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Article

Analysis of Recent Erosion Hazard Levels and Conservation Policy Recommendations for Lesti Subwatershed, Upper Brantas Watershed

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Abstract

The reduced age function of Sengguruh Dam/Reservoir due to erosion in the upper of Brantas Watershed (Lesti Subwatershed area) interferes with its role in flood control, irrigation water supply, and the supply of most of the hydroelectricity in East Java Province, Indonesia. This study aims to estimate erosion, analyze the interrelationship of the causative factors, and provides environmental conservation direction. The research uses mixed methods. The quantitative method of erosion rates is done by calculating the Modify Universal Soil Loss Equation which is supported by GIS tools. The qualitative method is carried out with questionnaires and interviews in the Lesti Subwatershed area. The results showed that the current erosion rate in each ha of land (average) in the Lesti Subwatershed was 153,868 tons /ha/year (exceeding the tolerable erosion rate of 30 tons/ha/year). The rate of erosion in the Lesti Subwatershed has always increased in the last 14 years. Of the 12 Subdistricts in the Lesti watershed, as many as 6 Subdistricts are identified as having high levels of Erosion Hazards so that they were a priority to be handled, namely in the Wajak, Dampit, Tirtoyudo, Gedangan, Sumbermanjing Wetan, and Bantur Subdistricts. Dampit Subdistrict, Turen Subdistrict, and Gondanglegi Subdistrict also face behavioral problems and high population pressure compared to other Subdistricts. Research also shows that there is a relationship between erosion and knowledge, attitudes, and behavior of the community in the form of population pressure and land use patterns. It is recommended that environmental conservation directives focus on these 6 Sub-districts through the application of soil and water conservation. The results of spatial analysis at priority locations suggest conservation measures in the form of law enforcement or counseling, and community empowerment to increase the ability and independence of the community through providing access to resources, education, and training.

Keywords: Conservation, Erosion, Population Pressure, Community Behavior, Watershed

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Andi Setyo Pambudi, Setyo Sarwanto Moersidik, and Mahawan Karuniasa

I. Introduction

Erosion and sedimentation have been recognized as important issues that reduce reservoir capacity and destroy many public facilities (Setyawan & Lee, 2017). Analyzing erosion and sedimentation cannot be released from the hydrological boundary of the Watershed (Anache *et al.*, 2018; Bisri *et al.*, 2017; Asdak, 2010). Dwelling or hydrological containers of economic activity based on the environment are described as watersheds (Common & Stagl 2005; Miller & Spoolman 2015; Reddy *et al.*, 2017). Watershed areas are often used as socio-economic, biophysical or political units for the management and planning of natural resources (Pambudi, 2019; Heathcote, 1998). Global climate change, increasing population and the intensity of economic activity are accelerating changes in watershed conditions which affect erosion where destroy is often caused by mismanagement in the upstream, such as the addition of cultivated and also residential land areas (Bellfield *et al.*, 2015; Kindu *et al.* ., 2017; Euler *et al.*, 2018).

The government has responded to the importance of restoring watershed conditions through the National Mid-Term Development Plan (RPJMN) 2015-2019 and 2020-2024 (GoI, 2014a). In this document, 15 priority watersheds are determined to be restored, one of them is the Brantas watershed (Bappenas, 2015). One of the upstream of the Brantas watersheds is the Lesti Subwatershed. Previous studies of erosion in this area show a significant increase in erosion rates. Yupi (2006) has calculated the erosion rate, especially the average of each hectare of land about 30.57 tons/ha/ year. The results of Setyono and Prasetyo (2012) showed an erosion rate of 105,763 tons/ha/year. Meanwhile, the study of Ma'wa et al. (2015) got 131,098 tons/ha/year. The erosion rate needs to be lowered and controlled in following the provisions that require further study.

Wischmeier and Smith (1978) in Arsyad (2006) state that the value of erosion rate or tolerable soil erosion (T) in each hectare of land that can be tolerated for land in America is 4.48-11.21 tons/ha/year. The maximum rate of soil erosion in each hectare of land tolerated by many researchers for Indonesia is based on research of Hardjowigeno (1995), which is 30 tons / ha / year.

Ideally, erosion data in the watershed should be updated regularly so that the handling policy can be under the existing factual conditions (Pambudi & Moersidik, 2019). The average erosion rate in the Lesti Subwatershed that can be tolerated is 30 tons/ha/year. When the erosion rate in the Lesti Subwatershed exceeds the tolerance limit, conservation is needed to control erosion rate so that sedimentation downstream can be reduced (Pambudi *et al.*, 2020; Jeloudar *et al.*, 2018; Nabi et al, 2017). Conservation efforts that are not proportional to the erosion rate have an impact on the magnitude of sedimentation in the Sengguruh Reservoir making the reservoir function is not optimal (Firdaus *et al.*, 2015; Djajasinga *et al.*, 2012). Conservation considerations require erosion rate data as well as soil solum which will spatially describe the Erosion Hazard Level (EHL) values in the Lesti Subwatershed (Pambudi *et al.*, 2020). This study is expected to provide recommendations for conservation actions that are in line with current EHL in the Lesti Subwatershed, including considering social aspects and population pressure.

This study aims to: 1) Analyze the influence of population pressure, community behavior, and land use on erosion in the Lesti Subwatershed; 2) Estimate the latest erosion in the Lesti Subwatershed and; 3) Provide conservation direction in the Lesti Subwatershed based on erosion estimation, population pressure and community behavior as part of efforts to restore the health of the Brantas watershed. The research uses a watershed ecological and conservation approach framework that covers economic, social, and environmental aspects. The results of the study are expected to be considered by policy makers or the public regarding the selection of appropriate conservation sites and conservation efforts that must be based on scientific analysis of hydrological and ecological sciences.

II. Material And Methods

This paper utilized literature study through referencing relevant theories and information-based policies of forestry and social forestry. The utilized secondary data were obtained or collected from various existing sources as books, documents, and applicable laws and regulations related to social forestry, both in the context of Indonesia and that of the world. Analysis of the gap or suitability between targets and realization was used as a basis for providing research recommendations in addition to the problems or obstacles encountered in social forestry policy in Indonesia.

2.1 Time and Location

The time for completing research was carried out from February 2019 to January 2020 (for 12 months). The research location is limited to the Lesti Subwatershed as one of the upstream of Brantas watersheds. Administratively, the Lesti Subwatershed is located in Malang District (Kabupaten Malang) with the total area of the Subwatershed is 64,740.84 ha. The research sites cover 12 Subdistricts in Malang District. The limitation of the study area starts from the headwaters of the Lesti River in Poncokusumo Subdistrict to the Sengguruh Dam (outlet).

