Erosion hazard levels in the tanralili sub-watershed, south sulawesi

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Abstract. Erosion that exceeds the normal threshold can cause damage to the environment. The reduction of the physical properties of soil is a result of erosion. The USLE method is an empirical model that can predict the amount of erosion. The purpose of this study was to determine the level of erosion hazard that occurs in the Tanralili sub-watershed. The benefit of this study is to find out areas that are experiencing severe erosion so that a recovery plan can be made for eroded soils to prevent even more significant decay. Erosion calculated using the USLE (Universal Soil Loss Equation) model. There are several variables used in the calculation, which are the rainfall erosivity factor, the soil erodibility factor, the topographic factor, and the cropping management factor in looking at vegetation cover in the field using a survey method. The analysis used in this study is descriptive and spatial. Very high erosion occurs in almost all of the Tanralilili sub-watershed, about > 480 tons/ha/year, which happened in slopes 15-45%. Massive erosion occurs in the west with a total amount of 180-480 tons/ha/year. The total erosion that occurred in 2018 was 701542.9 tons/ha/year.

1. Introduction

Soil erosion is a natural phenomenon that results in the depletion of soil material due to natural factors such as wind, water, gravity. However, soil erosion often accelerating due to human activities [1]. In areas with a wet tropical climate, water is the cause of soil erosion, while the wind does not have a significant effect [2]. This erosion event causes the land or part of the area carried away from a place that is eroded and then transported and subjected to deposition.

Physical characteristics that exist in each landscape on the earth's surface have different effects on the size of the surface flow and the rate of erosion. At the watershed scale, a rate of soil erosion depends on the size of the watershed and other factors such as topography, slope level, type of land use, etc. [3]. The length and slope elements were reflecting the fact of erosion increases, and it is representing the effect of the terrain on the magnitude of erosion [4]. The topographic condition of the region, in the form of a steep slope, can increase the amount of surface flow and accelerate the speed of surface flow, which will increase the transport energy of surface flow [2]. This condition will affect erosion. If the slope of the land surface becomes two times steeper, the amount of decay per unit area becomes 2.0 to 2.5 times greater [2]. The land cover also
influences erosion. A good ground cover vegetation such as thick grass or thick jungle will eliminate the effects of rain and topography on erosion [2]. The Tanralili watershed has decreased in quality due to changes in land use that occurred for ten years, and this resulted in damage in the upstream area which caused a high level of erosion that happens every year, which amounted to 74.72 tons/ha/year, with a forest area of ten years (1996-2005) has decreased to an area of 5795 ha or experienced damage at a rate of 1.58 ha/day [5].

Soil erosion is a naturally occurring process that aims to maintain stability among various ecosystem functions [6]. However, erosion that occurs continuously can have a harmful effect. Continuous erosion can cause damage to ecosystems so that handling will take a long time and is expensive [7]. Erosion not only contributes to severe land degradation and is detrimental to the economy at an alarming rate, but also supports sustainable social development [8]. Due to the many negative impacts caused by the erosion phenomenon, the erosion rate must be identified to implement urban planning in areas with severe erosion. Therefore, this study aims to determine the distribution of erosion hazard levels that occur in the Tanralili sub-watershed.

Previous studies related to erosion have been carried out in the loess plateau in North China using two methods, the RWEQ and RUSLE methods [9]. Research about subsequent erosion has been carried out in the A Sap Watershed, Region A Luoi, Province of Thua Thien Hue, Vietnam using the USLE method [10]. Other studies related to erosion have been carried out in the Kulhan watershed, the Chattisgarh case study using the USLE method [4]. Renewal in the study lies in the research area, namely in the Tanralili sub-watershed, South Sulawesi. During the past five years, there has never been a study related to erosion in the Tanralili sub-watershed. Also, in this study, there was a renewal in obtaining information on soil conservation actions, using surveys directly into the field to get accurate results. In terms of variables, there is a renewal in this study because it uses monthly rainfall data, which is analyzed using the Lenvain formula [11].

2. Methodology
2.1 Research Areas
This research was conducted in the Tanralili sub-watershed. Geographically, the Tanralili sub-watershed is located in Maros Regency, South Sulawesi, at 5°6’30”- 5°10’0” LS and 119°41’0”- 119°48’0” BT. The Tanralili sub-basin spreads through 5 villages, namely: Tompobulu Village, Bonto Manai Village, Bonto Matingg Village, Bonto Bomba Village, and Bonto Manurun Village. This research was conducted in April 2019.

