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Land Use and Environment Physical Condition on Sedimentation and Water Discharge of Lindu Lake Watershed

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Abstract---*Lindu lake sub-watershed has harmed by various human activities which do not pay attention to environmental sustainability principles. This research aims to know the influence of land use area and environment physical condition on sedimentation and water discharge in Lindu lake sub-watersheds. This research uses survey and non-experimental method on 3 rivers which are Langko (P1), Wongkodono (P2), and Kati (P3). The dependent variable in this research is land use area (area of the garden, shrubs, rice field, forest, and settlement) and environment physical condition (catchment area and average annual rainfall) and the independent variables are sedimentations and water discharge. The used statistical analysis is a multiple regression model. The result shows that the wider shrubs area (X_2) reduces sedimentation (Y_1) and increases water discharge (Y_2). Each addition of one shrub unit will decrease sediment in amount of 0,208 mg/L and affects water discharge an amount of 0,258 m^3/sec^{-1} with regression equation $Y_1 = 185{,}903 - 0{,}208X_2 - 587{,}269X_8$ and $Y_2 = 6{,}854 + 0{,}258\ X_2 - 71{,}708\ X_8$. As for the bigger river shape coefficient (X_8) so the smaller water discharge average. Hence, each reduction of one river shape coefficient unit will affect water discharge in the amount of 71,708 m^3/sec^{-1}. It can be concluded that significant predictor factor on sedimentation and water discharge are shrubs and river shape coefficient.*
Keywords---*environment physical condition, lindu lake watershed, sedimentation, water discharge.*

Introduction

There are various disturbances on watershed ecosystem especially from watershed inhabitants such as human (Jordan & Benson, 2015; Upadani, 2017; Williams *et al.*, 2016). If the watershed function is disturbed, so the hydrology system as the watershed main function will be disturbed as well, also rainfall catchment, recharge, and water storage will decrease (Nasrullah & Kartiwa, 2009; Oktarian *et al.*, 2016). That phenomenon will cause excessive water in the rainy season but lack of water in the dry season. Furthermore, it also causes fluctuation of river flow between the dry season and the rainy season which highly different. Hence, if the fluctuation of river flow is very sharp it means watershed is not functioning properly which also means the low quality of watershed (Hirpa, Gebremichael, & Over, n.d.; Rahman, 2009; Wahid, 2009; Wondzell *et al.*, 2007).

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According to Lukman and Ridwansyah (Lukman & Ridwansyah, 2003), recent measurable Lindu Lake maximum depth is 72,6 m. There is an indication of 30 m lake siltation since in 1970 Lindu Lake depth is recorded around 100 m. Siltation is an effect of sedimentation. Based on the condition of Lindu lake sub-watershed, if it is not resolved there might be a worse crisis of land (soil) and water resources in the future because of human activities.

Land use is human intervention whether it is permanently or periodically to fulfill their needs in the form of material or spiritual to the needs of complex land resources. Land use pattern of a particular region can give a depiction of the region economics condition and as an indicator of environmental pollution. Hence, there is an interest to provide wider land to expand basic economy which number is increasing (Agustiningsih *et al.*, 2012; Jie *et al.*, 2010).

Lindu lake sub-watershed has harmed by various human activities which do not pay attention to environmental sustainability principles. Recently, Lindu lake sub-watershed has lost more than 16.000 ha of forest area (Lukman & Ridwansyah, 2003). The main reason is illegal forest conversion into agricultural land. It causes lake on succession condition where it changes from an aquatic ecosystem to the terrestrial ecosystem. Main physical condition factor which affects watershed management is the climate factor which is rainfall (Ningkeula, 2015; Yan *et al.*, 2015). There are several factors that affect water discharge such as rainfall intensity, deforestation, forest conversion into agricultural land, interception, evaporation and transpiration, wind, also flow velocity (Ahmad, 2014; Handayani & Indrajaya, 2011; Love *et al.*, 2010; Quyen, Liem, & Loi, 2014; Wondzell *et al.*, 2007). The amount of river flow fluctuation and sedimentation portrays land use pattern and environment physical condition such as rainfall, watershed area, and river shape coefficient (Berhanu *et al.*, 2015; Duncan *et al.*, 2017). This research aims to know the influence of land use area and environment physical condition on sedimentation and water discharge in Lindu lake sub-watersheds.