2.2 Materials and Tools

In conducting research, secondary data from relevant agencies in the Brantas Watershed area are used, such as: 1) Rain data for the last 10 years from The Public Works and Water Resources Department of East Java Province; 2) Topographic Map, Soil Solum, Soil Type, Soil Texture and the latest 2018 Land Use Map from the Ministry of Environment and Forestry, specifically Brantas Watershed and Protected Forest Management Center (BPDAS-HL); 3) Data related to land tables from experts which have been agreed by many researchers in advance; 4) Contour and River maps of 1: 25,000 scale covering the Lesti Subwatershed area of the Geospatial Information Agency (GIA). This map consists of 7 sheet maps with indices 1607-414 Manjing Wetan Resources, 1607-423 Gamping, 1607-432 Turen, and 1607-441 Tlogosari, 1607-434 Bululawang, 1607-443 Tumpang, 1607-444 Ranupane; 5) Monograph data from BPS and; 6) Questionnaire Data (Primary Data).

The research design was carried out by giving 3 questionnaires namely a knowledge questionnaire sheet, an attitude questionnaire sheet, and a behavioral questionnaire sheet for the selection of environmental-related activities in the Lesti Subwatershed. The completion of the questionnaire was carried out through direct visits on 17 to 30 July 2019 or online via the bit.ly/SubDASLesti link with a total of 358 respondents in 12 Subdistricts in the Lesti Subwatershed. The analytical tool used is by using the help of Arc GIS 10.3 Software, SPSS Version 22 and Microsoft Excel 2019.

2.3 Research Methods

The method used is a mixed method with community behavior analysis using cross tabulation statistical analysis methods. Behavior analysis design starts from the results of a questionnaire-based survey in order to determine the relationship between attitudes, knowledge and behavior of the community with a sample analysis scale of 358 respondents in Malang District (12 Subdistricts) who are in the scope of the Lesti Subwatershed. The research ethics used was informed consent and confidentiality. The results of this survey form the basis for calculating Pearson's bivariate correlation in statistical science. Delegation of the Lesti Subwatershed is carried out by generating Digital Elevation Model (DEM) data from the Earth Map, in particular the 1: 25,000 scale Contour and River Maps covering the Lesti Subwatershed area from the Geospatial Information Agency (GIA). Rain data consistency test uses the double mass curve approach (Soemarto, 1987) and the calculation of regional maximum rainfall uses Polygon Thiessen. Analysis of rainfall design using the Pearson Log Type III distribution and 1.01 return time. To calculate surface runoff discharge, a modified rational formula is used. The calculation in this study such as: 1) Determine the Flow Coefficient (C); 2) Calculate the Concentration Time (Tc), Reservoir Coefficient (Cs) and Rain Intensity (I) and; 3) Running formula of runoff discharge and describe it in the form of Surface Runoff Discharge Distribution Map in various times with Arc GIS Software 10.3. Analysis related to population pressure using the Soemarwoto Formula (1985) and behavior analysis using the Pearson bivariate statistical method. The erosion rate was calculated by the MUSLE method with a database of surface runoff erosivity index, erodibility, length and slope as well as crop management factors and conservation measures (CP). The component of obtaining CP value is also related to community behavior and population pressure on land. Meanwhile, to get the level of erosion hazard an overlay is done between the erosion rate map and the soil solum map with the help of Geographic Information System tools. Conservation action recommendations use overlay techniques from attributes entered under Law 37 of 2014 on Soil and Water Conservation (GoI, 2014b).

III. Results And Discussion

3.1 Behavior Analysis

Analysis of Knowledge, Attitudes and Behavior in Lesti Subwatershed using pearson bivariate correlation analysis. This analysis was conducted to determine the closeness of the relationship between variables expressed by the correlation coefficient. This study uses SPSS software that is used to simplify the process of correlation analysis. There are three ways that can be used as a guide / basis for decision making in Pearson's bivariate correlation analysis, which is based on the significance value of sig. (2-tailed), based on r count values (Pearson correlations) and based on asterisks (*) in SPSS software.

The results of the SPSS software analysis to look for correlations of community knowledge, attitudes and behavior in the Lesti Subwatershed are shown in Table 1.

Table 1. Behavior Variable Correlation with the Knowledge Variable and Attitude Variable

		Knowledge	Attitude
Behavior	Correlation of Pearson	.629**	.188**
	Sig. (2-tailed)	.000	.000
	N	358	358

***. Correlation is significant at the 0.01 level (2-tailed).*

Source: *Analysis Result, 2019*

From this table it can be concluded that there is a relationship or there is a correlation between the behavior variable with the knowledge variable and attitude variable. Knowledge is in harmony with attitudes and behavior. In spatial analysis, behavioral variables are used because statistically they already represent the knowledge and attitudes of the people in the Lesti sub watershed. Questionnaires that have been filled out by respondents are then assessed or scored. If the respondent's value is above the median value then the value is classified as positive, conversely if the respondent's value is below the median value then it is classified as negative. The median value of each variable can be seen in Table 2.

Table 2. Median Values of Knowledge, Attitudes, and Behavior Variables

	Knowledge	Attitude	Behavior
median	50	60	80

Source: *Analysis Result, 2019*

The value of each respondent is then summarized in a cross tabulation per each Subdistrict.

Table 3. Percentage of Acquisition Values in Each Subdistrict

Subdistrict	**Knowledge**		**Attitude**		**Behavior**		**Total Respondent per Subdistrict**
	negative	**positive**	**negative**	**positive**	**negative**	**positive**	
Ampelgading	1 (3%)	31 (97%)	1 (3%)	31 (97%)	2 (6%)	**30 (94%)**	32
Bantur	25 (81%)	6 (19%)	12 (39%)	**19 (61%)**	17 (55%)	14 (45%)	31
Bululawang	0 (0%)	30 (100%)	1 (3%)	29 (97%)	1 (3%)	**29 (97%)**	30
Dampit	29 (94%)	2 (6%)	31 (100%)	0 (0%)	28 (90%)	3 (10%)	31
Gedangan	22 (71%)	9 (29%)	18 (58%)	13 (42%)	18 (58%)	13 (42%)	31
Gondanglegi	14 (47%)	16 (53%)	10 (33%)	**20 (67%)**	20 (67%)	10 (33%)	30
Pagak	10 (40%)	15 (60%)	7 (28%)	18 (72%)	7 (28%)	**18 (72%)**	25
Poncokusumo	4 (15%)	22 (85%)	0 (0%)	26 (100%)	2 (8%)	**24 (92%)**	26

Subdistrict	**Knowledge**		**Attitude**		**Behavior**		**Total Respondent per Subdistrict**
	negative	**positive**	**negative**	**positive**	**negative**	**positive**	
Sumbermanjing Wetan	25 (81%)	6 (19%)	21 (68%)	10 (32%)	17 (55%)	14 (45%)	31
Tirtoyudo	8 (27%)	22 (73%)	15 (50%)	15 (50%)	21 (70%)	9 (30%)	30
Turen	19 (61%)	12 (39%)	11 (35%)	**20 (65%)**	16 (52%)	15 (48%)	31
Wajak	18 (60%)	12 (40%)	12 (40%)	**18 (60%)**	21 (70%)	9 (30%)	30
Total	175 (49%)	183 (51%)	139 (39%)	219 (61%)	170 (47%)	188 (53%)	358

Note : Subdistrict that have positive qualifications of more than 50% on behavioral variables

Subdistrict that have negative qualifications of more than 50% on behavioral variables

Source: Analysis Results, 2019

Based on the cross tabulation, Subdistricts that have a positive value of more than 70% or can be said to be good Subdistricts in the management behavior of Lesti Subwatershed are Ampelgading, Bululawang, Pagak, and Poncokusumo Subdistricts. Not only do these four Subdistricts have good grades on behavioral variables, but they are also good at attitudes and knowledge related to watershed management. In the analysis also found Subdistricts that have less value on the behavior variable (classified as negative more than 50%), namely the Subdistricts of Dampit, Gedangan, and Sumbermanjing Wetan, Bantur, Gondanglegi, Tirtoyudo, Turen and Wajak. Subdistricts that are less good in behavior also tend to lack in attitudes and behavior.

