Conservation direction based on estimation of erosion in Lesti sub-watershed, Malang District

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Abstract. Management of watersheds is a part of regional development. Lesti sub-watershed as one of upstream Brantas watersheds faces erosion problems and criticality of land that is not balanced with conservation efforts based on ideal needs according to carrying capacity of the environment. The reduced function of the Sengguruh Reservoir in upper Brantas River has caused a disruption to its role in flood control, water supply for irrigation and generating a large portion of hydroelectric power in East Java Province. This study seeks to provide the latest erosion-based conservation direction with MUSLE methods and spatial analysis of GIS that considers proportional social, economic and environmental aspects. The results of the analysis are used in order to determine the priority sub-districts for handling conservation within Lesti Sub-watershed to reduce erosion problems. Of the 12 sub-district on Lesti Sub-Watershed, some sub-districts identified as having the highest Erosion Hazard Level (THB) area marked in red on the map are in sub-district of Wajak, Tirtoyudo, Dampit, Sumbermanjing Wetan, Gedangan and Bantur. Environmental conservation directives are suggested to be focused on these 6 sub-districts through the application of vegetative soil and water conservation, technical civilization and combination involving the community and in accordance with local conditions.

Keywords: Conservation, Sub-Watershed, MUSLE

1. Introduction
Management of Watersheds (DAS) as part of regional development in Indonesia to date still faces a variety of complex and interrelated problems. The increasing frequency of recent floods, droughts, landslides and water crises shows that watershed management in Indonesia is not optimal. The problem of watershed is the problem of ecological balance related to the carrying capacity of the environment. Ecology involves ecosystems with their constituent components, namely abiotic and biotic factors. Environment is defined as an area (region, etc.) as the boundary of economic activity, which affects the development of life in it \cite{1,2}. Place of hydrological cycle is described as watersheds \cite{1,3}. Watersheds are frequently utilized as biophysical as well as socio-economic units for natural resource planning and management \cite{3}. Watersheds are areas that are topographically restricted by hydrological boundaries and in the form of a river flow system due to rain, melting snow and ground water into the main river towards the outlet \cite{4,5}.

Watershed damage is often caused by mismanagement in the upstream, such as the addition of massive cultivation and settlement areas, resulting in erosion and sedimentation which impacts...
downstream in the form of decreased land productivity and disasters, both floods and landslides [6,7,8]. Slim [9] stated that a lot of efforts could be made in the recovery of upstream watersheds, among others, through identification of critical areas where they would later be used as a reference in determining priority watersheds for handling.

A watershed management related to interaction upstream-downstream and sustainability of environment which is affected to erosion, water quality, flooding, and climate [4,10]. There are upstream and downstream mechanisms in the watershed management process. Upstream protection of the watershed affects the downstream impacts which in practice relate to the community aspects as part of the watershed ecosystem itself. Pressure on protected areas of water sources and their impacts shows the role of the community, both in the surrounding environment and in general [11,12]. Further about this is management of management, which means to actions in order to attain sustainability in natural resource management, contribute to conservation priorities, and lower environmental degradation that threatens people's welfare [13,14]. Watershed management is closely related to ecosystem approaches and hydrological regulation [10,14,15,16]. Based on Republic of Indonesia Law No. 23 of 2014 concerning Regional Government and Government Regulation No. 37 of 2012 concerning Watershed Management, watersheds and their management are determined based on authority, with the smallest unit being the Province.

Management of highland areas (upstream) which is degraded, causing lowland (downstream) areas to be severely affected, especially erosion and sedimentation [17]. Islands and peninsulas from South & Southeast Asia cover large land areas with diverse ecoregions, land use and management practices [18]. It is announced that 43 percent of agricultural land in 8 South Asian countries experiences degradation. Calculation of erosion problems and conservation efforts in Asia including Indonesia always only stops mathematical calculations using the hydrological formula. In practice, the failure of conservation policies based on calculation of erosion by hydrology has not included social and economic elements in the existing formula.

