Predicting the impact of land-use change on soil erosion rate in Ussu sub-catchment area and sedimentation yield in Malili River

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Abstract. This study aims to predict the impact of land-use change in Ussu sub-catchment area during the last ten years on the rate of soil erosion and sedimentation yield in the Malili River. The USLE method was used to predict soil erosion rates in 2009 and 2015 using DEM data, Landsat 8 Image, station rainfall data, and land use. Sediment yield was determined using flow rates calculated using the spline cubic interpolation method, the SDR of the water sample was verified by the equations developed by SCS, Vanoni, Boyce and Auswald based on the suitability of the measured surrounding sub-watershed. The results show that soil erosion rates have increased in the period of 6 years. The erosion rate increased from 58,693 tons in 2009 to 155,136 tons in 2015. SDR value was obtained at 0.1894, so the potential sedimentation in the Malili River was predicted to a maximum of 1.57 cm in 2009 and 4.15 cm in 2015. Contributions of soil erosion on sedimentation have occurred as the impact of the increased deforested land around 654.8 ha.

1. Introduction

Land use in a catchment area greatly influences the magnitude of soil erosion rate as well as the sediment yield in rivers and the outlet of a watershed. Land-use changes without good soil conservation practices and the planning systems can cause an increase in the rate of soil erosion in the catchment and sediment deposition in the river, as happened in the Ussu sub-catchment. The increase in residential land, agriculture, ponds and open land has caused land damage due to erosion and ascent of the riverbed due to sedimentation.

Land use in Ussu sub-catchment has changed during the last ten years and it was affected the excessive or enhanced soil erosion due to poor land management. This can result in both on and off-site impacts that are detrimental to a whole range of receptors. Where soil erosion occurs, the soil resource can be severely depleted if the rate of erosion exceeds the rate of natural soil formation. This loss often corresponds to the most agriculturally important topsoil and any fertilizer or pesticide application, causing subsequent reductions in agricultural productivity. Soil erosion is a hazard traditionally associated with agriculture and often occurs in the tropical areas [1]. Whilst soil erosion is still a significant issue in the tropical areas; it is increasingly recognized as a hazard in Indonesia.

Since soil erosion and sediment redistribution have implications for both soil and water resources, and scientists have established that the movements of soil, sediment, and water are intrinsically linked, it is critical to implement integrated resource protection strategies. Soil erosion and sediment...
redistribution (transport, storage and remobilization) are controlled by hydrological and geomorphological processes, which operate within the context of a river basin. The river basin, therefore, represents a convenient and meaningful unit for the management of soil erosion and sediment redistribution since the shape and characteristics of the river basin control the pathways and fluxes of soil, water and sediment [2].

Sedimentation in the Malili River is a process whereby soil particles are eroded and transported by flowing water or other transporting media and deposited as layers of solid particles in the water body (Malili River). It is a complex process that varies with watershed sediment yield, rate of transportation and mode of deposition [3]. Sediment deposition reduces the storage capacity and life span of reservoirs as well as river flows [4]. It is, therefore, encouraging that policy-makers and managers are now opting to manage soil erosion and sediment transfers at a catchment or river basin scale.

2. Methods

2.1. Predicting soil erosion

Soil erosion was predicted using procedures including creating Ussu Sub-watershed, mapping land cover, plotting rainfall area, creating land-slope map, making land-unit map, and predicting erosion potential by overlaying thematic maps. Creating Ussu Sub-watershed boundaries was done by processing a 30 m x 30 m resolution Digital Elevation Model (DEM) data in Windows GIS Map software. The description of the Sub-watershed was carried out by the Automatic Watershed Delineation method so that the boundaries of the Sub-watershed and river network were mapped together.

Land cover in the Ussu Sub-watershed was analyzed using the remote sensing method. The data used were Landsat 7 and 8 image data in 2009 and 2015. The images were corrected geometrically and subsequently, radiometric correction. Analysis of land cover by using the image was carried out using the supervised classification method using the Arc GIS software in each of 2009 and 2015.

Rainfall in the Ussu Sub-watershed was obtained from the climatology data provider website, Global Weather. This was done because there were no rain stations located around the Ussu Sub-watershed. The determination of regional rainfall in the Ussu Sub-watershed was carried out using the Polygon Thiessen method so that each climatology station influenced the das area.

The slope map of the Ussu Sub-watershed was made using Digital Elevation Model (DEM) data with a resolution of 30 m x 30 m. Slope grade was made in 7 classes which are flat/nearly level (0-3), gently sloping (3-8), Moderately Sloping (8-15), Sloping (15-30), Moderately Steep (30-45), Steep (45-65) and Very Steep (> 65). Making the slope map of the Ussu sub-watershed was done using the GIS Arc software.

Making a map of land units was carried out to see the level of characteristic similarity of the land in the Ussu sub-watershed. Maps of land units were overlayed by overlaying maps that have been made before. Overlayed maps were watershed boundary maps, regional rainfall maps (polygon Thiessen), soil type maps, slope maps and land use maps in 2009 and 2015. Overlaying existing maps was done using the Arc GIS software.

2.2. Predicting sediment yield

Prediction of water discharge in the Ussu Sub-watershed was carried out by the Rational method. The general equation of the rational method. Calculation of rainfall intensity was carried out using the Mononobe equation. Sediment Delivery Ratio (SDR) is calculated to determine the potential of sediment entering the water body. Calculation of SDR values was done based on the equations developed by SCS, Vanoni, Boyce and Auswald where the equations were assessed according to the characteristics of the watershed in the Pongkeru watershed.

