An understanding of the condition of watershed and land use gives ground for the feasibility of the hypotheses to be tested. Hypothesis 1 and hypothesis 2 on the effect of the environmental condition of watershed and land use on sheet erosion rate, sediment yield, and sediment delivery ratio were tested using a multiple regression analysis.

RESULTS AND DISCUSSION

Description of Environmental Condition and Land Use

Rivers at Alo-Pohu Watershed follow a course where tributaries flow into the main river which is larger and forms a particular drainage pattern. A drainage pattern is determined by topographical and geological conditions as well as by climate and vegetation of the watershed. The drainage pattern mostly formed in Alo-Pohu Watershed is dendrite drainage pattern. Such a drainage pattern is mostly found in a watershed which is made up of the same type of rock and develops in different directions. A number of rivers in an area made up of limestone rocks form a rectangular drainage pattern. In a quantitative manner, conditions of a river can be measured with morphometry. The morphometry of Alo-Pohu watershed is presented Table 6.1.

Table 6.1 Morphometries of Alo-Pohu watershed

Sub - watershed	A (sq km)	Number of stream	Rb	Fu	L (km)	L_b (km)	D_d (km/sq km)	R_f
Pohu	148.77	957	3.37	6.43	442.26	34.07	2.97	1.78
Pulubala	109.56	203	3.12	3.70	232.50	27.98	2.12	2.03
Molamahu	129.67	571	2.85	4.40	304.27	32.23	2.35	2.16
Alo	75.88	354	3.17	4.67	187.57	22.45	2.47	1.41
Buhiya	24.40	124	7.37	5.08	55.79	12.99	2.29	0.89
Alo-Pohu	488.28	2411	4.15	4.94	1,222.38	129.72	2.50	1.75

Source: Result of interpretation of Topography Map Scale 1:50.000
Description:
A = Area of watershed (sq km), Rb = Bifurcation ratio, Fu = Stream Frequency
L = Length of stream (km), L_b= length of main stream (km)
Dd = Drainage density, Rf =shape of watershed

The result of land unit delineation indicates that land units at DAS Alo-Pohu vary. The reason is that the location of plot erosion is determined according to categories of land use and slope gradient which is disposed to sheet erosion. The physical characteristics of each erosion plot measured are presented in Table 6.2.

Table 6.2 Physical Characteristic Each plot

No	Plot Erosion	Land Use	Slope (%)	Lithology	Soil Type	Texture	Permeabilitas (cm/hour)	Organic material Erodibilitas	Erodibilitas	Slum (cm)
1	Datahu 1	Undergrowth	38.4 (Steep slope)	Lava basal	Podsolok	Sandlyloam	38.82 (very quickly)	2.91	0.41	32.5
2	Datahu 2	Dray land	17.6 (moderately steep slope)	Lava basal	Podsolik	Clay	0.49 (slowly)	2.78	0.46	54
3	Pulubala 1	Undergrowth	3.5 (flat slope)	Limestone	Grumusol	Clay	0.24 (slowly)	5.41	0.32	34
4	Pulu bala 2	Dray land	34.43 (steep slope)	Coral Limestone	Grumusol	Clay	0.44 (slowly)	2.87	0.35	63.4
5	Molamahu 1	Primary Forest	10.5 (gentle slope)	Breksi	Andosol	Dusty clay	39.75 (very quickly)	3.79	0.21	25.1
6	Molamahu 2	Waste land	26.8 (steep slope)	Coral Limestone	Grumusol	Sandy loam	0.37 (slowly)	4.72	0.36	87
7	Labanu 1	Dray and	26.8 (steep slope)	Breksi	Andosol	Sandy loam	2.18 (moderately)	2.23	0.37	30
8	Labanu 2	Secondary forest	32.5 (steep slope)	Tuff	Litosol	Clay	2.74 (moderately)	4.97	0.27	15.3
9	Buhiya 1	Undergrowth	13.2 (gentle slope)	Limestone	Grumusol	Dusty clay	4.46 (moderately)	6.29	0.27	31
10	Buhiya 2	Dray land	10.5 (gentle slope)	Limestone	Grumusol	Dusty clay	0.15 (slowly)	4.03	0.48	95

The Result of Measurement Sheet Erosion

The result of measurement of sheet erosion at each erosion plot is shown in Table 6.3.

