Prediction of erosion using the USLE method in the Malino Sub Watershed

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Abstract. One of the problems that occur in the Sub DAS Malino is population growth. The increase in population in an area will increase demand to encourage the community to convert forest land into non-forest land, especially agricultural land. It has an impact on erosion and flooding during the rainy season. The amount of erosion that occurs can result in damage and a decrease in soil quality; therefore, it is necessary to predict erosion using the Universal Soil Loss Equation (USLE) method. This study aims to determine the level of erosion hazard in the Malino sub-watershed, Jeneberang watershed. The data used in this study include data on land cover, rainfall, soil, and slope. The results showed that Sub DAS Malino has high erosion on the open land cover with 800.02 ton/ha/year of 0.44% area of the Sub DAS Malino.

1. Introduction
Jeneberang River is the main river included in the Jeneberang Watershed (DAS) located in South Sulawesi Province. Jeneberang watershed is one of 17 watersheds under the Jeneberang-Walanae Watershed Management Center (BPDAS). The Jeneberang watershed is included in the priority I (one) watershed category covering Makassar City, Maros Regency, Gowa Regency, Takalar Regency. One of the sub-watersheds in the Jeneberang watershed is the Malino sub-watershed.

The Malino sub-watershed is one of the sub-watersheds of the Jeneberang watershed, which is administratively located in Tinggi Moncong District, Gowa Regency, an area of 8,759.43 ha or about 10.96% of the Jeneberang watershed area (Ministry of Forestry, 2012 in [1]). One of the problems that occur in the Malino sub-watershed is the increase in population. As the population increases, their needs also increase to encourage people to change the function of forest land into non-forest land, primarily agricultural land [1].

It has an impact on erosion and flooding during the rainy season. Predicting the vulnerability to an erosion area takes some information in maps such as slope, rainfall, land cover, and soil types that can help information material in prevention [2].

Land use is very influential on the level of erosion and sedimentation. The poor land cover index has the potential for erosion. Erosion on a large scale will potentially pose a landslide hazard. Meanwhile, sedimentation on a large scale will result in silting of rivers and reservoirs, rising water levels in rivers/reservoirs so that they have the potential to cause flooding [3].

The amount of erosion that occurs can cause damage and decrease soil quality. Therefore, it is necessary to predict erosion, especially in the Malino sub-watershed, using the USLE model because it is relatively simple. The input of the required model parameters is easy to obtain because it is usually easily obtained and easily observed in the field (Hidayat, 2003 in [4]).
Based on this description, it is necessary to conduct erosion prediction research in the Malino sub-watershed to determine the erosion hazard level to minimize erosion, especially at the level of heavy and very heavy erosion.

2. Research methodology

2.1. Time and place
This research was conducted from July to September 2020. This research consisted of two series of activities, namely field activities and laboratory activities. Field activities were carried out in the Malino sub-watershed, Jeneberang watershed, Gowa district, South Sulawesi, and laboratory activities at the Silviculture Laboratory, Faculty of Forestry Hasanuddin University.

2.2. Tools and materials
The tools used in this study were GPS, soil drill, sample ring, label paper, writing instruments, camera, and hardware, namely a laptop equipped with geographic information system software ArcMap 10.3 application. The materials used in this study are the Malino sub-watershed map, Sentinel imagery in 2019, Topographic map at scale 1:50,000 in 1999, Soil type map in 1987 from RePPProt, National Digital Elevation Model (DEM) in 2010, rainfall data from the Meteorological, Climatological and Geophysical Agency. (BMKG) in 2010-2019.

2.3. Data collection
Data obtained is divided into two types, namely primary data and secondary data. Primary data is obtained through surveys or direct observations in the field. The observation steps include setting a sampling point on each land unit in each land unit. Then field observations are carried out in observing land cover conditions and soil conservation actions, measuring soil depth with a soil drill, taking soil samples for laboratory analysis, and taking soil samples. Photos of each land use at the research site. Parameters observed in the laboratory are permeability, texture, organic matter. Secondary data was collected through BMKG rainfall data to determine the value of erosive, soil type data was obtained from RePPProt data, slope data collection was obtained from DEMNAS data, and this data will then be collected to determine the LS value.