Erosion and conservation of watersheds has been widely studied in many countries, including efforts to handle them. The Government of Indonesia under National Medium-Term Development Plan (RPJMN) 2015-2019 has set 15 priority watersheds to be restored for 5 years, namely Citarum watershed, Ciliwung watershed, Serayu watershed, Solo watershed, Brantas watershed, Cisadane watershed, Kapuas watershed, watershed Siak, Musi watershed, Asahan Toba watershed, Jeneberang watershed, Saddang watershed, Moyo watershed, Way Sekampung watershed and Limboto watershed. Of the 15 Priority Watersheds that will be restored by the government through the 2015-2019 RPJMN, the Brantas Watershed is one of the main concerns because of its relevance to upstream issues. The Lesti sub-watershed as one of the upstream Brantas watersheds faces erosion problems and criticality of land that is not balanced with conservation efforts based on ideal needs in accordance with the carrying capacity of the environment. The reduced function of the Sengguruh Reservoir in the upper Brantas River has caused a disruption to its role in flood control, water supply for irrigation and generated a large portion of hydropower electricity in East Java Province [19].

This research will show the upstream and downstream linkages in the concept of watershed management that considers social, economic and environmental aspects. The questions discussed in this research are: 1) What is Lesti sub-watershed erosion rate in the current condition?; 2) What are the environmental conservation directives needed based on environmentally sound erosion estimates in the Lesti sub-watershed?

2. Material and methods

2.1. Area of Study and Research Design

The locus of this research is Lesti sub-watershed which is part of the Brantas watershed, administratively located in Malang District, in the upstream part of the east of Malang District. The research location covers almost all areas in the Lesti sub-watershed with the boundaries of the research area from the upper Lesti River in Poncokusumo Sub-District to the Automatic Water Level Recorder (AWLR) outlet.
Tawang Rejeni in Sumbermanjing Wetan Sub-District (figure 1). The location of the study was chosen based on the characteristics of the land with potential for erosion and other supporting erosion factors such as rainfall, topography, monography, socio-economic and conservation actions.

The upper reaches of the Lesti sub-watershed contributes large river water flows to the lower reaches of Malang District, precisely in the Sengguruh Reservoir [19,20]. The Lesti sub-watershed in Malang District is one of the sub-watersheds which plays the biggest role in contributing to the flow of large river water downstream in the Sengguruh Reservoir. Sengguruh, Sutami and Wlingi Reservoirs are three reservoirs in the upper Brantas River providing significant part in flood control, water supply for irrigation and generating a large portion of hydroelectric power in East Java Province. Ma'wa[19] stated that erosion from the upper reaches of the Lesti sub-watershed had the effect of reducing the storage capacity of the Sengguruh Reservoir which resulted in an acceleration in the age of use for the reservoir from the original plan.

2.2. Concepts of Calculating MUSLE and GIS
In general there are many erosion prediction methods that have been developed by scientists, such as USLE, MUSLE, RUSLE, WEPP, GUEST, ANSWER, AGNPS and others. In Indonesia, the most commonly used erosion estimation model is the USLE method and derivatives such as MUSLE and RUSLE. For example the MUSLE method that meets the requirements of modeling that is universal and the number of inputs or parameters needed is less than other methods that are complex. Prediction of the average erosion rate of a land on a slope with certain rainfall patterns for each type of land and the application of land management must at least pay attention to rain erosion factors, soil erodibility, slope, slope length, ground cover, and conservation measures.