Table 6.3 Result of sheet erosion at each erosion plot

No	Erosion Plot	Sheet Erosion (gram/m^2)				Description
		Max	Min	Average	Sd	
1	Datahu 1	611.04	0.00	41.21	111.97	Undergrowth
2	Datahu 2	6246.20	0.00	555.11	1261.09	Dry land, moderately steep slope
3	Pulubala 1	67.33	0.00	7.94	16.10	Undergrowth
4	Pulubala 2	345.58	0.00	33.55	78.30	Dry land, flat slope
5	Molamahu 1	241.58	0.00	25.52	64.20	Primary forest
6	Molamahu 2	3527.87	0.00	250.69	722.59	wasteland
7	Labanu 1	6735.18	0.00	551.54	1305.73	Dry land, steep slope
8	Labanu 2	125.82	0.00	19.58	36.62	Secondary forest
9	Buhiya 1	101.86	0.00	21.80	32.75	Undergrowth
10	Buhiya 2	180.16	0.00	32.92	47.61	Dry land, gentle slope

Source: Field data, 2007

The Result of Sediment Analysis

Sediment Concentration

Samples of sediment were taken at the same time as data on runoff rate was collected. Samples of suspended sediment were collected from the upper-, middle-, and lower course of the river to observe the difference in characteristics of sediment in the three parts of river. The result of sediment analysis in each part is presented in Table 6.4.

In order to examine whether or not there is significant difference in the sediment concentration between the upper-, middle-, and lower course a univariate t-test was carried out. Results of analysis indicate significant difference in the average sediment concentration between the upper course and the middle course as well as between the middle course and the lower course. Sediment concentration was larger downstream. This shows that there is an increase of sediment concentration from upper course to lower course areas. It happened due to erosion of the sloping riverbank all the way through the surface runoff from upper course to lower course and sediment contribution came from the tributaries.

Table 6.4 Concentration of suspended load

No	Location	CM_{min} (kg/m^3)	CM_{max} (kg/m^3)	Average (kg/m^3)	Sd (kg/m^3)
1	Pohu River				
	○ upstream	0.00	11.65	1.81	2.71
	○ middle	0.00	11.44	2.08	2.95
	○ downstream	0.00	12.87	2.44	3.32
2	Pulubala River				
	○ upstream	0.00	12.37	3.57	3.60
	○ middle	0.00	12.98	4.07	3.93
	○ downstream	0.00	13.87	4.64	4.38
3	Molamahu River				
	○ upstream	0.00	11.23	1.97	2.61
	○ middle	0.00	11.77	2.33	2.98
	○ downstream	0.01	12.65	2.56	3.25
4	Alo River				
	○ upstream	0.00	10.58	2.07	2.56
	○ middle	0.00	10.77	2.29	2.77
	○ downstream	0.00	10.80	2.72	3.02
5	Buhiya River				
	○ upstream	0.00	6,06	1.63	1.84
	○ middle	0.01	6.68	1.85	2.19
	○ downstream	0.00	7.66	2.08	2.48
6	Alo-Pohu River	0.06	13.89	4.19	4.24

Source: data analysis, 2007

Description:

CM_{min} = the minimum concentration of sediment,

CM_{max} = the maximum concentration of sediment Mean (N=45),

Sd = Standard deviation,

N = 45

The sediment grain size is the most important result in studying sedimentation process because it is one of the factors in deciding the process of sediment, precipitation and sediment transport. Results of the analysis show that, in minimum rate condition, the biggest concentration of suspended load grain size is clay content. This condition remains unchanged up to lower course areas. The condition shows that bigger particles of sediment will precipitate during their way from upper course to lower course. In maximum rate condition, there is an increase of dust and sand contents in lower course areas of Pohu, Molamahu, Alo and Alo-Pohu rivers. In Molamahu River, the percentage of plastic grain size is decreasing downstream, whereas the percentage of dust is increasing. It indicates that the distance between the sediment deposit and the location of sampling collection is relatively close. Therefore, bigger grain size of suspended load has not precipitated yet. The farther the distance of the source of sediment, the smaller the sediment grain size is.

Bed load data used in the research were obtained through approaches. It was conducted by predicting the bed load towards suspended load by considering the concentration of suspended load, basic component of the river, as well as suspended load composition. Basic composition of lower course areas found in the research area is generally sand. However, the composition of suspended load consists of more clay than sand. Therefore, based on the comparison developed by Borland and Maddock [*Suwarno,* 1991] and the value of the commonly used comparison numbers by the experts, the research applies 0.12 for comparison number between suspended load and bed load. The result of bed load concentration is shown in Table 6.5. Whereas the analysis result of total suspended concentration is shown in Table 6.6.