The results of the statistical and spatial analysis show that in the Lesti Subwatershed there is a link or correlation between the people's behavior and the existing land use. Overlay of spatial maps of behavior with the latest land use states that in Subdistricts that are dominated by negative values tend to have land use that is potentially prone to erosion, namely open or semi-open land such as settlements, dry land agriculture, mixed dryland agriculture, paddy fields, and open land.

3.2 Population Pressure Analysis

Ariani *et al.*, 2012, said that the TP value <1 means that there was no population pressure. It's showed the area was still able to support the population's living needs. Value of TP = 1 means that the area is still able to support the living needs of its inhabitants appropriately. Value of TP > 1 means that there has been a population pressure on the land in an area so that it has been unable to support the needs of life of its residents properly (Sapci & Considine, 2014; Rusli *et al.*, 2009). Population pressure on land is calculated by the formula Otto Soemarwoto (1985) as follows:

$$TP = Z \text{ x } \frac{f \, Po \, (1 + r)^t}{L}$$ (Formula 1)

There is an explanation of the formula. The TP means population pressure and Z related to minimum land area per farmer to be able to live properly. Furthermore,

t = Time span in years

L = Total area of agricultural land

r = The average population growth rate per year

Po = Total population of the initial year

f = Proportion of farmers in population (%)

Each farmer minimum land to be able to live properly (Z value) is formulated as follows:

$$Z = \frac{(0.25\, LSI_2) + (0.5 LSI_1) + (0.5 LST) + (0.76 LLK)}{(LSI_2 + LSI_1 + LST + LLK)}$$

(Formula 2)

There is an explanation of the formula.

LSI_1 = Irrigated rice field area 1 harvest a year (ha)

LSI_2 = Irrigated rice field area from 2 times a year harvest (ha)

LST = Rainfed lowland area (ha)

LLK = Dry land area (ha)

The proportion value of farmers in the population (f) is obtained from the formula submitted by Soemarwoto (1985), namely:

f = (Total farmers / Total people population) x 100% (Formula 3)

The population growth rate is using the geometry formula as follows:

$Pt = Po\ (1+r)^t$ (Formula 4)

Where:

Pt = Total population in the year t

Po = Total population of the initial year

r = Population growth rate

t = The time period, which is stated in years.

Table 4. Population Pressure Level on Land

Subdistrict in Lesti Subwatershed	Total Population	Total Farmer	Proportion of Farmer	Population Growth Rate	Minimum Area Worth Living	Land Area for Agriculture (Ha)	Population Pressure	Criteria
Poncokusumo	26.221	24.460	0,93	1,53	0,17	4.226,381	0,97542	< 1
Wajak	74.121	66.292	0,89	1,20	0,19	4.621,481	0,87528	< 1
Dampit	108.914	89.087	0,82	1,50	0,19	8.361,963	**3,61627**	**> 1**
Tirtoyudo	44.121	28.991	0,66	1,44	0,17	3.029,741	0,86021	< 1
Sumbermanjing Wetan	24.739	15.099	0,61	1,47	0,19	1.548,180	0,55234	< 1
Turen	107.607	61.445	0,57	1,68	0,16	3.713,927	**3,68583**	**> 1**
Bululawang	12.282	4.927	0,40	0,72	0,16	209,196	0,00427	< 1
Gondanglegi	82.052	57.984	0,70	1,50	0,16	5.444,617	**1,95847**	**> 1**
Ampelgading	14.823	9.084	0,69	1,24	0,16	307,824	0,13464	< 1
Gedangan	12.032	5.043	0,42	0,19	0,26	1.329,656	0,00001	< 1
Bantur	20.384	13.051	0,64	0,66	0,26	1.757,160	0,01192	< 1
Pagak	7.683	7.123	0,93	1,49	0,26	1.082,391	0,38289	< 1

Source: *Analysis Results, 2019*

3.3 Erosion Analysis

Meanwhile, related to hydrological analysis as data to support erosion calculations, watershed delineation is needed. The delineation process is carried out with the help of Geographic Information System (GIS) tools, specifically the ArcGIS software.

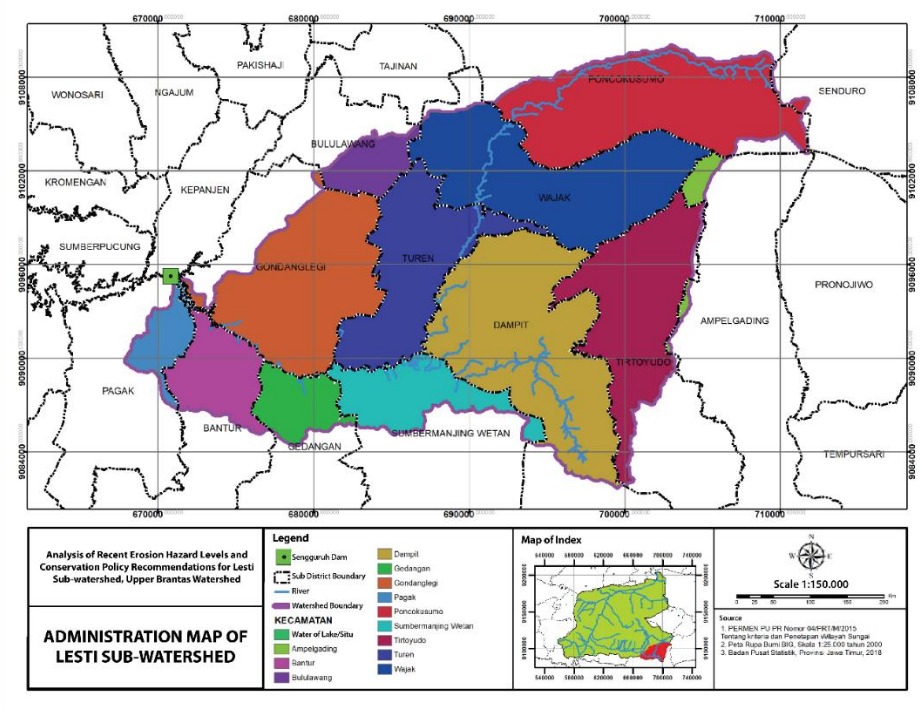

Figure 1. Results of Overlay Delineation of Watershed Boundaries and Sub District Boundaries of Lesti Subwatershed

Source: *Analysis Results, 2021*

Delineation begins by changing the contour map to DEM, then determining the direction of flow direction, flow accumulation, defining the river network synthetically, determining the outlet then finally defining the watershed and calculating watershed parameters. The shape and area of a watershed are influenced by the position of the outlet of a watershed. Lesti Subwatershed is located in Malang District with the total area of the Subwatershed is 64,740.84 ha. The research sites cover 12 Subdistrict. Study location starts from the headwaters of the Lesti River in Poncokusumo Subdistrict to the Sengguruh Reservoir outlet.

