*Bulgarian Journal of Agricultural Science, 29 (No 4) 2023, 615–622*

# The Hazard of Soil Erosion and Sediment Yield Prediction for Krueng Mane Watershed in Indonesia

**Annisa Dini Safira[1], Azmeri Azmeri[1*], Eldina Fatimah[1], Asri Syahrial[2], Tuti Rahmawati[3]**

[1] *Universitas Syiah Kuala, Engineering Faculty, Civil Engineering, Syech Abdur-rauf No. 7 Darussalam 23111, Banda Aceh, Indonesia*
[2] *Ministry of Public Works and Housing (PUPR) BWS Sumatera-I, Indonesia*
[3] *Aceh Regional Settlement Infrastructure Center, Aceh Besar, Indonesia*
[*] *Corresponding author:* azmeri@unsyiah.ac.id

## Abstract

Safira, A. D., Azmeri, A., Fatimah, E., Syahrial, A. & Rahmawati, T. (2023). The Hazard of Soil Erosion and Sediment Yield Prediction for Krueng Mane Watershed in Indonesia. *Bulg. J. Agric. Sci., 29*(4), 615–622

Land use in several locations at the Krueng Mane watershed has shifted from forests to rice fields, palm oil plantations, and settlements. Changes in land use supported by high rainfall can potentially increase soil erosion, or erosion rates and result in river silting due to sedimentation. This study aims to determine the rate of soil erosion, sedimentation, and distribution of soil erosion hazards in the Krueng Mane watershed. The erosion rate was calculated using the Geographic Information System (GIS)-based Universal Soil Loss Equation (USLE) method. The calculation shows that the erosion rate at the Krueng Mane watershed was 17,614.82 $Mg \cdot ha^{-1} \cdot y^{-1}$, and the sediment yield was 67,412,186.16 $Mg \cdot y^{-1}$. The erosion hazard level at the Krueng Mane watershed was dominated by a very mild category of 53.58% with an area of 22,287.46 Ha, followed by mild category (16.94%), moderate (23.00%), severe (5.40%), and extreme (1.08%). The interaction between USLE parameters significantly affected the average annual soil loss rate. Land with a high soil erosion hazard is closely correlated with steep gradients and changes in land use. Mild and very mild rates of soil loss are associated with conservation practices and protected areas. The result of this study is beneficial for planning land scenarios as interventions to reduce erosions.

*Keywords:* Krueng Mane Watershed; Soil erosion hazard; USLE; ArcGIS 10.4

## Introduction

Soil erosion is a series of soil abrasion, transport, and deposition events caused by water, or wind movement (Alalwanya et al., 2021; El Jazouli et al., 2017). Erosion is a challenging environmental problem in watershed ecosystems because it can worsen soil and water quality, reduce upstream land productivity, and cause downstream sedimentation (Naharuddin et al., 2021 Azmeri, 2020; Kim & Arnhold, 2018). Therefore, sustainable sediment management and spatially accurate models are required to estimate erosion rates (Azmeri et al., 2020; Gusma et al., 2023).

Universal Soil Loss Equation (USLE) is a simple calculation model, which is widely used to predict the amount of soil eroded in a land (Azmeri et al., 2020; Roy, 2019; Pham et al., 2018; Singh & Panda, 2017; Hui et al., 2010). El Jazouli et al. (2017) and Hui et al. (2010) stated that the USLE method is a quantitative model that is considered a contemporary, simple, and widely used approach for erosion assessment and is suitable for Geographic Information System (GIS)-based calculations. GIS is a component consisting of software, hardware, human resources, and data in geographic-based information. GIS can map and spatially describe the erosion parameters of an area; hence, erosion calculations become more straightforward and efficient

(Brahmanto, et al.,2020; Roy, 2019; Pham et al., 2018; El Jazouli et al., 2017; Ganasri & Ramesh, 2016; Hui et al., 2010).