Calculation of surface runoff discharge will be used to calculate the erosion index of surface runoff which is then to calculate the rate of erosion that occurs on the land. The MUSLE method is a modification of the USLE method, namely by changing of rain erosion factor (R) with run off (Rw). The MUSLE method and GIS analysis have taken into account both erosion and sediment movement in a watershed based on a single event with the equation as follows:

\[ A = R_w \times K \times LS \times CP \]

Which is :

\[ R_w = 9.05 \times (V_o \times Q_p)^{0.56} \]

Explanation :

- A = total of eroded soil (tons/year)
\[ \text{R}_W = \text{Surface runoff erosivity index} \]
\[ K = \text{Factor of soil erodibility} \]
\[ \text{LS} = \text{Factor of slope} \]
\[ \text{CP} = \text{Factor of tillage and land use} \]
\[ V_O = \text{Volume of surface runoff} \ (\text{m}^3) \]
\[ Q_p = \text{Peak flow} \ (\text{m}^3/\text{sec}) \]

### 3. Data Analysis and Discussion

#### 3.1. Estimation of Recent Erosion

Bisri [21] states that regional growth and development make several spatial changes. Watershed damage is often caused by mismanagement in the upstream, such as the addition of massive cultivation and settlement areas, resulting in erosion and sedimentation which impacts downstream in the form of decreased land productivity and disasters, both floods and landslides [6,7,8]. Slim [9] states that a lot of efforts can be made in the recovery of upstream watersheds, among others, through the identification of critical areas based on erosion calculations which will later be used as a reference in determining priority watersheds for handling (figure 2).

![Figure 2. Stages of Analysis.](image)

Wischmeier and Smith [22] state that the tolerable erosion rate (T value) that can be tolerated for land in America is 11.21-4.48 tons/ha/year. In Indonesia, the maximum tolerated soil erosion rate that many researchers refer to is based on Hardjowigeno [23] research, which is 30 tones/ha/year. Based on the description of the problem statement, the hypothesis in this research is: "The erosion rate in the Lesti sub-watershed has been more than 30 tones/ha/year so that the Lesti sub-watershed is already in critical condition." Setyono and Prasetyo [24] stated that the total erosion value in the Lesti sub-watershed was 6,551,087.516 tons/ha/year, with an average erosion rate of 105,763 tons/ha/year. The results of erosion rate calculations conducted by the authors to estimate the latest erosion rate were delivered through several stages.

#### 3.1.1. Hydrogical Analysis

The average rainfall determination in this study uses the Thiessen Polygon method, Thiessen's polygon depiction is done by inputting each rain station coordinate in ArcGIS Software to obtain a map of the distribution of rain stations. Rainfall data for the last 10 years from 2009 to 2018 in the Lesti Sub-watershed, from the analysis of the Turen rain station has the largest area of influence that is equal to 26,496,837 Ha (40.93%), after that the Dampit Station is 23,731,127 Ha (36.65%), Poncokusumo Station is 13,257,853 Ha (20.48%) and the last Tajinan Station 1,255,021 Ha (1.94%). In analyzing the erosivity index, Williams (1975) modified the USLE formula into a MUSLE
precipitate from each surface runoff event by changing the rain erosivity index with surface runoff erosion (Rw). In this study, the determination of Rw value was calculated per Sub-watershed Sub-Sub Lesti. Thus, the average monthly rainfall (R) and rainy days (Rn) is the same for 31 sub-watersheds, which is the average area of 4 (four) rain stations. The results of the spatial analysis of GIS show that the current erosion index (Rw) in the Lesti sub-watershed is 90,273,876 m²/hour.

The description of soil type maps is carried out to determine the soil erodibility value (K) (table 1). This depiction uses a map of soil types from the BP Brantas Watershed and software Autodesk Map 2017. Values of K are estimated by looking at the map and referring to the tables listed in the reference. The K factor data is entered into the attribute data on the soil type map.

| Nr | Type of soil            | Texture | K Factors | Area (m²) | Area (Ha) | Percentage (%) |
|----|-------------------------|---------|-----------|-----------|-----------|----------------|
| 1  | Brown Andosol and Gray Regosol Association | Medium | 0.12      | 75,355,911.45 | 7,535.59  | 11.64          |
| 2  | Gray Alluvial Complex and Grayish Alluvial Brown | Smooth - Harsh | 0.29      | 74,946,327.05  | 7,494.63  | 11.58          |
| 3  | Reddish Brown Latosol     | Smooth  | 0.23      | 276,626,471.11 | 27,662.65 | 42.73          |
| 4  | Mediterran Reddish Brown  | Medium  | 0.21      | 61,224,371.93  | 6,122.44  | 9.46           |
| 5  | Brown Regosol             | Smooth  | 0.12      | 151,369,572.17 | 15,136.96 | 23.38          |
| 6  | Gray Regosol              | Smooth  | 0.12      | 7,885,746.29   | 788.57    | 1.22           |
|    | Total                    |         |           | 647,408,400.00 | 64,740.84 | 100.00         |