Table 6.5 Bed load analysis at Alo-Pohu watershed

No	Location	CDs_{min} (kg/m^3)	CDs_{max} (kg/m^3)	Average	Standard Deviation
1	2	3	4	5	6
1	Pohu River				
	○ upstream	0.0004	1.3985	0.2073	0.3599
	○ middle	0.0005	1.3727	0.2499	0.3811
	○ downstream	0.0005	1.5439	0.2931	0.4291
2	Pulubala River				
	○ upstream	0.0004	1.4850	0.4278	0.4493
	○ middle	0.0000	1.5582	0.4879	0.4876
	○ downstream	0.0000	1.6641	0.5569	0.5400
3	Molamahu River				
	○ upstream	0.0004	1.3480	0.2366	0.3449
	○ middle	0.0006	1.4125	0.2803	0.3847
	○ downstream	0.0007	1.5174	0.3072	0.4189
4	Alo River				
	○ upstream	0.0002	1.2696	0.2923	0.3322
	○ middle	0.0002	1.2923	0.2963	0.3544
	○ downstream	0.0001	1.2962	0.3329	0.3853
5	Buhiya River				
	○ upstream	0.0006	0.7273	0.1958	0.2290
	○ middle	0.0007	0.8017	0.2218	0.2695
	○ downstream	0.0005	0.9197	0.2495	0.3059
6	Alo-Pohu River	0.0070	1.6672	0.5023	0.5256

Source: Data analysis, 2007

Description:

CD_{min} = the minimum concentration of bed load

CD_{max} = the maximum concentration of bed load

R = mean (N=45)

SD = standard deviation

Table 6.6 Total sediment analysis at Alo-Pohu watershed

No	Location	C total $_{min}$ (kg/m^3)	C total $_{max}$ (kg/m^3)	Average	Standard Deviation
1	Pohu River				
	o upstream	0.0039	13.0525	1.9353	3.3593
	o middle downstream	0.0044	12.8118	2.3322	3.5570
		0.0050	14.4101	2.7360	4.0047
2	Pulubala River				
	o upstream	0.0033	13.8596	3.9932	4.1934
	o middle downstream	0.0000	14.5429	4.5533	4.5506
		0.0000	15.5316	5.1977	5.0401
3	Molamahu River				
	o upstream	0.0035	12.5809	2.2078	3.2190
	o middle downstream	0.0054	13.1834	2.6157	3.5908
		0.0070	14.1626	2.8675	3.9097
4	Alo River				
	o upstream	0.0022	11.8492	2.3861	3.1002
	o middle downstream	0.0018	12.0617	2.6360	3.3074
		0.0010	12.0987	3.1072	3.5958
5	Buhiya River				
	o upstream	0.0057	6.7883	1.8277	2.1373
	o middle downstream	0.0061	7.4827	2.0698	2.5149
		0.0050	8.5836	2.3284	2.8548
6	Alo-Pohu River	0.0657	15.5602	4.6886	4.9055

Source: data analysis

Water level

The results of measurement show that the maximum water level occurring in Alo River was 5.65 m and Alo-Pohu River 5.83 m, whereas the minimum water level was 0 (zero) in Pulubala River. The minimum water level at Alo-Pohu River was 0.58 m and the maximum on 5.83 m. This indicates that Pulubala River is waterless in dry season. It is due to the fact that the river bottom is so sandy that the river water is easily absorbed into the river bottom in dry season.

Discharge

Discharge is influenced by water level. Result of the measurement shows a minimum discharge of Alo-Pohu River was 0.91 cu m/second and maximum discharge 170.57 cu m/second. Result of analysis depicting the relationship pattern at each river in Alo-Pohu Watershed is shown in Table 6.7.

Table 6.7 Equations of the relation of water level to discharge

No	Location	Equation	R	R^2
1	Pohu River	$Q = 3.381\ h^{1.904}$	0.94	0.89
2	Pulubala River	$Q = 3.475\ h^{2.109}$	0.97	0.95
3	Molamahu River	$Q = 2.070\ h^{2.607}$	0.98	0.96
4	Alo River	$Q = 3.048\ h^{2.267}$	0.99	0.97
5	Buhiya River	$Q = 1.683\ h^{1.793}$	0.89	0.79
6	Alo-Pohu River	$Q = 3.133\ h^{2.222}$	0.99	0.98

Source: Result of statistical analysis with SPSS 16

Description :

Q = discharge (m3/sec)

h = water level (m)