Rainfall data consistency test with the double mass curve method shows that the available rain data can be used for further analysis. In determining the regional average rainfall, this study method uses the Thiessen Polygon. This polygon is depicted by entering the coordinates of 4 rain stations with the help of ArcGIS 10.3 software to get the rain station distribution map in the Lesti Subwatershed Map. The next process is to create a Thiessen Polygon through assign proximity with a map of the Lesti watershed as a boundary of the area of influence.

From the result analysis, the Turen Rain Station has the largest area of influence that is 26,496,837 Ha (40,928% or thiessen coefficient 0,409), after that the Dampit Station is 23,731,127 Ha (36,665% or thiessen coefficient 0,367), Poncokusumo Station 13,257,853 Ha (afterwards 20,478% or thiessen coefficient 0,205) and the last is T Crafts Station 1,255,021 Ha (1,938% or thiessen coefficient 0,019).

Table 5. Regional Average Daily Maximum Rainfall (2009-2018)

Number.	Year	Koefisien Thiessen				Maximum Rainfall Average Daily Area
		Stat. Poncokusumo	Stat. Dampit	Stat Tajinan	Stat. Turen	
		0,205	0,367	0,019	0,409	
1	2009	150	117	71	127	126,959
2	2010	85	106	79	68	85,624
3	2011	94	108	79	100	101,297
4	2012	79	89	60	69	78,204
5	2013	110	109	69	115	110,885
6	2014	115	75	76	102	94,261
7	2015	95	74	71	63	73,740
8	2016	75	89	64	83	83,193
9	2017	115	147	114	88	115,660
10	2018	85	103	73	74	86,863

Source: Analysis Results, 2019

In hydrological analysis, the next process in order to predict erosion in the Lesti sub watershed is to calculate the design rainfall. The definition of design rainfall can be interpreted as the greatest rainfall that is likely to occur in an area with certain opportunities. In this study, the method for analyzing design rain is the Log Pearson Type III method.

Table 6. Calculation of the Pearson Type III Log Distribution (2009-2018)

Number.	Year	Xi (mm)	P (%)	Log Xi	Log Xi-Log X	(Log Xi-Log X)^3
1	2015	73,74	9,09	1,87	-0,11	-0,001215
2	2012	78,20	18,18	1,89	-0,08	-0,000535
3	2016	83,19	27,27	1,92	-0,05	-0,000160
4	2010	85,62	36,36	1,93	-0,04	-0,000073
5	2018	86,86	45,45	1,94	-0,04	-0,000045
6	2014	94,26	54,55	1,97	0,00	0,000000
7	2011	101,30	63,64	2,01	0,03	0,000030
8	2013	110,88	72,73	2,04	0,07	0,000350
9	2017	115,66	81,82	2,06	0,09	0,000700
10	2009	126,96	90,91	2,10	0,13	0,002159
Total		956,69		19,74		0,001211
Average		95,67		1,97		
Stand. Dev		17,52		0,08		
Skewness (Cs)				0,36		

Source: *Analysis Results, 2019*

Xi = Regional Average Rainfall (after being sorted from small to large).

The return period (Tr) is calculated by taking the various opportunities/possibilities desired. The reset time is determined by the formula Tr = (1/chance) x 100%. The calculation in this analysis will use a return with the greatest chance of 99% (assuming there is no 100% certain chance) so that the return period with this opportunity is 1.01 years. Calculations of the design rainfall values with a variety of complete returns are presented in Table 7.

Table 7. Calculation of Design Rain with Various Returns

Number	Tr (year)	Average R (Log)	Std Dev. (Log)	Skewness (Cs)	Opprotunity (%)	K	Design Rainfall	
							Log	mm
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
1	1,01	1,97	0,08	0,36	99	-2,061	1,81	65,17
2	2	1,97	0,08	0,36	50	-0,059	1,97	93,28
3	5	1,97	0,08	0,36	20	0,819	2,04	109,18
4	10	1,97	0,08	0,36	10	1,314	2,08	119,29
5	25	1,97	0,08	0,36	4	1,867	2,12	131,71
6	50	1,97	0,08	0,36	2	2,240	2,15	140,81
7	100	1,97	0,08	0,36	1	2,585	2,18	149,79
8	1000	1,97	0,08	0,36	0,1	3,606	2,25	179,85

Source: *Analysis Results, 2019*

Note:

[1] = Number

[2] = Return Period

[3] = (SlogXi)/n

[4] = $((\Sigma(\text{LogXi-LogX}))/(n-1))^{0,5}$

[5] = $(n.\Sigma(\text{LogXi-LogX})^3)/((n-1)(n-2)(\text{SLogX})^3)$

[6] = (1/Tr)*100

[7] = table of factors of log person distribution III based on the value of Cs and opportunities or return period

[8] = LogX + K.SlogX

[9] = antilog dari LogX

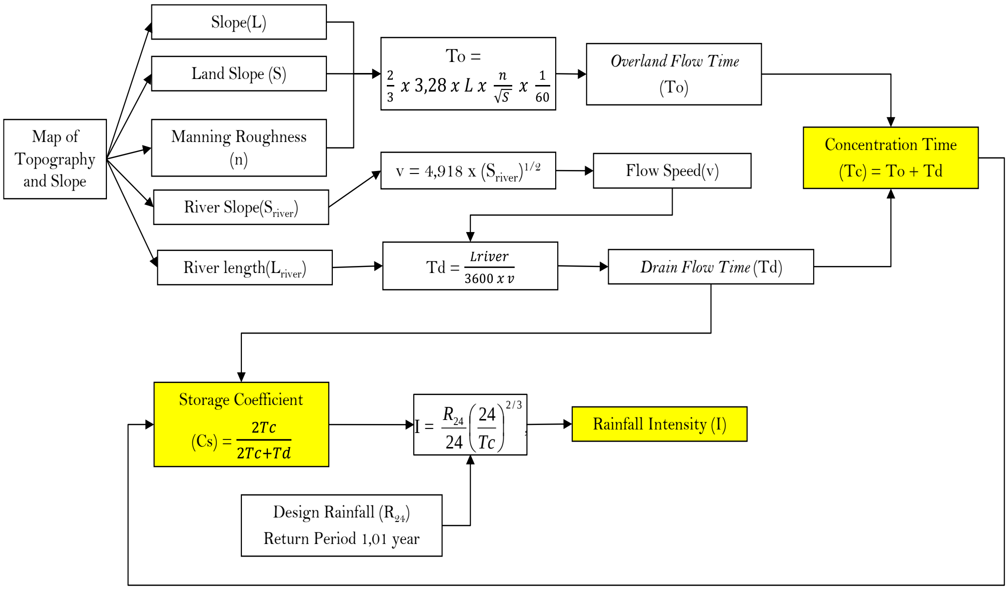

Figure 2. Flow Analysis of Concentration Time (Tc), Reservoir Coefficient (Cs) and Rain Intensity (I)