2.2 Material
This study uses six variables (Figure 1), namely: Rainfall, soil type, Topography, Land cover, and soil conservation measures. The data used in this study are rainfall data for 30 years from 1981-2010 obtained from the Meteorology, Climatology and Geophysics Agency, 2017 land use maps obtained from the Badan Informasi Geospasial (BIG), maps of soil types obtained from the Pekerjaan Umum dan Perumahan Rakyat (PUPR) Maros Regency, and 30 m SRM Digital Elevation Model data obtained from USGS. Knowing the specific actions of soil conservation used the field survey method.
2.3 Methods

We calculated the erosion hazard level using the USLE (Universal Soil Loss Equation) model carried out by overlaying with the ArcGIS 10.4 application. The USLE model is a parametric model for predicting erosion from a soil plane reported by Wischmeier and Smith (1978) [12]. USLE is a model for erosion designed to predict long-term average erosion from a sheet erosion or groove erosion under certain circumstances [2]. USLE estimates soil erosion due to rain but does not estimate sediment yield at the watershed outlets [13]. The following is the USLE equation [12]:

\[ A = R \cdot K \cdot L \cdot S \cdot C \cdot P \]  \hspace{1cm} \{1\}

In determining the erosion hazard level classification, the classification made by [14] is used. This classification divides erosion into five classes ranging from normal erosion to very heavy erosion. We selected sample points in this study using a purposive sampling technique with specific considerations [15], which are the differences in rainfall, land use, and slope.

The calculation of the USLE method uses rainfall as one of the variables, known as rain erosivity. The force applied by raindrops is one of the benchmarks of the magnitude of erosivity [16]. The amount of rainfall, intensity, and distribution of rain will determine the dispersion strength of rain on the soil, the amount and strength of the surface flow, and the level of erosion damage that occurs [2]. As a result of this, the rain factor is one of the important factors in erosion. In this study, we determine rain erosivity factors using Lenvain’s formula [11] as follows:

\[ R_m = 2.21 (\text{Rain})^{1.36} \]  \hspace{1cm} \{2\}

Where:
- \( R_m \): Average erosivity index of rain/month (units/month)
- \( (\text{Rain}) \): Monthly rainfall (cm/month)

Soil erodibility is the main parameter and an essential condition for making erosion predictions, conservation practices, and evaluating environmental impacts related to erosion [17]. Various types of soil have different sensitivity to erosion. The sensitivity of soil erosion or the ease of soil erosion is a function of multiple interactions of the physical and chemical properties of soil [2]. In this study, soil erodibility values used tables made by Puslitbang Pengairan Bogor 1985 [18]. We used an erodibility value of 0.23 because the type of lithosol soil dominates the research area. The erodibility value of lithosol soil based on the table K index made by Puslitbang Pengairan Bogor Research has a value of 0.23 [18].

Topographic factor analysis is critical in the USLE application, and this is because this parameter characterizes surface runoff velocity and is, therefore, an indicator of soil erosion problems in watersheds [4]. Slope and slope length are two topographic properties that influence surface flow and erosion. The sloping the slope, the number of soil grains splashed to the bottom of the hill by the interaction of rainwater collisions [2]. This condition will affect the occurrence of erosion that occurs. The length and slope values used in this research are using indices developed by [2].

Vegetation is a layer of soil protection from erosion. The energy of the raindrops will be caused by the presence of plant canopy so that when it reaches the surface, the destructive power has been reduced and becomes smaller or equal to the rain energy which falls directly to the surface of the soil [2]. The natural vegetation of ground cover, such as natural forest, has a smaller index value compared to land cover without plants. We used the vegetation cover and crop management index values (C) in this study from data from the land research center 1973-1981 (unpublished) in [2]. In general, the C-factor showing between 1 and 0,
C equal to 1 indicates that there is bare land which is a barren land and for C near zero have a solid cover and contain well-supported soil [10].

Soil conservation is an effort to restore damaged land. Right soil island that has a high soil conservation index. The index of soil conservation measures (P) can be determined based on the type of land cover [19]. Special soil conservation measures used in this study use the P factor value made by [20].

