Erosion prediction of several land utilization in Dadakitan Village, Baolan sub-district, Toli-Toli Regency

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Abstract. This study aims to determine the amount of soil erosion and the danger index of erosion in several lands uses in Dadakitan Village, Baolan Sub-District, Toli-Toli Regency. In this study, slope class maps and land use maps were overlaid, in order to obtain six land uses include the use of paddy fields, coconut plantation, cocoa plantation, cloves plantation, and forests. Erosion prediction was carried out for all land uses. The survey was then carried out on six land uses to observe the slope and the dominant vegetation. Soil samples were taken deliberately for each land use; three samples for each sample of intact soil and disturbed soil. Erosion prediction analysis was using the USLE (Universal Soil Loss Equation). The results showed that the erosion hazard index occurred in Dadakitan Village was classified as low, high, and very high. Low erosion occurred in paddy fields, coconut plantation, and cocoa plantation. In contrast, high levels of erosion occurred on clove plantation, and very high erosion level occurred on forest lands. The dominant factors affecting the occurrence of erosion in this area were soil erodibility, topography, plant management, and conservation measures.

1. Introduction
In life, the land is one of the primary natural resources on earth, providing food, water, air and being a source of biodiversity. However, natural resources, such as land itself, are easily damaged or degraded [1]. Soil erosion is one of the damages to the land that reduces the productivity of natural ecosystems in agriculture [2,3].

The process of erosion inland collisions will inevitably occur, causing soil transportation and detachment in a different place [4–6]. In several tropical countries, even though the implementation of soil and water conservation projects, erosion will still occur [7]. Soil loss during erosion will cause nutrients and fertile soil to be transported out, resulting in the soil’s ability to absorb and retain water to decrease [8]. Dadakitan village has an area of 144.87 km², most of the land cover is secondary dryland forest (7211.41 ha), monoculture clove gardens (3558.95 ha), mixed cocoa gardens (460.34 ha), mixed coconut gardens (319.20 Ha), and paddy fields (23.37 Ha). Some of the slopes are above 40% plus the replacement of forest, and other natural vegetation with agricultural land makes this area prone to erosion [9].

In calculating the erosion, the USLE formula (universal soil loss equation) is performed. It is a general equation developed by Wischmeir and Smith in predicting soil loss due to surface runoff and erosion under certain conditions. Also, apart from being practical and straightforward, this method has been frequently used [5]. USLE estimates soil loss based on rainfall erosivity (R), soil erodibility (K), slope length (L), slope (S), crop management (C), and soil conservation action factors (P) [10]. Arsyad (2009) said that USLE is an erosion model designed to predict long-term average erosion of sheet or
furrow erosion under certain conditions [8]. Unfortunately, it cannot predict deposition and does not take into account the sediment yield from erosion of trenches, cliffs, and riverbeds.

This study aims to determine the amount of soil erosion and the danger index of erosion in several lands uses in Dadakitan Village, Baolan Sub-District, Toli-Toli Regency.

2. Methods

The research site was located in Dadakitan Village, Baolan Sub-District, Toli-Toli Regency and the Laboratory of the Soil Science Unit, Faculty of Agriculture, Tadulako University. This research was conducted from March to August 2020. The tools used in this research were GPS (Global Positioning System), slope maps and land use maps, ring samples, knives or cutters, transparent plastics, rubber bands, calculators, and writing instruments. Also, the primary materials used in this study were intact soil samples, partial soil samples, label paper, and several chemicals used in the analysis of soil samples in the laboratory.

This study used a survey method directly in the research site and continued with land sampling which was determined randomly on land units based on the maps that had been made, including the administrative map, slope map, and overlapping land use.

Data processing to obtain erosion prediction results were processed using the USLE (Universal Soil Loss Equation) equation by entering primary data and secondary data into the USLE equation, below:

$$A = R.K.L.S.C.P$$  \hspace{1cm} (1)

Note: R = rainfall erosivity; K = soil erodibility; L = slope length; S = slope; C = crop management; P = soil conservation action factors

Rain Erosivity Factor (R):

$$R = 10.80 + 4.15 \times RF$$  \hspace{1cm} (2)

Note: RF = Average Monthly Rainfall (cm yrs\(^{-1}\))

Soil Erodibility Factor (K):

$$K = 1.292 \cdot \{2.1 \cdot M.14\} \cdot (10-4)(12-a) + 3.25 \cdot (b-2) + 2.5 \cdot (c-3) / 100$$  \hspace{1cm} (3)