2.4. Data analysis
The method used in estimating erosion is the USLE (Universal Soil Loss Equation) method developed by Wishchmeier and Smith (1978), with the following equation [5]:

\[ A = R \times K \times LS \times C \times P \]  \hspace{1cm} (1)

Where: A is the amount of erosion (tons/ha/year), R is the rain erodibility index, K is the soil erodibility factor, LS is the slope length and slope factor, C is the soil and plant management factor, and P in the soil and water conservation technique factor. Erosivity is the ability of rain to erode the soil. For the USLE method, the erosive value is calculated using the Lenvain formula. The mathematical equation is as follows:

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

Description:
\[ R \] = Monthly rainfall erosivity
\[ (\text{Rain})_b \] = Monthly rainfall in cm

K is a soil erodibility factor whose magnitude depends on the type of soil. The value of K is obtained from the formula [5], (Wischmeier and Smith, 1978)
\[ K = \frac{(2.71M^{1.14} \times 10^{-4})\times(12-OM)+4.20(s-2)+3.23(p-3))}{100} \]  

(3)

Description:
- \( K \) = soil erodibility
- \( a \) = percentage of organic matter (C-organicx1.724)
- \( b \) = soil structure code
- \( c \) = soil cross-sectional permeability class code
- \( M \) = grain size parameter obtained from (% dust + % fine sand) (100 - % clay)

The length and slope factor values are determined for each land unit. Determination of the value of the LS factor by analyzing the slope class-map obtained from the DEMNAS data analysis then the LS value is searched using a raster with the formula:

\[ LS = Pow(flowacc) \times resolution^{2.21, 0.6} \times Pow(sin[slope gradient] \times 0.01745, 1.3) \]  

(4)

Description:
- \( LS \) = Length and slope factor
- \( Flowacc \) = Accumulated flow
- \( Resolution \) = Pixel resolution
- \( Slope Gradient \) = Slope
- \( Pow \) = Power

Determination of the CP factor value is carried out by direct observation in the field at each point observations in land unit determined, then matched with tables of C and P values in Table 1 and Table 2.

**Table 1. Land Cover Index (C value) (Ministry of Forestry, 2009).**

| No | Plant Type                        | C     |
|----|----------------------------------|-------|
| 1  | Rice paddy                       | 0.01  |
| 2  | Undisturbed Bush                 | 0.01  |
| 3  | Building                         | 0.3   |
| 4  | Mixed garden                     |       |
|     | - High density                   | 0.1   |
|     | - Medium density                 | 0.2   |
|     | - Low density                    | 0.5   |
| 5  | Undisturbed forest, little litter| 0.005 |
| 6  | Undisturbed forest, lots of litter, undisturbed | 0.001 |
| 7  | Empty land cultivated            | 0.95 Uncultivated |
| 8  | land                             | 1.0   |
| 9  | Elephant grass, year 1           | 0.5   |
| 10 | Elephant grass, year 2           | 0.1   |

**Table 2. Soil Conservation Index (P Value) (Ministry of Forestry, 2009).**

| No | Soil Conservation Technique      | P     |
|----|---------------------------------|-------|
| 1  | Terrace bench, good             | 0.04  |
| 2  | Bench terrace, medium           | 0.15  |
| 3  | Bench terrace, poor             | 0.40  |
| 4  | Traditional terrace al          | 0.35  |
| 5  | Terrace gulud, either           | 0.15  |
6 Strip permanent grass, well, meetings and lanes 0.04
7 permanent grass ugly Strip 0.4
8 Strip Crotolaria 0.5
9 mulch hay as much as 6 t / ha / yr 0.15
10 Straw mulch 3 t/ha/year 0.25
11 Straw mulch 1 t/ha/year 0.60
12 Corn mulch, 3 t/ha/year 0.35
13 Crotolaria mulch, 3 t/ha/ th 0.50
14 Peanut mulch 0.75
15 Beds for vegetables 0.15
16 Without conservation measures 1.00

In determining whether a land unit requires conservation action, a comparison is made between the soil solum depth and the surface erosion value, which can be seen in Table 3.