This study uses spatial and descriptive analysis. We used spatial analysis to describe the pattern of erosion hazard level in the Tanralili sub-watershed. Spatial analysis is a technique or process that involves a function of calculation and evaluation of mathematical logic carried out on a spatial data to obtain extraction, added value, or new information that is also spatial [21]. We used descriptive analysis to describe the level of erosion hazard that occurred in the Tanralili sub-watershed. Descriptive analysis can provide a description (description) of the results of research obtained from data processing and field checking. In the field of physical geography, we explain physical phenomena/symptoms such as erosion, delta formation processes, causes of changes in river flow patterns, etc. using descriptive data analysis [22].

3. Results and Discussion

3.1 Rainfall Erosivity (R) Factor
Based on rainfall data obtained from Tanralili Station and BB Station. Malino received a plentiful average rainfall for thirty years, i.e., from 1981-2010, the total monthly rainfall average at Tanralili Station was 378.3 cm/second while at the BB station. Malino's total average rainfall is 420.1 cm/second. Based on figure 2, we can see that there are two erosion index values in the Tanralili watershed. The results of the calculation of erosivity index in the Tanralili sub-watershed (figure 2) point that 1662,664 ha or 32% of the Tanralili sub-watershed has an erosion index of 3254.35, namely in Tompobulu Village and some parts of Bonto Manai and Bonto Matinggi Villages while 3523,476 ha or 68% of the Tanralili sub-watershed has an erosion index of 3819.42 located in the Village Bonto Manai, Bonto Matinggi, Bonto Somba, and Bonto Manurung have an erosion index of 3819.42. The erosivity index in the east is higher than the west, and this is because the rainfall in the east is higher than the rain in the west.

3.2 Soil Erodability (K) Factor
The Tanralili watershed is dominated by litosol soil types, which are spread in almost all Tanralili basins. Litosol soil in the Tanralili sub-watershed is formed from the main ingredients of limestone, Tufa, Vulkan, and alkali. The soil erodibility index in the Tanralili sub-watershed is 0.23. Map This type of soil in the Tanralili sub-watershed is the result of an extraction process from the map of the Maros Regency soil type obtained from the Public Works and Public Housing Office of Maros Regency.
3.3 Topographic Factor (LS)
The Tanralili watershed has a hilly to the mountainous region. In the eastern part of the Tanralili watershed, it has a steep slope compared to the western part. This results in the length index and slope (LS) values getting higher towards the east (figure 3). The length index and gradient of the hills in the Tanralili sub-watershed range from 0.4-9.5. Based on figure 3, it can be seen that in Tompobulu Village the index length and slope ranges from 0.4-3.1, Bonto Matinggi Village has an extended index and slope of 3.1-9.5, Bonto Manai Village has a long index and slope 3.1 and 6.8 while Bonto Somba Village and Bonto Manurung Village has an LS 6.8 - 9.5 index. Covering an area of 1800.36 ha or 48.2% of the total area of the Tanralili sub-watershed has an LS index of 9.5, an area of 1207.229 ha has an LS index of 3.1, an area of 705.2883 ha has an LS index 1.4, an area of 1467.75 ha has an LS index of 6.8 and 5,515 ha of the Tanralili sub-basin has an index of 0.4.

3.4 Cover management factor (C)
The Tanralili sub-watershed has a variety of vegetation covers, such as fields/fields, rice fields, shrubs, forests, settlements, grasslands, and empty land. The dominant vegetation cover is in the form of forests covering an area of 2867.94 ha and rice fields covering an area of 1303.70 ha. The vegetation cover index value (C) in the Tanralili sub-basin varies, ranging from 0.001 to 1. Figure 4 describes the distribution of the C index in the Tanralili sub-watershed. Upland fields have an index value of C 0.8, and the jungle has an index C 0.001, paddy fields have an index C 0.561, bushes have an index C 0.3, settlements have an index C 1, grasslands have an index C 0.3 while vacant land and dunes have an index C 1. In Tanralili sub-watershed, index C 0.001 occurs in the area of 2860.52 ha or 55.2% of the Tanralili sub-watershed area, C 0.3 index is 420.1 ha or 8.1%. Index C 0.561 covering 1302.8 ha, index C 0.8 covering 581.9 and index C 1 covering an area of 20.8 ha. Bonto Matinggi Village, Bonto Manurung Village, and Bonto Somba Village have a dominant C index, which is 0.001 because, in these villages, vegetation cover is dominated by forests while index C 0.561 found in Tompobulu Village with vegetation cover in the form of rice fields.
3.5 Support practice (P) factor