Source: *Analysis Results, 2021*

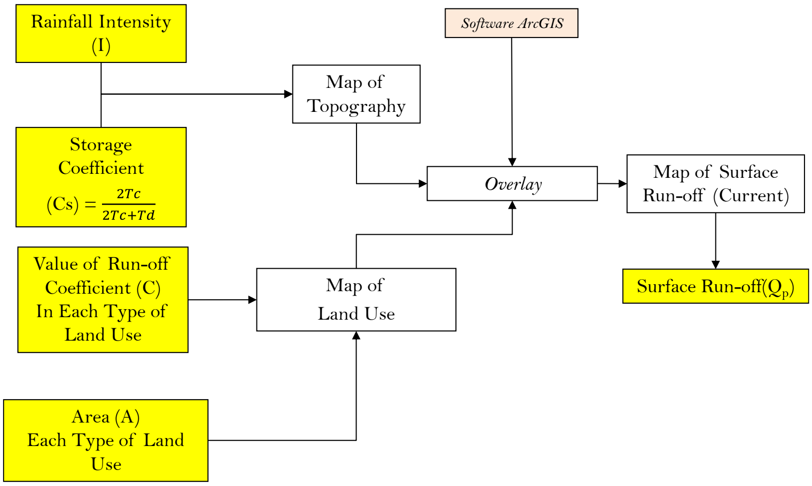

Figure 3. Flow Analysis of Surface Runoff Discharge Calculation in the Lesti Subwatershed

Source: *Analysis Results, 2021*

The next step analysis is determine runoff discharge. This analysis is done through overlays using ArcGIS software. The data used are Coefficients Cs and I. Furtehermore, the data used are land use maps for Coefficient C. The formula used is the modified rational runoff equation, namely:

$$Q = 0{,}00278.\ Cs.\ C.\ I.\ A \qquad \text{(Formula 5)}$$

Table 8. Coefficient C (Runoff) of Lesti Subwatershed in 2018

Number	Land Use	Coefficient C	Area (m²)	Area (Ha)	Percentage (%)
1	Water Body	0,00	131396,37	13,14	0,02
2	Thicket	0,15	4941972,16	494,20	0,76
3	Secondary Dry Land Forest	0,08	67709252,20	6770,93	10,46
4	Plantation Forest	0,06	27804756,09	2780,48	4,29
5	Plantation Graden	0,20	9742083,24	974,21	1,50
6	Settlement	0,25	140276061,24	14027,61	21,67
7	Dryland Farming	0,25	39999030,37	3999,90	6,18
8	Mixed Dryland Farming	0,25	125190399,28	12519,04	19,34
9	Rice Field	0,05	231120165,15	23112,02	35,70
10	Open Land	0,30	493283,91	49,33	0,08
		Total	647408400,00	64740,84	100,00

Source: *Analysis Results, 2019*

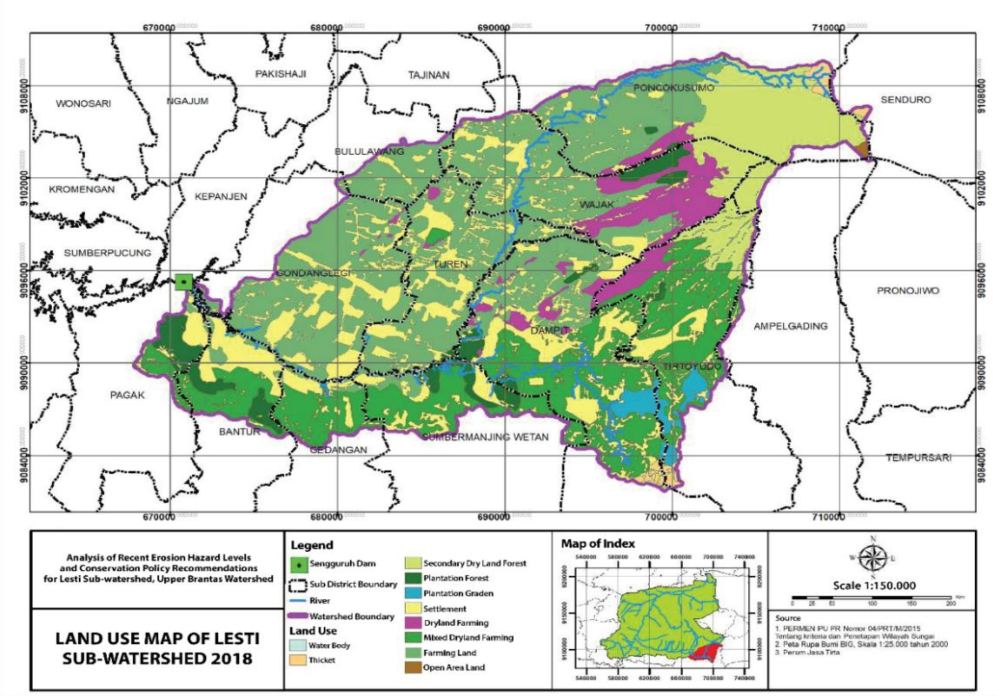

Figure 4. Land Use Map of Lesti Subwatershed 2018

Source: *Analysis Results, 2021*

The value of surface runoff / runoff coefficient (C) which is large indicates that the amount of surface runoff that occurs in the land is large. This means that the condition of the water system and land use on the land have been damaged. The value of the surface runoff / small runoff coefficient shows that the amount of surface runoff that occurred on the land is small. This means that the amount of water that seeps into the ground and that contributes (recharge) groundwater is large. In this study, the magnitude of drainage coefficient values based on 2018 land use conditions in the Lesti Subwatershed can be seen in Table 9.