**Table 3. Classification of Soil Erosion Hazard Levels (Ministry of Forestry, 2009).**

| Solum Solum (cm) | Erosion Class (tonnes/ha/year) |
|-----------------|--------------------------------|
|                 | 0 (<15) | I(15-60) | II(60-180) | III(180-480) | IV(>480) |
| Deep >90        | SR      | R        | S          | B          | SB       |
| Moderate 60-90  | I       | II       | III        | IV         | SB       |
| Shallow 30-60   | S       | B        | SB         | IB         | IV       |
| Very shallow <30| B       | SB       | SB         | SB         | SB       |

Description: 0 – SR = very light; I – R = light; II – S = moderate; III – B = heavy; IV – SB = very heavy

3. Results and discussion

3.1. Land cover

The land unit formed has an area of 25 ha or more. Land units with an area of less than 25 ha were combined with other land units because they did not meet the category for a 1:50,000 scale map, so in this study, there were 14 land units for sampling points, as shown in Figure 1.
3.2. Erosion prediction

3.2.1. Erosivity (R). The ability of rain to cause erosion is called erosivity. From calculating the rainfall erosivity index (R) using monthly average rainfall data for the last ten years at the BMKG station, the Malino sub-watershed has five distributions of rainfall values using the Isohyet method shown in Figure 2.

![Figure 2. The map of erosivity.](image)

Based on the analysis results using the method, Isohyet erosivity, the highest rainfall value found at the research site is the lowest value of 157.99 mm/year and the highest index value of 254.28 mm/year. This highest index value can be used as an indicator of runoff, classified as high in the Malino sub-watershed when it rains. This surface runoff carries soil particles resulting from the destruction of soil aggregates due to the intense power of rain pressure due to the kinetic energy of rain. According to Asdak (2010), if the amount and intensity of rainfall are high, the potential for runoff and erosion will also be increased [6].

3.2.2. Erodibility (K). Value of soil erodibility factor (K) was obtained based on the analysis results at the Silviculture Laboratory, Faculty of Forestry, Hasanuddin University. The results of the analysis can be seen in Table 4.
Table 4. Erodibility (K) value for each land unit sample

| Land Unit | Texture (%) | Organic Material (%) | Permeability | Structural Code | K   |
|-----------|-------------|----------------------|--------------|-----------------|-----|
|           | sand   | clay | dust |             |                 |     |
| 1         | 25.64 | 33.82 | 37.08 | 3.74      | 36.08 | 3   | 0.16 |
| 2         | 30.09 | 8.94  | 60.97 | 3.72      | 6.45  | 2   | 0.46 |
| 3         | 48.90 | 8.89  | 40.12 | 3.73      | 11.01 | 4   | 0.35 |
| 4         | 42.57 | 6.31  | 51.12 | 1.94      | 6.59  | 2   | 0.44 |
| 5         | 36.25 | 8.06  | 55.69 | 1.99      | 26.29 | 2   | 0.41 |
| 6         | 44.49 | 8.92  | 42.77 | 1.51      | 5.30  | 3   | 0.44 |
| 7         | 64.14 | 2.90  | 32.96 | 2.54      | 5.50  | 3   | 0.33 |
| 8         | 52.28 | 2.63  | 45.09 | 1.65      | 20.86 | 4   | 0.46 |
| 9         | 57.14 | 18.93 | 23.94 | 3.70      | 8.70  | 2   | 0.14 |
| 10        | 53.16 | 3.12  | 43.72 | 1.32      | 11.55 | 4   | 0.49 |
| 11        | 37.64 | 7.37  | 54.99 | 2.89      | 7.13  | 2   | 0.43 |
| 12        | 43.54 | 6.97  | 48.64 | 3.08      | 25.75 | 2   | 0.30 |
| 13        | 47.81 | 12.96 | 39.22 | 1.46      | 10.39 | 4   | 0.40 |
| 14        | 26.99 | 14.63 | 58.38 | 3.78      | 29.89 | 2   | 0.32 |