Note: K = soil erodibility; M = particle size (% dust + fine sand (100-% clayey); a = Percent of organic matter; b = Soil texture class; c = Soil permeability class

Slope length and slope factors (LS):

$$LS = L^{1/2} \cdot (0.00138 \cdot S2 + 0.00965 \cdot S + 0.0138)$$  \hspace{1cm} (4)

Note: L = Length of slope (m); S = Slope independence (%)

Plant management factors and soil conservation factors (CP)

Tolerable erosion:

$$T = (ESD/RL) + SFR \times BD \times 10$$  \hspace{1cm} (5)

Note: T = The amount of tolerable erosion (ton ha\(^{-1}\)years\(^{-1}\)); ESD = The equivalent depth is the yield into the effective soil with the value of the depth factor; RL = Lifespan of land (400 years); SFR = Soil formation rate (1mm years\(^{-1}\)); BD = Bulk density (g.cm\(^{-3}\)).
Erosion Hazard Index (EHI):

\[ EHI = \frac{A}{T} \]  

(6)

Note: \( A \) = The amount of potential erosion (ton ha\(^{-1}\) yrs\(^{-1}\)); \( T \) = Tolerable erosion (ton ha\(^{-1}\) yrs\(^{-1}\))

3. Result and Discussion

3.1. Rain erosivity factor (R)

The rain erosivity factor was determined based on the processing of rainfall data using the [11], as in Table 1. The results of the calculation of the rain erosivity factor were based on monthly rainfall data for the last nine years from the Lalos Toli-Toli Meteorological Station issued by the Meteorology, Climatology and Geophysics Agency (BMKG) Sis Al-Jufri Airport Palu. The rain erosivity was valued 849.73 (Table 1). The rain erosivity factor is one of the causes of erosion because rainwater will break the soil aggregate with its kinetic energy and produce surface runoff by eroding the soil in its path.

According to Taslim et al., (2019), the nature of rain such as the thickness of rain and the intensity of the rain significantly affects erosion [12]. In this case, the falling rain will fill the macropore spaces as a result of which the infiltration rate will be hampered, the surface runoff will increase, and the erosion will be higher [13,14].

**Table 1. Rain erosivity factors for the last nine years (2011-2019).**

| Month    | Average rainfall |
|----------|------------------|
| January  | 111.70           |
| February | 59.80            |
| March    | 47.73            |
| April    | 48.51            |
| May      | 63.00            |
| June     | 70.38            |
| July     | 97.51            |
| August   | 68.46            |
| September| 62.43            |
| October  | 71.95            |
| November | 60.48            |
| December | 87.80            |
| **Total**| **849.73**       |

Source: BMKG Sis Al-Jufri Airport Palu

3.2. Soil erodibility factor

Soil analysis was carried out to determine the soil organic matter content, soil texture, and permeability in order to obtain soil erodibility results as in Table 2.

Based on Table 2, various soil erodibility values were obtained, mixed coconut land had the most soil erodibility high category, paddy fields. In contrast, mixed cocoa land valued the lowest erodibility, among others. The difference in soil erodibility value is influenced by soil properties such as permeability, texture, structure and organic matter content, where the soil properties influence one another.

Inland use, cocoa had a low erodibility value, due to high clay, whereas in mixed coconut land uses it composed fine sand, high dust, and low clay resulting in a high erodibility value. Those, due to the sand and dust that is easily carried away by rainwater. As stated by Firmansyah (2007), that erodibility is influenced by soil texture, large particle sizes will withstand the carrying capacity, and fine particles will withstand destructive power since their cohesiveness, particles that cannot withstand both are dust with very fine sand [15].
Table 2. Soil erodibility factors in 6 land use units.

| Land Use Unit | Erodibility (K) | Classification  |
|---------------|-----------------|----------------|
| 1             | 0.40            | Rather high    |
| 2             | 0.50            | High           |
| 3             | 0.23            | Low            |
| 4             | 0.30            | Medium         |
| 5             | 0.34            | Rather high    |
| 6             | 0.27            | Medium         |

3.3. The factor of length slope (L) and slope (S)

Based on the length and slope of the slope in the study location, the length slope (LS) value is obtained as in Table 3.