People in the Tanralili sub-watershed have not been widely implementing the management of soil conservation. They have conserved in the form of making terraces on rice fields and the presence of grasslands. Figure 6 is one of the soil conservations carried out in the Tanralili sub-watershed, which is to make rice fields become terraces to reduce the amount of erosion. Most of the areas in the Tanralili sub-watershed have not received soil conservation measures. This condition resulted in the majority of the regions in the Tanralili sub-watershed having a conservation specific action index of 1. Figure 5 showing that an area of 4.85 ha of the Tanralili sub-watershed area has a P index value of 0.04, 1003.24 ha has a P index of 0.4, and 4178.04 ha sub-watershed area Tanralili has a P index value of 1. Almost in every village, the P index is spread evenly, except that in Bonto Manurung Village, the index value is P 0.04, which is in the meadow.
3.6 Erosion Hazard Levels in the Tanralili Sub-watershed

Erosion that occurred in the Tanralili sub-watershed was 701542.9 tons/ha/years. Very severe erosion hazard levels occur in almost parts of the Tanralili sub-watershed. Figure 8 shows the distribution of erosion hazard levels in the Tanralili sub-watershed, while figure 9 describes the percentage of erosion hazard levels in the Tanralili sub-watershed. This erosion reached >480 tons/ha/year, which occurred in an area of 2056.4 ha in the Tanralili sub-watershed. Very severe decay occurs mostly in the cover of moor vegetation, rice fields, shrubs, and settlements. Very severe erosion, which is >480 tons/ha/year, occurs mostly on steep slopes with a slope 15-45%; this erosion occurs a lot in Tompobulu, some parts of Bonto Manai Village, Bonto Matinggi village and Bonto Somba village. Steep slopes and longer slope lengths result in more significant runoff volumes and a higher flow velocity which increases soil loss (23). The severe erosion is 180-480 tons/ha/years, which occurred in an area of 261.6 ha in the Tompobulu village. Severe and very severe erosion occurs on the land cover, where no people took soil conservation action.

In the village of Bonto Manurung, parts of the central sub-watershed of Tanralili have moderate hazard level erosion, which is 60-180 tons/ha/year with an area of 7.6 ha. Nearly all of the Tanralili sub-watershed area has experienced erosion, although erosion that occurs is still at a normal stage, which is equal to <15 tons/ha/year, which occurs in an area of 2860.5 ha. Erosion with a mild level of danger often occurs in forest vegetation cover. Erosion that is common in the Tanralili sub-watershed is sheet erosion, groove erosion, and trench erosion. Figure 7 is one of the erosions that occur in the Tanralili sub-watershed, namely trench erosion. This erosion found in an outcrop.

4. Conclusions

Erosion that occurred in the Tanralili sub-watershed was 701542.9 tons/ha/years. Very severe erosion hazard levels occur in almost parts of the Tanralili sub-watershed. This erosion reached > 480 tons/ha/year, which happened in an area of 2056.4 ha in the Tanralili sub-watershed. Very heavy decay occurs on slopes that have a slope of 15-45%, this erosion occurs mostly in Tompobulu Village because almost part of the area experiences very heavy erosion, also, massive decay occurs in Tompobulu Village and in some parts of Bonto Manai Village, and the village of Bonto Matinggi of 180-480 tons/ha/years which happened on an area of 261.6 ha. In the village of Bonto Manurung, parts of the central sub-watershed of Tanralili have
moderate hazard level erosion, which is 60-180 tons/ha/year with an area of 7.6 ha. Nearly all of the Tanralili sub-watershed area has experienced erosion, although erosion that occurs is still at a normal stage, which is equal to <15 tons/ha/year which occurs in an area of 2860.5 ha.

5. Acknowledgment
The author would like to thank the parties who helped so that this research carried out, especially the University of Indonesia, which has provided Final Assignment of Indexed International Publication (PITTA B Grant) Fiscal Year 2019 with contract number: NKB-0646 / UN2.R3.1 /HKP.05.00/2019.

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