Research Method

The used materials are roll meters, sample bottles, cameras, GPS, hagameter, filter paper, and stationery. This research is conducted with survey and non-experimental method. The variable approach is conducted by field survey. This research started from January until April 2017 which located in the Catchment area of Lindu Lake. Afterward, the sedimentation analysis is conducted in the Laboratory of Soil Science Unit, Faculty of Agriculture, Tadulako University, Palu.

Examined Catchment Area of Lindu Lake

Table 1
Sub-watersheds research

No	Sub-watersheds		Area (km^2)
	River Name	Observation Station	
1.	Langko River	P1	9,68
2.	Wongkodono River	P2	2.794
3.	Kati River	P3	138,04

Research Variable

The dependent variable in this research is land use area (area of the garden, shrubs, rice field, forest, and settlement) and physical condition of the environment (catchment area, and average annual rainfall) and the independent variables are sedimentations and water discharge (Table 2).

Table 2
Dependent and Independent Variable

Variable	Sub Variable	Notation	Unit*)
Area of Land Use Pattern	Plantation	X_1	%
	Shrubs	X_2	%

	Rice field	X_3	%
	Primary forest	X_4	%
	Secondary forest	X_5	%
Environment Physical Condition	Area of sub-watersheds	X_6	km^2
	Average of rainfall	X_7	mm th^{-1}
	River shape coefficient	X_8	Km^2
Sedimentation		Y_1	Ton ha^{-1} th^{-1}
Water Discharge		Y_2	m^3/det

Data Collection
Number of Points and Observation Period

a) There are 3 (three) catchments of the observation point, each observation points is measured twice at the edge of the river and middle of the river. Thus, the number of water sample on each 3 observation points is 6 samples on each measurement.
b) For observation period, on each of the points is repeated with an interval 7 days (1 week), so measurement during research is 7 times measurement.

Flow Rate Measurement

The measurement of river discharge and flow rate uses the direct method with the equation of a buoyancy formula:
Q = V. A
Information: V= Average flow rate (m/sec); A = Area of river cross section (m^2);
Q = river flow rate (m^3/sec)

Water Sampling Technique (Floating Sediment)

Water sampling technique by using bottle is a modification of Depth – Integrating Suspended technique. The bottle of sediment sample is made simpler with two holes. The first hole for water sample entry and another one for an air hole.

Floating Sediment Analysis

The amount of sediment concentrate is determined from sediment sample analysis which using evaporation method with equation:
C = x (*b-a)* x 1000 (*mg/l)*
Information:
C = Sediment concentrate (mg/l)
V = Volume of sediment sample (ml)
b = The weight of the cup contains sediment deposition (gram)
a = The weight of empty cup (gram)
the amount of sediment concentrate and water discharge are determined with equation : Qs = 0,00864.C. Q. where Qs = total of sediment (ton/day).
C = sediment concentrate (mg/l), and Q = river flow rate (m^3/second)

Transported Sediment Value

The amount of sediment per area is calculated with the equation:

$$SDR = \frac{Transported\ Sediment\ (Y)}{the\ amount\ of\ erosion\ (A)}$$

Where the determination of erosion amount (a) is obtained from the application of simulation formula USLE which is: A = R. K. LS. C. P. therefore, transported sediment is obtained with the formula: Y = SDR/A.