Factor of LS affect the amount of erosion that occurs. The slope affects the speed and volume of surface runoff. Basically the steeper the slope, the greater the slope percentage, so the faster the runoff rate. The magnitude of the average slope length in the Lesti Sub-watershed and the slope can be seen from the attribute data of the sub-watershed sub-map that has been made using the DEM method through ArcSWAT. Determination of the length and slope factors is determined based on the Slope Slope Factor (S) table in Chapter II sourced from the Engineering Plan for Land Rehabilitation and Watershed Conservation, Ministry of Forestry, Republic of Indonesia.

Plant management factors are factors that describe the ratio between the amount of erosion from certain planted land and certain management to the amount of soil erosion that is not planted and processed clean [16]. In the conditions of land use, the determination of the size of crop management factors (C) and soil conservation (P) action factors are combined and determined based on tables of CP values of several plants and planting management (Wischmeier and Arnoldus modification by Boediono, 1982) in Utomo 1994.

3.1.2. Erosion Rate Calculations and Spatial Analysis of Erosion Hazard Levels. Determination of the rate erosion by means of spatial analysis overlay using software (figure 3). ArcGIS This analysis is done by using the Geoprocessing toolbox in software ArcGIS. The data used are maps of surface runoff erosivity index (Rw), erodibility of soil (K), slope length factor (LS) and land use map (CP). The results of the calculation of the MUSLE formula and spatial analysis of geographic information systems show that the amount of soil (A) that has recently eroded is 9,961,518,329 tons/ha/year. The most recent erosion rate is calculated by dividing the current total erosion with the watershed area, so that the average erosion rate in the Lesti sub-watershed is 153.868 tons/ha/year (exceeding tolerable erosion rates). The calculation results show that the erosion rate in the current Lesti Sub-watershed with the MUSLE Method has a tendency to be higher than the T value or erosion rate that can be tolerated for land in Indonesia. The next analysis is related to Erosion Hazard Level (TBE). TBE analysis was carried out to determine the erosion hazard class of a land by looking at the rate of erosion that occurred (A) and the depth of the soil solum.
4. Conclusion and Recommendation
The results of previous studies from Yupi [25] stated that the erosion rate in the Lesti sub-watershed was 30.57 tons/ha/year, and the Setyono and Prasetyo [24] studies were 105.763 tons/ha/year. Meanwhile Ma'wa [19], the erosion rate was 131.098 tons/ha/year. Based on the results of calculations conducted by the authors stating the latest erosion rate of 153.868 tons/ha/year, it can be said that there has always been an increase in the erosion rate of the Lesti sub-watershed since the last 14 years so that better handling of conservation is needed.

Some sub-districts identified as having the highest Erosion Hazard Level (TBE) area marked in red on the map are in Wajak Sub-District, Tirtoyudo Sub-District, Dampit Sub-District, Sumbermanjing Wetan Sub-District, Gedangan Sub-District and Bantur Sub-District. Environmental conservation directives are suggested to be focused on these 6 sub-districts through the implementation of soil vegetation and water conservation, technical civilization and combination involving the community and in accordance with local conditions. Dampit Sub-district is the most vulnerable area to erosion so it is the most priority to be handled. In order to achieve a more operational analysis of conservation directions, it is necessary to analyze additional population pressure on each sub-district (economic aspects) and analyze community behavior in each sub-district (social aspect) as part of the Crop Management Factor and Lesti Sub-Watershed Action Factor (CP) current.

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