The correlation of stream discharge to suspended load discharge

Result of analysis depicting pattern correlation stream discharge to suspended load discharge at each the river in Alo-Pohu Watershed is shown in Table 6.8

Table 6.8 Equations of regression between discharges and suspended Load discharge at Alo-Pohu watershed

No	Location	Equation	R	R^2
1	Pohu River	$Qs = 0.675\ Q^{1.813}$	0.92	0.84
2	Pulubala River	$Qs = 0.508\ Q^{1.746}$	0.98	0.96
3	Molamahu River	$Qs = 0.277\ Q^{1.862}$	0.97	0.94
4	Alo River	$Qs = 0.333\ Q^{1.846}$	0.94	0.89
5	Buhiya River	$Qs = 1.091\ Q^{2.379}$	0.95	0.90
6	Alo-Pohu River	$Qs = 0.221\ Q^{1.726}$	0.98	0.96

Source: Result of statistical analysis with SPSS 160

Description:

Qs = suspended load discharge (kg/sec)

Q = discharge (m^3/sec)

The Correlation of Total Stream Debit to Total Sediment Discharge

Result of regression analysis depicting pattern relation between discharges with total sediment discharge at each the river in Alo-Pohu Watershed is shown in Table 6.9

Table 6.9 Equations of regression between discharge and total sediment discharge

No	Location	Equation	R	R^2
1	Pohu River	$Qst = 1.047\ Q^{1.613}$	0.93	0.87
2	Pulubala River	$Qst = 0.746\ Q^{1.656}$	0.95	0.91
3	Molamahu River	$Qst = 0.427\ Q^{1.752}$	0.98	0.95
4	Alo River	$Qst = 0.592\ Q^{1.714}$	0.96	0.93
5	Buhiya River	$Qst = 1.279\ Q^{2.229}$	0.94	0.89
6	Alo-Pohu River	$Qst = 0.255\ Q^{1.719}$	0.98	0.96

Source: Result of statistical analysis with SPSS 160

Description:

Qst = total sediment discharge (kg/sec)
Q = discharge (m3/sec)
R = correlation coefficient
R^2 = coefficient of determination

Temporal Variation of Sediment at Alo-Pohu Watershed

Based on result of regression analysis relation between discharges with total sediment discharge at Alo-Pohu Watershed can help predict level of sediment yield at Alo-Pohu Watershed. Sediment yield at Alo-Pohu Watershed is shown in Table 6.10. The sediment yields in Alo-Pohu watershed reached an amount of 1, 642, - 868.7 tons/year. The total area of Alo-Pohu watershed is 488.28 sq km. In the other words, the average amount of sediment yields is 3.364 tons/sq km/year. The biggest sediment contributor was Alo River with total sediment gained amounting to 947,187.9 tons/year and the smallest sediment contributor was Buhiya River with 15,459.6 tons/year. This is due to the biggest runoff rate possessed by Alo River whereas Buhiya River possessed smallest runoff rate.

Table 6.10 Sediment yield at Alo-Pohu watershed

Month	Sediment yield (ton)					
	Pohu	Pulubala	Molamahu	Alo	Buhiya	Alo-Pohu
January	5,08	2,37	3,05	13,98	0,98	7,21
February	2,25	0,18	0,17	1.23	0,69	1,53
March	0,68	0,07	0,03	2.65	1,41	0,22
April	1,04	0,01	1,58	2,43	0,01	1,24
May	1,03	0,92	1,91	27,31	0,67	6,81
June	0,78	0,46	0,16	10,66	0,59	9,78
July	0,72	0,18	0,01	7,64	0,55	0,34
August	0,43	0,06	0,01	1,52	0,04	0,05
September	0,84	0,42	1,59	0,19	0,003	0,81
October	0,32	0,00	0,004	0,07	0,00	0,13
November	1,10	0,10	0,09	0,30	0,03	0,26
December	5,19	9,93	5,53	29,72	1,36	10,30
Total	19,46	14,70	14,13	97,68	6,34	38,68

Source: data analysis, 2007

The Effect of Watershed Conditions and Land use on the Amount of Sheet Erosion

Factors affecting the amount of sheet erosion in a watershed are characteristics of slope, types of soil, and land use. The result of regression analysis of the effect of watershed conditions and land use on the amount of sheet erosion is presented in Equation 6.1:

Log Y = -0.756 + 1.191 Log Rain– 0.381 DPt – 0,982 DB – 1.221 DHs – 1.036 DHp + 0.384 Dslope + 0.636 Drather slope + 0.691 Dsteep …………….. (6.1)