Statistical Analysis

The used statistical analysis method is the multiple regression model to know the relation of an independent variable (X) with the variable response (Y)

This research uses the regression equation as follows :
$Y=a+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+b_6X_6+b_7X_7+b_8+X_8+\varepsilon$..............
Where:
Y_1 = Sedimentation
Y_2 = Water discharge
X_1 = Plantation
X_2 = Shrubs
X_3 = Rice field
X_4 = Forest
X_5 = Settlement
X_6 = Sub-watershed
X_7 = Average of rainfall
X_8 = River shape coefficient
a = Constants value
b (1-5) = Regression coefficient value
ε = Error

Results and Analysis

Table 3 shows the river with the highest water discharge is Kati river (P3) with average 10,0 m^3/sec when it is not raining and after raining it becomes 24,58 m^3/sec. Meanwhile, the smallest water discharge is on Wongkodono river (P2) 0,125 m^3/sec when it is not raining and after raining it becomes 1,25 m^3/sec.

Table 3
River Water Discharge Based on Rainfall Period during Research

River Name	Water Discharge (m^3/sec)							
	Not Raining				After Raining			
	1	2	3	4	1	2	3	4
Langko (P1)	0.4	0.5	0.6	0.9	1.1	1.2	7.2	1.1
Wongkodono (P2)	0.1	0.2	0.1	0.1	0.5	0.5	3.6	0.4
Kati (P3)	6.8	6.8	13.7	12.7	15.1	15.6	52.5	15.1

Table 4 Shows River with the largest sedimentation is Kati River (P3) with average sedimentation value (when raining or after raining) in the amount of 165 mg/L and the least is in Langko River (P1) with sedimentation average (when raining and after raining) in the amount of 109.42 mg/L.

Table 4
Data of River Sedimentation Based on Rainfall period during Research

River Name	Sedimentation (mg/L)	Information
Langko River (P1)	100	Not raining
	128	Not raining
	108	Raining
	168	Raining
	126	Not raining
	118	Not raining
	18	Raining
Wongkodono River (P2)	124	Not raining
	124	Not raining
	122	Raining
	144	Raining
	174	Not raining
	120	Not raining

	126	Raining
Kati River (P3)	144	Not raining
	190	Not raining
	303	Raining
	264	Raining
	14	Not raining
	56	Not raining
	184	Raining

Table 5 shows land use by local inhabitants is garden and rice field. The biggest garden land use is in Langko River (P1) in the amount of 16,91% and rice field in the amount of 8,78%.

Table 5
Land Use

Land Use	Langko river (P1)		Wongkodono river (P2)		Kati river (P3)	
	Area of Ha	%	Area of Ha	%	Area of Ha	%
Garden (X1)	163.73	16.91	336.76	12.06	974.31	7.06
Shrubs (X2)	14.75	1.52	0	0	46.88	0.34
Rice Field (X3)	84.98	8.78	112.41	4.03	116.83	0.85
Primary Forest (X4)	314.08	32.43	1,662.70	59.56	5,396.10	39.07
Secondary Forest (X5)	390.84	40.36	678.64	24.31	7,275.87	52.69

Table 6 shows the largest catchment area is in Kati River (P3) in the amount of 13,809.99 km^2 and the smallest in Langko River (P1) in the amount of 968.38 km^2. Meanwhile, the average of rainfall is 2.205.42 mm th^{-1} and the biggest river shape coefficient is in Langko River (P1) in the amount of 0.125

Table 6
Environment Physical Condition

Environment Physical Condition	Langko river (P1)		Wongkodono river (P2)		Kati river (P3)	
	Nilai	Satuan	Nilai	Satuan	Nilai	Satuan
Catchment Area (X6)	968.38	Km^2	2,790.54	Km^2	13,809.99	Km^2
Average of Rainfall (X7)	2,205.42	mm th^{-1}	2,205.42	mm th^{-1}	2,205.42	mm th^{-1}
River Shape Coefficient (X8)	0.125	-	0.089	-	0.036	-