Based on the analysis of soil samples, the erodibility of the soil in the study area ranged from 0.16 to 0.49. This erodibility value is classified as low to high based on the classification of the erodibility value of Dangler and El-Swaify (1976 in [7]). According to Asdak (2010), the higher the erodibility value, the more susceptible the soil is to erosion [6]. On the contrary, the lower the erodibility value, the more resistant to erosion. The erodibility value is determined by the resistance of the soil to external damage and the ability of the soil to absorb water.

3.2.3. Slope Length and Slope Factor (LS). Malino sub-watershed are divided into five classes were 0-8%, 8-15%, 15-25%, 25-40%, and >40%. Each slope class will have a different level of erosion. This clearance will be used in the formula to get the value of the slope's length and slope (LS). The LS values in the Malino sub-watershed can be seen in Figure 3.

Figure 3. The map of LS.
The slopes in the Malino sub-watershed are dominated by slopes above 40% or very steep with almost the same slope length values. Arsyad (2010) suggests that the length of the slope plays a role in the amount of erosion that occurs, the longer the slope, the greater the volume of runoff that happens so that soil erosion is more significant or erosion occurs [7]. The slope of the slope significantly influences the erosion that occurs because it dramatically affects the velocity of runoff. The greater the value of the hill, the chance of water infiltration decreases so that the volume of surface runoff is more significant, which results in the danger of erosion.

3.2.4. **Plant management and soil conservation factors (CP).** The next factor influencing erosion in protecting the soil surface against damage is ground cover vegetation. Land use with a high CP value indicates that the existing vegetation is not sufficient to control erosion. In addition, a high CP value also shows that there is a lack of application of soil conservation measures. The CP values in the research location can be seen in Table 5.

### Table 5. Land cover and soil conservation factor of land unit sample.

| Land Unit | Land Cover                             | C    | P    | Index CP |
|-----------|----------------------------------------|------|------|----------|
| 1         | Secondary Dryland Forest               | 0.005| 1    | 0.005    |
| 2         | Settlement                             | 0.3  | 1    | 0.3      |
| 3         | Agricultural Land Dry Mixed Bushes     | 0.5  | 1    | 0.5      |
| 4         | Rice Fields                            | 0.01 | 0.40 | 0.004    |
| 5         | Secondary Dryland Forest               | 0.005| 1    | 0.005    |
| 6         | Agriculture Dry Land Mixed Bushes      | 0.5  | 1    | 0.5      |
| 7         | Rice Fields                            | 0.01 | 0.40 | 0.004    |
| 8         | Vacant land                            | 0.95 | 1    | 0.95     |
| 9         | Secondary Dryland Forest               | 0.005| 1    | 0.005    |
| 10        | Shrub                                  | 0.01 | 1    | 0.01     |
| 11        | Agriculture Dryland Mixed Shrub        | 0.5  | 1    | 0.5      |
| 12        | Plantation                             | 0.7  | 0.15 | 0.105    |
| 13        | Rice field                             | 0.01 | 0.4  | 0.004    |
| 14        | Vacant land                            | 0.95 | 1    | 0.95     |

Empty land cover and plantations have a high CP index value because plants that grow in plantation areas do not have good and strong roots to withstand rainfall. No conservation action is taken; even on open land, there is no conservation action. It can damage the surface layer of the soil especially coupled with steep slope conditions. However, in contrast to the cover of paddy fields, shrubs, and secondary dryland forests, paddy fields with low CP index values are 0.004, 0.01, and 0.005. It happens because the land cover has a high canopy and density, and the forest has a high density and strong roots, so the ability to withstand rainfall is enormous. Based on research by Bhan & Behera (2014), vegetation has a significant influence on erosion because vegetation blocks rainwater from falling directly to the soil surface so that the crushing power of the soil can be reduced [8].