Description:

Y = sheet erosion (ton/sq km)
Rain= raindrop diameter (mm)
DPt = dryland farm
DB = undergrowth
DHs = secondary forest
DHp = primary forest
Dslope = gentle slope (8-15%)
Drather steep = moderately steep slope (15-25%)
Dsteep = steep slope (25-45%)

The result of analysis suggests a significant effect of watershed conditions on the amount of sheet erosion with the value for correlation coefficient (R) 0.633 and coefficient of determination (R^2) 0.40. This signifies that sheet erosion amounting 40 % is determined by watershed conditions as well as land use. The Standard Error of Estimate is 0.57. Regression analysis using Dummy variable treated open land utilization variable and flat slope variable as excluded variable. Thus, they were employed as instrument for comparing other categories. The value of regression coefficient of land utilization for dry-land variable (included variable) is 0.381. In other words, the amount of sheet erosion in dry-land is 38.1% lower than that in wasteland (excluded variable). The regression coefficient of undergrowth is -0.982, signifying that the amount of sheet erosion in undergrowth is 98.2% lower than that in wasteland. The same is true in secondary forest in which the amount of sheet erosion is 122.1% lower than that in wasteland. As for primary forest, the amount of sheet erosion is 1.036 lower than the amount of sheet erosion occurring in wasteland.

The effectiveness of vegetation ground cover plants depends on the height, density of vegetation and roots. At higher plants (tall trees) raindrops falling to the earth's surface will be captured and collected at the plant canopy (interception). Withheld rain will evaporate back into the air, flowing through the leaves, twigs and stems, and dripped directly into the ground. Water dripping of rain falling to the ground from a height of certain trees has so great speed so that it turns out a big erosive power. In land conditions with lower plants (grasses), rain drops will be restrained so that erosion power decreases. The low plant cover not only reduces the surface flow velocity, but also prevents the concentration of surface flow. Decrease in surface flow velocity provides an opportunity for infiltration. This is evidenced by the lower sheet erosion occurring in scrub land compared with soil erosion in the open. Besides the role of the plant canopy, root can bind soil particles on the surface and increase surface roughness, thus it reduces erosion. This is supported by results of research conducted by [*Asdak,* 2006] stating that the flow of surface and sheet erosion increases with the reduction of plants in each experimental plot. The research shows that the structure of land cover crops is an important factor affecting the amount of sheet erosion.

The results of analysis indicate as well that the values of regression coefficient of Dslope variable (included variable), Drather steep and Dsteep are 0.384, 0.636, and 0.691, respectively. This means the amount of sheet erosion occurring in gentle-slope is 38.4% higher than that in flat-slope. The amount is 63.6% and 69.1% higher in moderately-steep-slope and steep-slope respectively than that in flat-slope (excluded variable). Rain splash is the main process of soil particle release. When rain falls to the ground without vegetation, the soil particles are broken apart and thrown. On flat land, soil particles are spread evenly in all directions on the soil surface. However, on a slope tilting toward more dominant soil particles go downward slope. Soil particles will clog the soil pores so that the soil infiltration capacity is reduced. When rainfall intensity exceeds infiltration capacity, there will be a puddle on the ground that later would become surface flow (overland flow). This subsequently becomes the media of sediment transport where soil particles are eroded. The steeper the slope, the greater the surface flow velocity can easily erode the soil surface layer. If the ground slopes is twice as steep, then the amount of erosion per unit area will be 2.0 to 2.5 times more [*Arsyad,* 1989]. This is also supported by [*Suratman,* 2005] stating that the greatest erosion rates are in hilly and mountainous areas that have been converted into dry land farming areas (fields). In the regression equation, the variable is not a predictor of soil erosion amount in the watershed surface-Pohu Alo, because when viewed from the level of sensitivity to erosion, soil types on the DAS-Alo Pohu do not vary.