Factors which Influence Sedimentation (Y_1)

The result of multiple regression analysis from eight variables, it turns out only two variables which have a significant influence on sedimentation and an equation is obtained as follows:

Y_1= 185,903 - 0,208X_2 – 587,269X_8

Where Y_1 = Sedimentation, X_2= shrub, X_8= River shape coefficient

The result shows that variables which have a significant effect on the sedimentation process are river shape coefficient and shrubs. The bigger river shape coefficient, sediment will increase in the amount of 587,269 mg/L as multiple regression calculation has been conducted that Lindu lake watershed has big river shape coefficient so the occurrence of sedimentation is also bigger

Factors which Influence River Flow Rate (Y_2)

Multiple regression analysis from eight variables in equation generates only two variables which have a significant influence on the change of measured average flow rate and an equation is obtained as follows:

Y_2 = 6,854 + 0,258 X_2 – 71,708 X_8

Where Y_2 = measured average flow rate, X_2= shrubs, X_8= river shape coefficient. From regression relation in equation (1) it is obtained a very good R^2 which is 1 or 100% the change of measured flow rate average is related to variables of shrubs and river shape coefficient.

Discussion

The result of the research shows the largest shrubs so it will decrease sedimentation and make water discharge higher, each addition of one shrub unit will decrease sediment in the amount of 0,208 mg/L and affects water discharge the amount of 0,258 m^3/sec^{-1}. Shrubs existence maintains Lindu Lake watershed sustainability in a long-term, so it will prevent the occurrence of the siltation process in Lindu Lake watershed. Nevertheless, water discharge will be high if shrubs less absorb the water. Hence, if the rain pours the water will runoff directly to the river and make water discharge high. Water runoff is an amount of water which flows over the land in the form of canals or creeks and end up gather/flow to the main river.

Shrubs and bushes are an area of dry land which has been overgrown with various heterogeneous and homogeneous natural vegetation which its density is rare until dense (BSN, 2010). In Indonesia, generally, shrubs is a former forest area that does not show any trace of trees cutting down (Savitri & Pramono, 2017). Generally, shrubs also an unproductive area and was abandoned by farmers. Hydrologically, shrubs have important hydro-orological functions especially to maintain microclimate, soil moisture, and microorganism activity (Makarieva *et al.*, 2018; Ryu *et al.*, 2008). Shrubs in several areas are so wide and usually, it is untouched by farmers' activity so the existence is still original.

Furthermore, the bigger river shape coefficient the smaller water discharge average. Thus, each reduction of one unit river shape coefficient will affect water discharge in the amount of 71,708 m^3/sec^{-1}. When an amount of water in a region increases so the faster time that needed for water to flow. Consequently, water discharge will increase when the rain comes.

The increasing of water discharge after rain comes in several sampling points is still normal. It causes by not very high rainfall when the samples are taken. The highest water discharge after rain is in Kati River in the amount of 52,5 m^3/sec since there was heavy rain the whole day before the data was taken. That increasing of water discharge will not cause any negative effect on local inhabitants activity especially agricultural activity such as rice field area (Suadnya *et al.*, 2017; Wagner *et al.*, 2009). Moreover, the amount of water discharge will not affect other agricultural activity such as seasonal crops around sampling points.

The amount of water discharge has an effect on the agricultural activity which is the amount of water that enters the agricultural area. If the discharge is too low the lack of water to fulfill agricultural need will possibly happen. In contrast, if the discharge is too high it will give a negative effect to agriculture especially rice field area. Nonetheless, water availability is important to run agricultural activity, and basically, all the crops such as seasonal crops around the research area need more water than annual crops.

Conclusion

The main factor and predictor on sedimentation and water discharge of Lindu lake watershed are shrubs and river shape coefficient. Hence, land expansion by reducing shrubs can give negative effect in form of siltation and causes damage such as river ecosystem loss and flood because of high sedimentation

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