Based on Table 3, the lowest LS value was found in the use of paddy fields with a value of 0.01, a slope of 0.02%, and a slope length of 48.95 m. The highest Slope value was in secondary forest land use (Land use unit 5) with a value of 1.17, a slope of 0.47%, and a slope length of 634.52 m. Arif et al., (2017) stated that long and steep slopes cause the increase in shear strength at the soil surface [16]. A higher surface flow velocity will be obtained on steeper slopes, but longer slopes accumulate runoff from a wider area and also result in higher flow velocity [17].

Table 3. Slope length and slope.

| Land Use Unit | Land Uses         | Length slope and Slope (LS) |
|---------------|-------------------|----------------------------|
| 1             | Paddy field       | 0.01                       |
| 2             | Coconut plantation| 0.02                       |
| 3             | Cacao plantation  | 0.04                       |
| 4             | Cloves plantation | 0.41                       |
| 5             | Secondary forest  | 1.1                        |
| 6             | Secondary forest  | 0.93                       |

3.4. Plant management and conservation measures (CP)

The CP value of each land use in Dadakitan Village can be seen in Table 4. Plant management and conservation measures must be carried out regularly and pay attention to the principles of soil and water conservation for erosion prevention. In Table 5, we can see that clove land valued 0.18, cocoa land valued 0.15, and coconut land valued 0.1, while paddy fields were 0.004, and forest land (Land use unit 5 and 6) have a CP was valued 0.005 of each.

Table 4. Calculation of plant management and conservation action (CP)

| Land Use Unit | Land uses        | CP  |
|---------------|------------------|-----|
| 1             | Paddy field      | 0.01|
| 2             | Coconut plantation| 0.02|
| 3             | Cacao plantation | 0.04|
| 4             | Cloves plantation| 0.41|
| 5             | Secondary forest | 0.17|
| 6             | Secondary forest | 0.93|

The land area covered by living or dead vegetation is more resistant to erosion due to raindrops and wind energy dissipated by the vegetation layer [18,19]. Those affects rainwater interception, reduces surface runoff and biological activities related to vegetative growth affect structural stability, soil porosity and transpiration which results in reduced groundwater [20].
3.5. Prediction of erosion in Dadakitan village

Based on the calculation results, the amount of erosion in several lands uses in Dadakitan Village was obtained as in Table 5. The table shows the results of various erosion calculations; actual erosion was obtained by calculating the value of $A = R \times K \times L \times S$, while potential erosion was obtained using the equation $A = R \times K \times S$.

| Land Use Unit | Land Uses        | R (cm)  | K     | LS     | CP     | A (ton ha$^{-1}$ yrs$^{-1}$) |
|---------------|------------------|---------|-------|--------|--------|-------------------------------|
| 1             | Paddy field      | 849.73  | 0.40  | 0.83   | 0.004  | 0.01                          | 3.40                          |
| 2             | Coconut plantation | 849.73  | 0.50  | 1.09   | 0.1    | 0.85                          | 8.50                          |
| 3             | Cacao plantation | 849.73  | 0.23  | 1.66   | 0.15   | 1.17                          | 7.82                          |
| 4             | Cloves plantation | 849.73  | 0.30  | 3.08   | 0.18   | 18.81                         | 104.52                        |
| 5             | Secondary forest | 849.73  | 0.34  | 3.64   | 0.005  | 1.69                          | 338.02                        |
| 6             | Secondary forest | 849.73  | 0.27  | 2.56   | 0.005  | 1.07                          | 213.37                        |

Note: $R =$ Rain Erosivity, $K =$ Soil Erodibility, $LS =$ Length of Slope and Slope, $CP =$ Plant Management and Conservation Measures, $A =$ Erosion, Actual and Potential

The highest actual erosion was found in clove land use, about 18.81 tonnes ha$^{-1}$ yr$^{-1}$ and the lowest was in paddy field use, about 0.01 tonnes ha$^{-1}$ yr$^{-1}$ (Table 5). While the highest potential value was found in secondary forest land use (Land use unit 5), about 338.02 tonnes ha$^{-1}$ yr$^{-1}$, and the lowest was in the use of paddy fields, about 3.40 tonnes ha$^{-1}$ year$^{-1}$.

Putra et al., (2018) stated that erosion in the cold waters of the upstream part of Padang city on paddy fields was lower than in mixed gardens, shrubs, while the lowest was in forest erosion [5]. The highest erosion occurred on mixed garden land, and the lowest was on forest land where the erosion ranged from 1.20 tonnes ha$^{-1}$ year$^{-1}$ and 4.73 tonnes ha$^{-1}$ year$^{-1}$, respectively.