Sheet Erosion Distribution in Alo-Pohu Watershed

Sheet erosion rate in each sub-watershed is shown in Table 6.12. Spatio-temporal distribution of sheet erosion at Alo-Pohu Watershed is shown on Picture 6.1

Table 6.12 Sheet erosion rate at Alo-Pohu watershed based on sub-watershed

Month	Sheet erosion (ton)					
	Pohu	Pulubala	Molamahu	Alo	Buhiya	Alo-Pohu
January	12,38	18,56	30,70	21,87	15,28	20,15
February	5,89	7,77	12,11	7,05	5,10	8,32
Mach	4,86	9,04	9,69	9,80	6,66	10,02
April	4,08	7,52	11,65	9,39	8,09	7,79
May	3,36	10,37	21,80	11,19	8,07	11,12
June	8,39	11,45	18,32	10,01	7,34	11,83
July	3,72	5,64	7,12	8,34	9,25	5,91
August	0,77	0,99	4,12	4,52	3,93	2,61
September	1,63	3,84	5,15	3,84	3,84	3,82
October	5,49	5,99	6,36	6,09	5,82	5,80
November	1,70	5,37	12,44	12,02	10,14	7,07
Des	21,98	27,12	33,49	30,98	28,30	27,79
Total	74,26	113,68	172,98	135,10	111,83	122,24

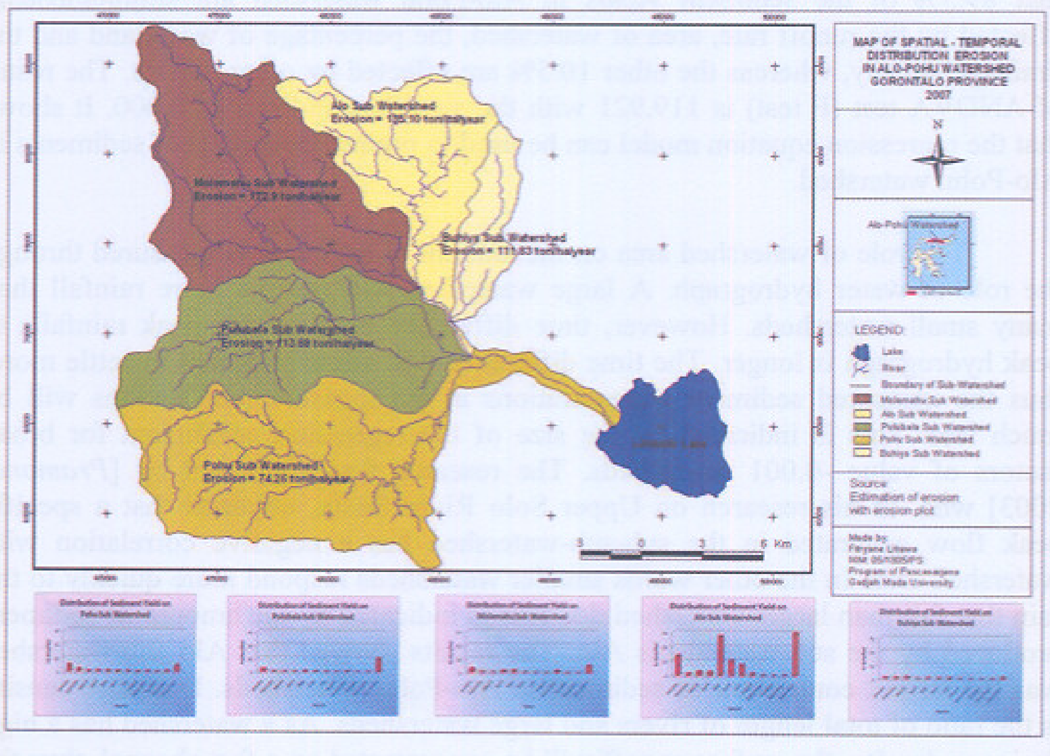

Figure 6.1 the Spatio-Temporal Distribution of Sheet Erosion at DAS Alo-Pohu

The Influence of Watershed Environmental Condition and Land Use On Sediment in Alo-Pohu Watershed.

Sediment yield in a certain watershed greatly depends on intensity of erosion as well as on the distribution process of soil particles eroded. The result of stepwise regression is obtained in a model of regression equation below:

$Log\ Sy = 0{,}217 + 1{,}781\ Log\ Q - 0{,}001\ A + 0{,}024\ Tt + 0,\ 146\ Dd$ .... (6.2)

Description:

Sy = sediment yields (tons)
Q = average monthly discharge (m^3/sec)
A = area of watershed (km^3)
Dd = drainage density (km/km^2)
Tt = percentage of wasteland (%)

The result of stepwise regression analysis shows that rate variables, the total area of watershed (A), the percentage of wasteland, and drainage density simultaneously bring effects on the sediment yields in Alo-Pohu watershed, with correlation coefficient (R) 0.95 and coefficient of determination (R^2) 0.895. It means that 89.5% of the sediment yields in Alo-Pohu watershed are simultaneously affected by the runoff rate, area of watershed, the percentage of wasteland and the drainage density, whereas the other 10.5% are affected by other factors. The result of ANOVA test (F test) is 119.921 with the significance level of 0.000. It shows that the regression equation model can be used to predict the results of sediments in Alo-Pohu watershed.