3.2.5. **Prediction of erosion value.** The value of prediction of erosion using the USLE formula can be seen in Table 6.
Table 6. Erosion prediction in Malino Sub-watershed.

| Land Unit | Land Cover                  | Slope   | Erosion (ton/ha/year) | Erosion Hazard Class Soil | Depth | Class Erosion Hazard Level |
|-----------|-----------------------------|---------|-----------------------|---------------------------|-------|---------------------------|
| 1         | Secondary Dryland Forest    | 15-25%  | 0.71                  | I                         | 71 cm | Light                     |
| 2         | Settlements Agriculture Dry Land Mixed Shrub | 15-25% | 90.05                 | IV                        | 29 cm | Very Heavy                |
| 3         | Rice Fields Forest Dryland  | 15-25%  | 162.06                | III                       | 71 cm | Heavy                     |
| 4         | Secondary Agriculture Dryland Mixed Shrub | 25-40% | 4.11                  | I                         | 82 cm | Light                     |
| 5         | Rice Fields Dryland         | 25-40%  | 439.74                | IV                        | 67 cm | Very Heavy                |
| 6         | Open Land Secondary Dryland Mixed Shrub | 25-40% | 826.04                | IV                        | 27 cm | Very Heavy                |
| 7         | Secondary Dryland Forest    | >40%    | 1.95                  | I                         | 78 cm | Light                     |
| 8         | Shrub Dryland Agriculture Plantation | >40%   | 12.30                 | II                        | 54 cm | Moderate                  |
| 9         | Shrub Dryland Agriculture Mixed Shrub | >40%    | 597.67                | IV                        | 64 cm | Very Heavy                |
| 10        | Rice fields Dryland        | >40%    | 80.00                 | III                       | 73 cm | Heavy                     |
| 11        | Plantation                 | >40%    | 4.10                  | II                        | 50 cm | Moderate                  |
| 12        | Open Land                  | >40%    | 800.02                | IV                        | 43 cm | Very Heavy                |

Based on the analysis results in Table 6, the most significant erosion was found in the vacant land cover found in number 8 and 14. The empty land cover does not have ground cover plants and soil conservation measures. The rainwater that falls will directly hit the soil surface, destroying soil particles and causing soil erosion. Plant management factors and conservation measures are needed to reduce erosion. According to Saputri (2008) in Dedy (2016), the effect of land cover on the erosion rate can protect the soil surface from raindrops and reduce the speed of runoff to minimize erosion [9]. Land cover with the second most significant contributor to erosion occurred in dryland mixed with shrubland agricultural land cover, which was found at number 3, 6, and 11. The erosion was 162.06, 439.74, and 597.67 ton/ha/year, respectively. Apart from crop management and conservation measures, the slope factor is also very influential on this land cover, the longer and sloping the slope, the more significant the impact on erosion. This is in line with Arsyad (2010) states that the steeper the hill, the greater the number of soil grains that are splashed to the bottom of the slope by the collision of rainwater droplets [7]. If the slope of the soil surface were twice as steep, the amount of erosion per unit area would be 2.0 to 2.5 times greater.

Furthermore, the third largest land cover is in settlements, followed by plantations, rice fields, and dry forests on secondary land. Secondary dryland forest has the smallest erosion value because secondary dryland forest has a land cover of various kinds of vegetation which has an important role in slowing down surface runoff and absorbing a lot of water to prevent erosion in the area. The canopy of plants found in secondary dryland forests also blocks rainwater that falls to the ground, minimizing splash erosion.
4. Conclusion

Based on the research that has been done can be concluded that the erosion prediction results using the USLE method show four levels of erosion vulnerability, namely light with 49.88%, moderate 4.40%, heavy 6.92%, and very heavy 38.80%. The high erosion is caused by erosivity factors, steep slopes, and the lack of conservation measures and good plant management.

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