Table 9. Current Runoffs Discharge of Lesti Subwatershed

Number	Sub Subwatershed	Sub Subwatershed Area (Ha)	Q Return Period 1.01 Year (m^3/sec)	Q Return Period 2 Years (m^3/sec)	Q Return Period 5 Years (m^3/sec)	Q Return Period 10 Years (m^3/sec)	Q Return Period 25 Years (m^3/sec)
1	1	2244,76	6,738595	9,645109	11,288965	12,333764	13,618433
2	2	1272,64	3,804667	5,445708	6,373843	6,963745	7,689079
3	3	2585,00	4,276788	6,121467	7,164774	7,827877	8,643220
4	4	4662,40	9,919690	14,198284	16,618158	18,156174	20,047302
5	5	171,96	0,569628	0,815321	0,954280	1,042599	1,151195
6	6	3090,40	10,385970	14,865682	17,399303	19,009615	20,989636
7	7	317,52	0,937318	1,341604	1,570259	1,715588	1,894281
8	8	2945,28	9,854448	14,104904	16,508861	18,036764	19,915453
9	9	140,48	0,313284	0,448411	0,524835	0,573409	0,633134
10	10	2574,12	2,445301	3,500018	4,096541	4,475677	4,941859
11	11	4081,72	4,453628	6,374583	7,461028	8,151551	9,000606
12	12	2224,80	7,882032	11,281739	13,204533	14,426619	15,929279
13	13	1464,68	8,338987	11,935786	13,970054	15,262988	16,852764
14	14	1653,56	3,484639	4,987645	5,837712	6,377994	7,042319
15	15	2388,72	7,105916	10,170863	11,904326	13,006078	14,360776
16	16	280,08	0,846645	1,211823	1,418359	1,549629	1,711037
17	17	1828,48	3,614917	5,174116	6,055962	6,616443	7,305605
18	18	4787,96	5,518171	7,898286	9,244424	10,100001	11,152005
19	19	1,36	0,016832	0,024092	0,028198	0,030809	0,034018
20	20	4,80	0,047501	0,067989	0,079577	0,086942	0,095998
21	21	2781,72	17,928147	25,660976	30,034483	32,814190	36,232078
22	22	192,04	0,575156	0,823235	0,963542	1,052719	1,162368
23	23	1613,12	10,626847	15,210455	17,802838	19,450498	21,476440
24	24	1898,44	14,039289	20,094763	23,519598	25,696348	28,372850
25	25	1412,76	12,330739	17,649276	20,657316	22,569160	24,919939
26	26	2285,20	9,767103	13,979885	16,362536	17,876896	19,738933
27	27	2224,52	3,278022	4,691909	5,491571	5,999819	6,624753

Number	Sub Subwatershed	Sub Subwatershed Area	Q Return Period	Q Return Period	Q Return Period	Q Return Period	Q Return Period
			1.01 Year	2 Years	5 Years	10 Years	25 Years
		(Ha)	(m^3/sec)	(m^3/sec)	(m^3/sec)	(m^3/sec)	(m^3/sec)
28	28	1674,48	6,867159	9,829125	11,504343	12,569076	13,878257
29	29	4468,48	13,216747	18,917441	22,141619	24,190836	26,710527
30	30	2922,56	15,194143	21,747732	25,454289	27,810095	30,706763
31	31	4546,80	24,910828	35,655454	41,732362	45,594711	50,343805

Source: *Analysis Results, 2019*

In calculating the erosion rate, the formula formula MUSLE (Modify Universal Soil Loss Equation) is used

$A = R_W \times K \times LS \times CP$ (Formula 6)

Where : $R_W = 9{,}05\ (V_O \times Q_p)^{0{,}56}$

From this formula, Value of CP related to factors of land use and land management and V_O means urface runoff volume (m^3). Symbol A means erosion eate (tons/ha/year), R_W means surface runoff erosivity index *(run-off)*. Furthermore, K is equal to soil erodibility factor and LS is Slope factor.

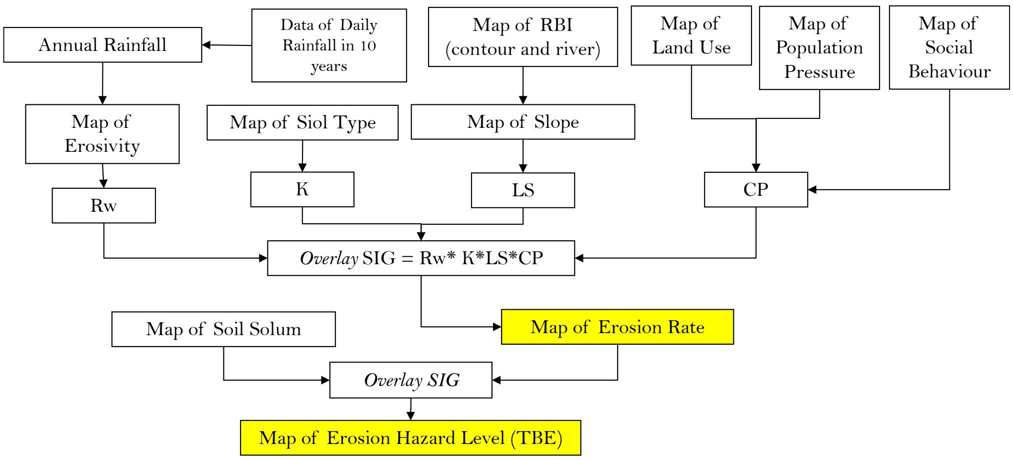

Figure 5. Flow Analysis of Erosion Rates and Erosion Hazard Levels in Lesti Sub Watershed

Source: *Analysis Results, 2021*

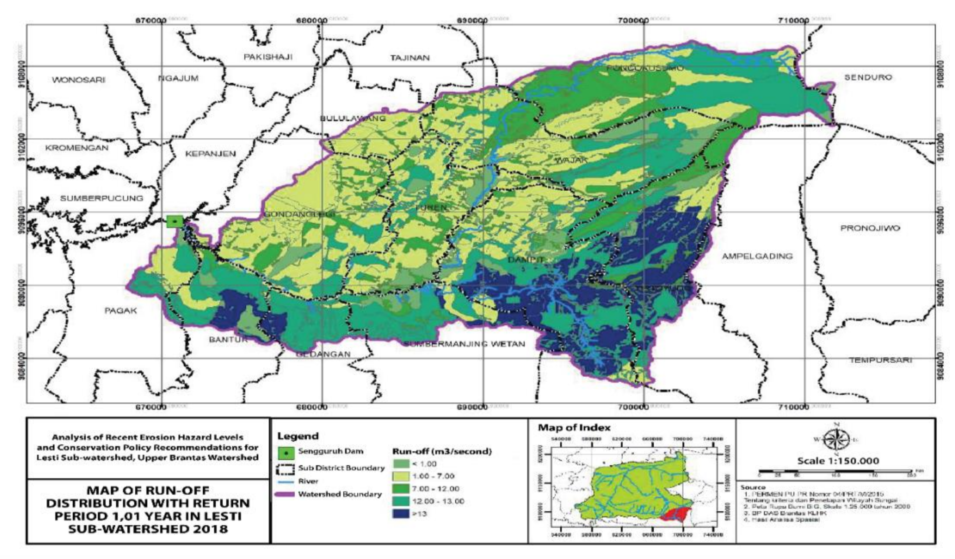

Figure 6. Runoff Distribution Map of Lesti Subwatershed

Source: *Analysis Results, 2021*

Based on the final results of calculation, the erosion rate (current) of this area is 153,868 tons / ha / year. When compare with tolerable erosion rate of 30 tons / ha / year, this area is out of tolerate of erosion. Lesti Subwatershed need to get specific and targeted conservation directions so that efforts are made more effective and efficient. The rate of erosion in Lesti Subwatershed has an effect on the level of erosion hazard in the area. Erosion Hazard Level Category (EHL) estimates the maximum soil loss on a land (Utomo, 1994; Suresh, 1993).