The SDR value obtained was used to determine the total sediment entering the Ussu River and a part of Malili River. The contribution of sediment to the river channel was calculated by converting
sediment weight to sediment volume, then converting to the potential sediment thickness in the river each year from the river length and the average width of the Ussu river.

3. Results and discussion

3.1. Land use in Ussu Sub-watersheds

The Ussu Sub-watershed is a sub-watershed located in the northern part of the Malili River which empties directly into the Gulf of Bone. The Ussu sub-watershed has an area of around 22,436 ha. Details of the condition of the Ussu Sub-watershed are presented in figure 1.

The soil type in the Ussu Sub-watershed area was dominated by Inceptisol and Oxisol soils. Soil characteristics in this area have a solum depth of about 1 to 2 meters with a dusty soil texture and even clay. The soil structure in this area is fragile and has a 10% to 30% organic material, as well as high nutrient content.

The spread of inceptisol soil type is in the area with the Afa-Ama climate type (according to Koppen), whereas according to Schmidt-Fergusson in the types of rain A, B, and C with rainfall of 2000-7000 mm/year, without or having months- dry months less than three months. This land is located in the area of ash, tuff and volcanic fan, at an altitude of 10-1000 meters from the surface of the sea, with the shape of the area that is hilly, wavy, to mountainous.

Land use in 2009 had nine land cover classes and was dominated by secondary dryland forest with an area of 12,954.9 ha, dryland agriculture mixed with shrubs 3,890.1 ha and shrubs/bushes 3,258.9 ha. Land use in 2015 changed from 2009. Land cover was still dominated by secondary dryland forests but experienced a broad decline to 12,055.1 ha.

| Land Use                     | Area (ha) | 2009     | 2015     |
|------------------------------|-----------|----------|----------|
| Secondary dry-land forest    | 12,954.9  | 12,055.1 |
| Secondary mangrove forest    | 1,164.3   | 997.7    |
| Settlement                   | 157.5     | 282.4    |
| Agriculture of Mixed Shrubs  | 3,890.1   | 4,241.1  |
| Dry Land                     | 62.0      | 4.4      |
| Rice field                   | 96.1      | 96.1     |
| Shrubs                       | 3,258.9   | 3,135.2  |
| Ponds                        | 840.5     | 1,082.4  |
| Un-covered Land              | 24.9      | 554.8    |

The condition of land change from 2009 to 2015 has experienced a significant change in which some areas of land cover have increased in several sectors. The biggest condition of land change in 2015 was open land with extensive changes increasing to 529.87 ha, settlements amounting to 124.93 ha and ponds at 241.85 ha. The condition of an increase in the area of open land and settlement is a conversion from the area of secondary dryland forest which experiences a decrease in land area of up to 899.79 ha. While changes in pond area are the result of conversion from mangrove forests. The condition of the Ussu sub-watershed has a very steep slope with an area of 14,873.1 ha. The dominance of this very steep lerang region results in a large surface flow occurring.

3.2. Soil Erosion

In the Ussu Sub-watershed, the erosion level increases continuously from 2009 to 2015. One of the main factors which were the condition of the Ussu Sub-watershed was mostly very steep. In 2015 the value of erosion level was in the category of Very Heavy with an area of 457 ha. Efforts to erosion control in the Ussu sub-watershed need to be done immediately by looking at the high erosion data.
that occurs every year. The erosion hazard level in the Ussu sub-watershed from 2009 to 2015 can be seen in table 2.

Figure 1. Ussu Sub-Catchment Area
Table 2. Erosion level in Ussu Sub-Catchment

| Level of Erosion | Year of 2009 | Year of 2015 |
|------------------|--------------|--------------|
| Very Light       | 18,121       | 13,693       |
| Light            | 2,239        | 6,534        |
| Medium           | 1,655        | 1,331        |
| Heavy            | 422          | 423          |
| Very Heavy       | -            | 457          |

3.3. Sediment Yield
The results of the sediment rate in 2009 provided a drift sediment yield of 41,085.10 tons/year with a prediction of basic sediments of 17,607.90 tons/year (total sediments around 58,693 tons/year). In 2015 the calculation of the sediment rate gave a sediment yield of 108,597.05 tons/year with basic sediment prediction of 46,541.59 tons/year (total sediment around 155,138.65). This value gives a Sediment Delivery Ratio (SDR) value of 0.1894. This value is very close to the value of the calculation result with the empirical formula of the four formulas (SCS, Vanoni, Boyce and Auswald) of 0.1357.

Based on the results of the study, it was found that the Ussu sub-watershed has contributed sediment deposits along the Ussu and Malili rivers meetings to the estuary in the amount of 1.57 cm/year and 2015 increased to 4.15 cm/year. The thick value of this deposit is the maximum value that will occur if all the basic sediments do not move into the Bone Bay. Most sediments are floating sediments that do not settle if there is no slowdown of flow along the Malili river path to the estuary. The condition of the increase in sediment thickness was due to changes in open land and settlements which increased by 654.80 ha.

This is clear that the land-use change in the period of 2009 to 2015 was playing a role in the occurrence of erosion in the Ussu sub-watershed and sediment deposition in the Ussu and Malili rivers. This result can be useful information for the authority of catchment to overcome the situation by creating programs to reduce erosion by soil conservation and trapping sediment along the rivers.

4. Conclusions
The Ussu sub-catchment area experience serious problems in soil erosion and sedimentation in the body of Ussu and Malili river. Land cover and land slope need rehabilitation programs to prevent the area from further erosion and protect the river from being more serious sedimentation.

Land use needs to be modified to find appropriate management to overcome the worse situation in the catchment and the Ussu and Malili Rivers.

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