3.6. Tolerable erosion

Erosion that is tolerated was obtained from the results of the prediction of erosion with the soil depth factor, soil formation factor, and soil density, as in Table 6.

| Land uses          | DS (mm) | MDS (mm) | RF  | SFR  | BD  | T (Ton Ha$^{-1}$ yrs$^{-1}$) |
|--------------------|---------|----------|-----|------|-----|-------------------------------|
| Paddy field        | 350     | 250      | 400 | 1    | 1.48 | 15.05                         |
| Coconut plantation | 730     | 500      | 400 | 1    | 1.75 | 18.08                         |
| Cacao plantation   | 400     | 500      | 400 | 1    | 1.64 | 16.15                         |
| Cloves plantation  | 400     | 500      | 400 | 1    | 1.60 | 15.75                         |
| Secondary forest   | 820     | 750      | 400 | 1    | 1.22 | 12.38                         |
| Secondary forest   | 940     | 750      | 400 | 1    | 1.15 | 11.96                         |

Note: $DS =$ Depth of Soil, $MDS =$ Minimum Depth of Soil, $RF =$ Lifespan of Land, $RSF =$ Soil Formation Rate, $BD =$ Bulk density, $T =$ tolerated erosion

Based on Table 6, it shows that the tolerable erosion in the use of secondary forest land (Land use unit 6) with a value of 11.96, secondary forest (Land use unit 5) 12.38, cloves plantation of 15.75, mixed cocoa plantation of 16.15, mixed coconut plantation of 18.08, and paddy fields of 15.05. The highest tolerated erosion was found on coconut plantation of 18.08, and the lowest was on secondary forest land (Land use unit 6) with a value of 11.96.
The prediction of actual erosion in the village of Dadakit an showed in Table 6 indicates the land that exceeds the tolerable erosion value in Table 7, namely the use of clove land which was caused by factors of slope length and slope as well as crop management and conservation measures.

3.7. Erosion hazard index
The erosion hazard index shows different results for each land use, and it can be seen in Table 7.

| Land Use Unit | A (Ton Ha\(^{-1}\) yrs\(^{-1}\)) | T (Ton Ha\(^{-1}\) yrs\(^{-1}\)) | EHI   | Criteria |
|---------------|----------------------------------|----------------------------------|-------|----------|
| 1             | 3.40                             | 15.05                            | 0.23  | Low      |
| 2             | 8.50                             | 18.08                            | 0.47  | Low      |
| 3             | 7.82                             | 16.15                            | 0.48  | Low      |
| 4             | 104.52                           | 15.75                            | 6.64  | High     |
| 5             | 338.02                           | 12.38                            | 27.30 | Very high|
| 6             | 213.37                           | 11.98                            | 17.84 | Very high|

Note: A = Potential Erosion, T = Tolerable Erosion, EHI = Erosion Hazard Index

The erosion hazard index shows different results for each land use, and it can be seen in Table 7. The lowest erosion hazard index was found in low-category lowland land use, valued of 0.23 tonnes ha\(^{-1}\) yrs\(^{-1}\), while the highest erosion hazard index found in the secondary forest land use (Land use unit 5) with a very high category, the value of the erosion hazard index was 27.30 tonnes ha\(^{-1}\) yrs\(^{-1}\). This was due to the length of the slope and slope of the slope, as stated by Chaplot and Bissonnais (2003); Pasaribu et al., (2018), the length and slope of the slope are cause more significant erosion, this is related to the kinetic energy of ground rainwater, which increases with increasing slope and the water will flow faster down (erosion rate will be faster) if the slope is high [1,21].

4. Conclusion
The level of erosion hazard that occurred in several lands uses in Dadakit Village was categorized as low, high, and very high. The erosion values that were tolerated ranged from 11.96 tonnes ha\(^{-1}\) yrs\(^{-1}\) to 18.08 tonnes ha\(^{-1}\) yrs\(^{-1}\). Erosion on land use in Dadakit Village was predominantly caused by soil erodibility, topography, crop management, and conservation measures. Conservation actions needed to be taken maintaining existing vegetation, using plant debris as mulch, using bench terraces, reforestation, and land evaluation. There needs awareness from all parties, both the local government and the community to evaluate the capacity of the land in order to take conservation actions to preserve the environment, so it can inhibit the rate of erosion and reduce losses due to erosion.