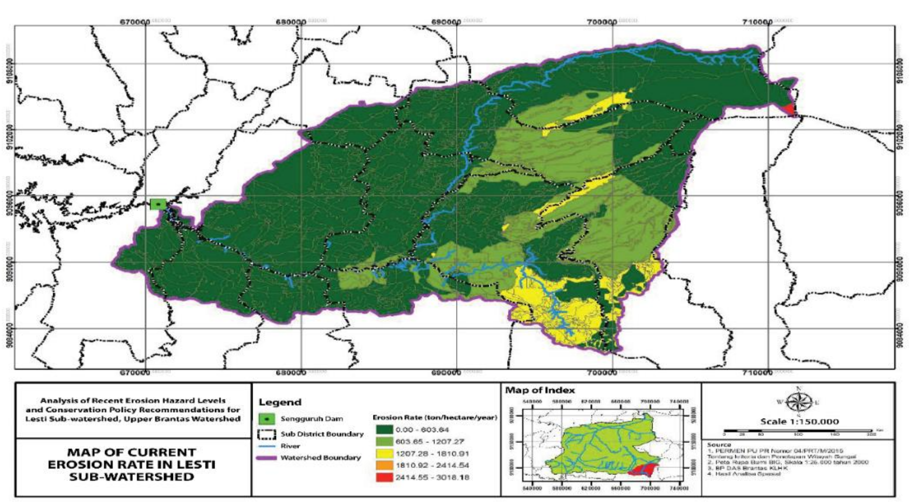

Figure 7. Current Erosion Rate Map of Lesti Subwatershed

Source: *Analysis Results, 2021*

Environmental conservation analysis is carried out by taking into account the population pressure on the land of each Subdistrict (economic aspects) and behavior analysis of the people of each Subdistrict (social aspects) as part of the consideration. Qualitative and quantitative analysis through overlay techniques in the concept of Geographic Information Systems refers to 3 maps and their attributes, namely the Erosion Hazard Levels (EHL), Population Pressure Maps for Land in each Subdistrict and the Community Behavior Map in each Subdistrict in Lesti Subwatershed.

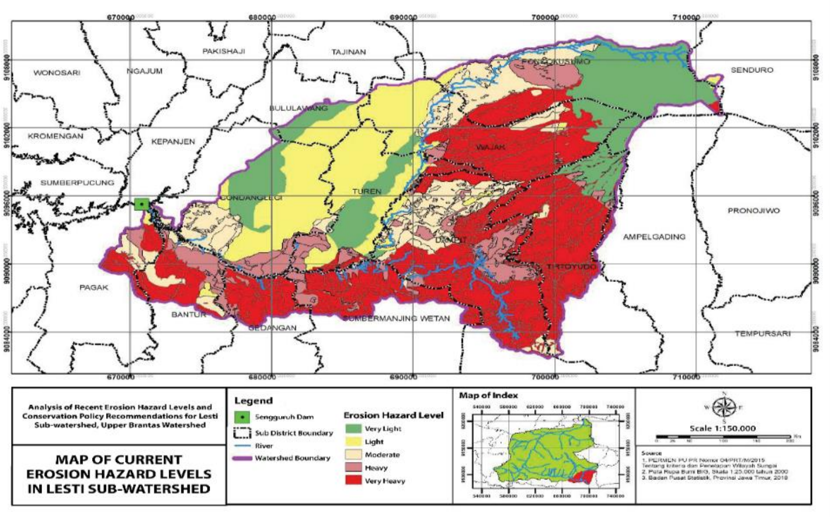

Figure 8. Current Erosion Hazard Levels Map of Lesti Subwatershed

Source: *Analysis Results, 2021*

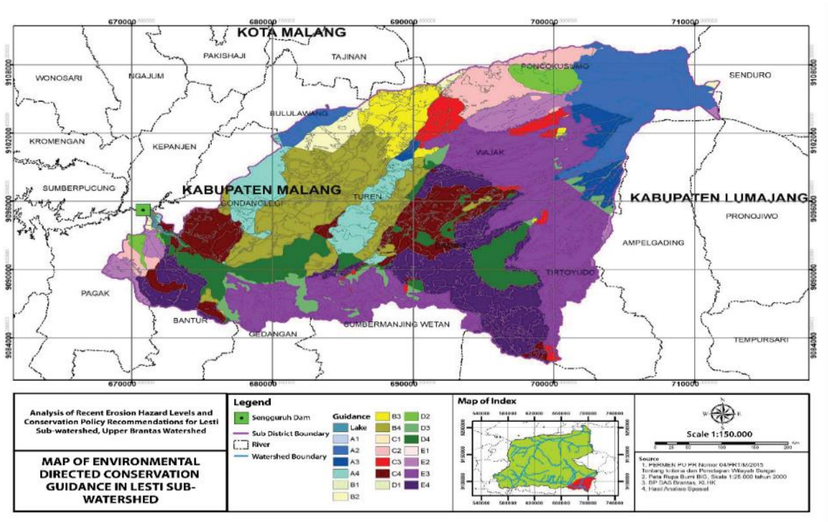

Figure 9. Environmental-directed Conservation Guidance Map of Lesti Subwatershed

Source: *Analysis Results, 2021*

Giving recommendations also considers the current land use conditions as recommendations that are more in line with field conditions so that it is expected to be more targeted. In addition to the 6 priority Subdistricts, also given environmental conservation directions in 6 other districts that have a lower level of Erosion Hazard Level (EHL) are given while taking into account existing land use.

Table 10. Directions for Subwatershed Conservation in 6 Priority Subdistricts

Sub-District	Conservation Direction	Current dominant Land Use
Wajak	Wajak sub-district with the land use forf paddy fields and settlements is recommended to take conservation actions in the form of law enforcement or counseling, and community empowerment to increase community capacity and independence through providing access to resources, education and training. In dry land agricultural areas and plantation forests, it is advisable to carry out conservation activities in an agronomic manner by using wood cover vegetation, shrubs, grasses and other cover vegetation.	Rice fields, dry land agriculture, settlements, plantation forests
Tirtoyudo	Tirtoyudo Subdistrict, with land use dominated by mixed dryland agricultural land, settlements, plantations, and dry land agriculture, is recommended to take conservation actions in the form of law enforcement or counseling, and community empowerment to increase community capacity and independence through providing access to resources, education and training. . In areas that are already in the form of plantations, it is recommended to leave them untreated without intervention because they are in accordance with environmental conservation principles.	Mixed Dryland Agriculture, Settlements, Plantation, Dry Land Agriculture, Plantation Forest
Dampit	Dampit sub-district with land use is dominated by residential land, mixed dry land farming, dry land agriculture, and rice fields have a very heavy erosion hazard level with large population pressure and negative behavior. In some areas of a certain scale, it can be suggested that efforts to provide environmental awareness education and technical civil development in the form of terracing mounds equipped with reinforcing grass and water channels on the upper slopes.	Settlements, Mixed Dry Land Agriculture, Dry Land Agriculture, Rice Fields
Sumbermanjing Wetan	Sumbermanjing Wetan Subdistrict, with land use dominated by mixed dryland agricultural land and settlements, is recommended to take conservation actions in the form of law enforcement or counseling, and community empowerment to increase community capacity and independence through providing access to resources, education and training. Meanwhile, in certain areas that have land use in the form of plantations, agronomic conservation efforts can be made to keep the run-off rate even lower by using wood cover vegetation, shrubs, grasses and other cover vegetation.	Mixed Dry Land Agriculture, Settlements, Plantation Forest
Gedangan	Gedangan Subdistrict, whose land use is dominated by mixed dryland agricultural land, settlements, rice	Mixed dry land agriculture,