The role of watershed area on the amount of sediment is measured through the role of water hydrograph. A large watershed will receive more rainfall than many small watersheds. However, time difference between the peak rainfalls to peak hydrograph is longer. The time difference will allow sediment to settle more, thus the measured sediment concentrations at the measurement stations will be much less. This is indicated by the size of the regression coefficient for broad factors of value -0.001 watersheds. The research was supported by [*Pramono*, 2003] who, in his research on Upper Solo River Basin, obtained that a specific peak flow generated in the sub-sub-watershed has a negative correlation with watershed area. In the other words smaller watersheds respond more quickly to the rain that fall than larger watershed do. This is indicated by the amount of sediment produced by the sub-watersheds Alo. The results showed that Alo sub-watershed was the largest contributor of sediment in Alo-Pohu watersheds. Drainage density is the ratio of total length of rivers and large watersheds. As a watershed has a high drainage density, the surface runoff will be concentrated on a fast channel, thus the flow velocity will be even greater. Large flow velocity generates transport capacity of sediment particles, too large, so that the sediment concentration measured at the measurement station becomes larger.

The role of vegetation on the sediment is more focused on the role of vegetation in slowing the flow velocity and increasing the amount of surface water suspended above the ground surface, and thereby reducing the amount and speed of surface runoff (overland flow). The spatio-temporal distribution of sediment yields and SDR are shown in Fig. 6.2.

The Influence of Watershed Environmental Condition and the Land Use On Sediment Delivery Ratio

Level of SDR is influenced by environmental factor. Result of calculation obtained level of SDR at each sub-watershed in Alo-Pohu Watershed as shown in Table 6.13.

Table 6.13 Sediment delivery ratio at each sub-watershed

No	Sub-watershed	Sediment yield (ton)	Sheet Erosion (ton)	SDR
1	Pohu Sub Watershed	289.520,77	1.680.129,66	0,17
2	Pulubala Sub Watershed	161.023,70	1.928.499,29	0,08
3	Molamahu Sub Watershed	183.278,94	3.492.366,24	0,05
4	Alo Sub Watershed	947.187,87	1.600.753,15	0,59
5	Buhiya Sub Watershed	15.459,65	425.862,11	0,04
6	Alo-Pohu Sub Watershed	1.642.868,7	9.294.659,62	0,18

Source: Result of calculation

The result of stepwise regression is obtained in a model of regression equation below:

$Log\ SDR = -2,385 + 1,104\ Log\ Q - 0,465\ Rf + 0,686\ Dd$........................ (6.3)

Description:

SDR = Sediment Delivery Ratio
Q = average monthly discharge (m^3/sec)
Rf = shape of watershed
Dd = drainage density (km/km^2)

Correlation coefficient (R) is 0.838 and coefficient of determination (R^2) 0.702. Results of analysis show that the variability of the SDR value was jointly influenced by the flow, basin shape, and drainage density. These factors play a role in sediment transport system. Flow serves as a media of surface sediment transport. The greater the volume and velocity of flow, the greater the amount of sediment will be the results show that DAS formed factor negatively correlated with the amount of SDR. In sub-watersheds SDR value tends to be greater. Thus the amount of sediment that settles the material is small. In sub-watershed the distance between the peaks and the river is shorter, so the opportunity for the occurrence of precipitation also becomes smaller. Thus the SDR value will be greater.