References
[1] Pasaribu P H P, Rauf A and Slamet B 2018 Kajian tingkat bahaya erosi untuk arahan konservasi tanah pada berbagai tipe penggunaan lahan di Kecamatan Merdeka Kabupaten Karo J. Serambi Eng. 3
[2] Molla T and Sisheber B 2017 Estimating soil erosion risk and evaluating erosion control measures for soil conservation planning at Koga watershed in the highlands of Ethiopia Solid Earth 8 13–25
[3] Zuazo V H D and Pleguezuelo C R R 2009 Soil-erosion and runoff prevention by plant covers: a review Sustain. Agric. 785–811
[4] Hessel R and Jetten V 2007 Suitability of transport equations in modelling soil erosion for a small Loess Plateau catchment Eng. Geol. 91 56–71
[5] Putra A, Triyatno T, Syarief A and Hermon D 2018 Penilaian erosi berdasarkan metode usle dan arahan konservasi pada das air dingin bagian hulu Kota Padang-Sumatera Barat J. Geogr. 10 1–13
[6] Zhang X C J, Zheng F L, Chen J and Garbrecht J D 2020 Characterizing detachment and transport
processes of interrill soil erosion *Geoderma* 376 114549

[7] Pagiu S 2005 Prediksi erosi tanah di Sub DAS Miu pada kawasan Taman Nasional Lore Lindu (TNLL) *AgriSains* 6

[8] Arsyad S 2009 *Konservasi tanah dan air* (Bogor: PT Penerbit IPB Press)

[9] Badan Pusat Statistik (BPS) 2019 *Kecamatan Baolan dalam Angka 2019 Kabupaten Toli-Toli* (Toli-toli)

[10] Devatha C P, Deshpande V and Renukaprasad M S 2015 Estimation of soil loss using USLE model for Kulhan Watershed, Chattisgarh-A case study *Aquat. Procedia* 4 1429–36

[11] Utomo W H 1994 *Erosi dan konservasi tanah* vol 194 (Malang: IKIP Malang)

[12] Taslim R K, Mandala M and Indarto I 2019 Prediksi erosi di Wilayah Jawa Timur: Penerapan USLE dan GIS *J. Ilmu Lingkung.* 17 323–32

[13] Assouline S and Ben-Hur M 2006 Effects of rainfall intensity and slope gradient on the dynamics of interrill erosion during soil surface sealing *Catena* 66 211–20

[14] Wen L, Zheng F, Shen H, Bian F and Jiang Y 2015 Rainfall intensity and inflow rate effects on hillslope soil erosion in the Mollisol region of Northeast China *Nat. hazards* 79 381–95

[15] Firmansyah M A 2007 Prediksi erosi tanah podsolik merah kuning berdasarkan metode Usle di berbagai sistem USAhatani: Studi kasus di Kabupaten Barito Utara dan Gunung Mas *J. Pengkaj. dan Pengemb. Teknol. Pertan.* 10 126080

[16] Arif N and Danoevodo P 2017 Pemodelan spasial erosi kualitatif berbasis raster (Studi kasus di DAS Serang, Kabupaten Kulonprogo) *J. Ilmu Lingkung.* 15 127–34

[17] Ahmad I and Verma M K 2013 Application of USLE model & GIS in estimation of soil erosion for Tandula reservoir *Int. J. Emerg. Technol. Adv. Eng.* 3 570–6

[18] Fattet M, Fu Y, Ghestem M, Ma W, Foulonneau M, Nespoulous J, Le Bissonnais Y and Stokes A 2011 Effects of vegetation type on soil resistance to erosion: Relationship between aggregate stability and shear strength *Catena* 87 60–9

[19] Gyssels G, Poesen J, Bochet E and Li Y 2005 Impact of plant roots on the resistance of soils to erosion by water: a review *Prog. Phys. Geogr.* 29 189–217

[20] Pimentel D and Burgess M 2013 Soil erosion threatens food production *Agriculture* 3 443–63

[21] Chaplot V A M and Le Bissonnais Y 2003 Runoff features for interrill erosion at different rainfall intensities, slope lengths, and gradients in an agricultural loessial hillslope *Soil Sci. Soc. Am. J.* 67 844–51