Sub-District	Conservation Direction	Current dominant Land Use
	fields, is recommended to take conservation actions in the form of law enforcement or counseling, and community empowerment to increase community capacity and independence through providing access to resources, education and training. In certain areas that have a very severe level of erosion hazard with large population pressure and negative behavior, it is recommended to relocate small-scale residents.	settlements, rice fields
Bantur	Bantur sub-district with land use is dominated by mixed dry land agricultural lands, settlements, plantations, it is recommended to take conservation actions in the form of law enforcement or counseling, and community empowerment to increase community capacity and independence through providing access to resources, education and training. In certain areas that have a very severe level of erosion hazard with large population pressure and negative behavior, it is recommended to relocate small-scale residents.	Mixed Dry Land Agriculture, Settlements, Plantation Forest

Source: *Analysis Result, 2021*

IV. CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis results, both spatially, statistically and numerically, several conclusions are given to answer research questions. In the Lesti Subwatershed, there is a correlation between community behavior and population pressure with current land use, which results in erosion vulnerability. In Subdistricts that have a population pressure value> 1 and negative behavior in general are directly proportional to the condition of erosion-prone land use and lands with high runoff coefficient values such as settlements, dry land paddies or open land. In Subdistricts with low population pressure and positive behavior is characterized by the use of vegetation-covered land such as plantations and mixed agriculture which in theory watershed conservation is very good at reducing the rate of erosion.

Calculation results by authors show that the current erosion rate in each hectare of land (average erosion rate) in the Lesti Subwatershed is 153.868 tons/ha/year. This is not in accordance with the erosion rate that can be tolerated in the Lesti Subwatershed, which is 30 tons/ha/year. There is a very large gap of 123.868 tons/ha/year so that it requires watershed conservation in priority areas to reduce the erosion rate in the future. Based on the calculations results by the authors and from previous researchers, it can be said that there has always been an increase in the erosion rate since the last 14 years. The result of overlaying the erosion rate with soil solum shows that conservation direction is prioritized in 6 Subdistricts with a high erosion hazard level, namely Wajak Subdistrict, Tirtoyudo Subdistrict, Dampit Subdistrict, Sumbermanjing Wetan Subdistrict, Gedangan Subdistrict and Bantur Subdistrict.

Future direction of watershed conservation in Lesti Subwatershed requires an environmental science-based approach that considers social aspects (community behavior), economic aspects (population pressure) and environmental aspects (land use / environmental carrying capacity). There are 2 principles of environmental science that can be considered in the future direction of conservation, namely the principle of interaction and sustainability. Watershed conservation paradigm as a derivative of Law no. 37 of 2014 in the form of a Draft of Government Regulation currently being compiled by the government needs to pay more attention to ecological concepts that involve the fulfillment of human and natural needs in more synergy according to their respective roles. This research found a new idea, namely environmental education and relocation of small-scale population that can be input into the Draft of Government Regulation. Relocation of small-scale population is needed especially in priority areas where population pressure is high, community behavior is negative and the erosion hazard level is very heavy. Nevertheless, the selection of new locations resulting from relocation must still consider aspects of social, economic and environmental needs so as not to cause other problems in the future.

Based on the conclusions, several suggestions/recommendations can be established, both per conservation priority area, and general recommendations from the point of view of environmental science, as follows:

a) Wajak Subdistrict with the use of paddy fields and settlements are advised to take conservation measures in the form of law enforcement or counseling, and community empowerment to increase the ability and independence of the community through providing access to resources, education, and training. In dryland agricultural areas and plantations, it is recommended to carry out agronomic conservation activities using cover vegetation of woody plants, shrubs, grasses, and other cover vegetation.

b) Tirtoyudo Subdistrict with land use dominated by mixed upland, settlements, plantation, and dryland agriculture is recommended to take conservation measures in the form of law enforcement or counseling, and community empowerment to increase the ability and independence of the community through providing access to resources, education, and training. In areas that are already in the form of plantations, it is recommended to be left naturally without intervention because it is following the environmental conservation principles

c) Dampit Subdistrict with land use dominated by settlement, mixed upland agriculture, dryland agriculture, paddy fields have a very high erosion hazard level with large population pressure and negative behavior is recommended for gradual relocation of the population. In some areas of a certain scale, it can be suggested efforts to provide environmental awareness education and technical civil development in the form of making guludan terraces which are equipped with reinforcement grass and waterways on the upper slopes

d) Sumbermanjing Wetan Subdistrict with land use dominated by mixed upland agriculture land and settlement, it is recommended to carry out conservation actions in the form of law enforcement or counseling, and community empowerment in the context of increasing community capacity and independence through providing access to resources, education, and training. Meanwhile, in certain areas that have land use in the form of plantation forest, agronomic conservation efforts can be made to keep the run-off rate even lower by using cover vegetation of woody plants, shrubs, grasses, and other cover vegetation.

e) Gedangan Subdistrict with land use dominated by mixed upland agriculture, settlement, paddy fields, it is recommended to take conservation measures in the form of law enforcement or counseling, and community empowerment to increase the capacity and independence of the community through providing access to resources, education, and training. In certain areas which have a very high erosion hazard level with large population pressure and negative behavior, it is recommended to relocate a small-scale population.

f) Bantur Subdistrict with land use dominated by mixed upland agriculture lands, settlements, plantations it is recommended to take conservation measures in the form of law enforcement or counseling, and community empowerment to increase the capacity and independence of the community through providing access to resources, education, and training. In certain areas which have a very high erosion hazard level with large population pressure and negative behavior, it is recommended to relocate a small-scale population.

g) When the conservation directives for behavioral improvement through environmental education have been successful individually by the community, then it needs to be developed into a value system that is integrated and wide-scale watershed scope. The value system in the community such as cooperation needs to be encouraged again. This system already exists in the lives of rural communities, but needs to be raised again on a broader scale, even if it needs to be made a common philosophy in one goal namely environmental care for better watershed health. Mutual cooperation is a shared value system of Indonesian society where personal values such as volunteerism, togetherness, and tolerance can be accumulated in the transformation of a unique joint movement.

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