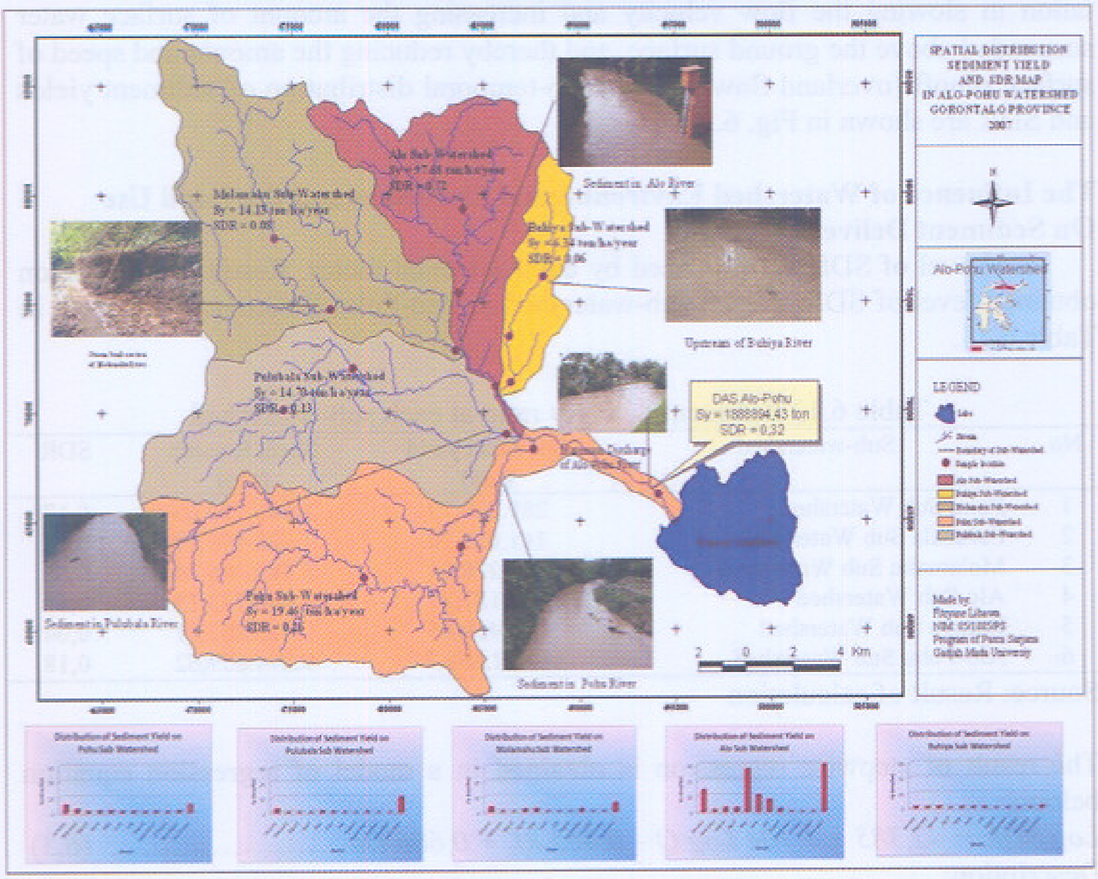

Figure 6.3 Spatio-temporal distribution map of sediment yield and SDR mat Alo Pohu watershed

Based on spatio-temporal distribution of sheet erosion and the sediment yields, the periods of erosion can be predicted and the priority of watershed environmental conservation area is obtained. Therefore, the arrangement of land use and restoration of critical land can be chosen based on the risk levels of erosion. Meanwhile, the cautiousness can be enhanced in perilous moments so that the condition can be socialized to the society.

Based on the sediment analysis, the increase of sediment concentration from upper- middle- and lower course is disclosed. This indicates that there have been landslides at the river banks which give impact on the sediment yields. Therefore, management activities in lower course areas are needed by conducting riverbank protection, for instance, through the planting of vegetation and the placement of rocks to prevent landslides. Another factor affecting the amount of sediment is the avalanche slope. Thus, management activities need developing along the river channel and flood plains for example by making the protection of riverbanks through planting vegetation and setting up stone to retain landslide. In considering the amount of vegetation flow velocity, grass group that is flexible can be used to bluff with a high flow speed, while the fragile one is used for low flow.

CONCLUSIONS

Based on the aforementioned explanation, the research concludes that the level of sheet erosion is influenced by characteristic of environmental condition and land use. The amount of sheet erosion varies in each land units and is affected by rain fall, slope gradient and land use. Sheet erosion occurring in Alo-Pohu watershed is categorized as moderately erosion (60-< 180 tons/ha/year). This is supported by the types of land in the research areas which belong to moderately susceptible and susceptible to erosion.

The amount of sediment yields in the research areas was simultaneously affected by the discharge, area of watershed, drainage density, and the percentage of wasteland in watershed. The higher the rate of surface runoff, drainage density and percentage of wasteland, the bigger the amount of sediment yields obtained. Meanwhile, the smaller the area of watershed, the smaller the amount of sediment yields is.

The SDR in Alo-Pohu watershed was simultaneously affected by the discharge, the shape of the watershed, and drainage density. The higher the rate of discharge and the drainage density, the higher the SDR value is. In elongated-shaped watershed, SDR values are bigger and on the other hand, on the round-shaped watershed, the SDR values are smaller.

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