Erosion in watersheds is caused by land use around the watershed that neglects soil and water conservation principles (Gocić et al., 2020; Turner et al., 2018; Zhu & Li, 2014). Similarly, in several locations in the Krueng Mane watershed, land use has shifted from forest to rice fields, palm oil plantations, and settlements. Changes in land use and high rainfall can lead to soil erosion resulting in silting of rivers caused by sedimentation. The Krueng Mane river is planned as an intake location for the Lhokseumawe drinking water supply system (SPAM). In this case, sedimentation can settle and interfere with the operations of the SPAM intake door. High sedimentation rates can also affect the quality of river water (Lintern et al., 2018; Tundu et al., 2018; Turner et al., 2018). Therefore, it is necessary to calculate the rate of soil erosion and the level of erosion hazard at the Krueng Mane watershed using the Geographic Information System (GIS)-based Universal Soil Loss Equation (USLE) method. Moreover, sediment yield is estimated based on the Sediment Delivery Ratio (SDR).

## Materials and Methods

### Study Area

The study was conducted in the Krueng Mane watershed, covering an area of 415.98 km$^2$, part of the Pase Peusangan river area. The study location covers the upstream watershed to the SPAM intake location, which is located in Sawang District at 5°11′26.8″N – 96°54′51.8″E (Figure 1). The location is under the authority of the Aceh Provincial Government.

### Data Collection

The data includes the parameters required to determine the soil erosion rate as follows:

1. The ten-year (2012–2021) satellite rainfall data from the CHIRPS (Climate Hazards Group InfraRed Precipitation with Station) on Climate Hazards Center UC Santa Barabara's website. Rainfall data is presented in monthly rainfall in cm;
2. The Digital Elevation Model (DEM) from satellite images sourced from the National DEM website. The data was used to obtain topographical data and determine watershed boundaries. The presented DEM data has a spatial resolution of 0.27 arcseconds or 8.1 meters using the EGM2008 vertical datum;
3. The 2019 Aceh soil type map shape file was obtained from the Aceh Web GIS Portal, soil type data was used to obtain soil erodibility factor (K);
4. The 2019 Aceh land cover map shape file was obtained from the Ministry of Environment and Forestry. The data was used to obtain land use information at the Krueng Mane watershed, which was subsequently used to determine the land use and processing factor (CP).

The soil loss per unit area (A, Mg·ha$^{-1}$·y$^{-1}$) consist of four parameters were used in the USLE method, i.e., rainfall erosivity factor (R), soil erodibility factor (K), slope length factor (LS), as well as crop and land management factor (CP). The erosion rate was calculated using the above four parameters (Equation 1 and Figure 2).

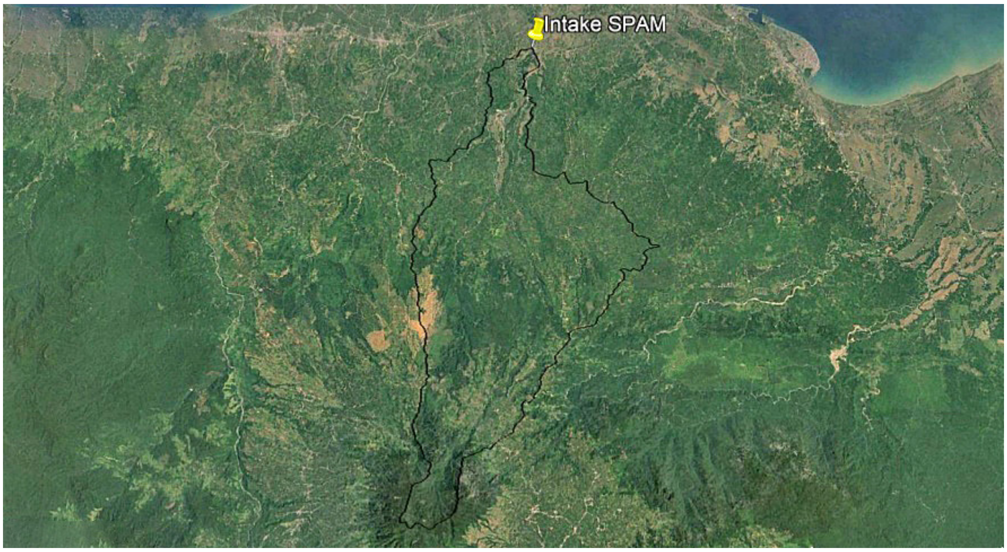


**Fig. 1. The Study area – Krueng Mane Watershed**

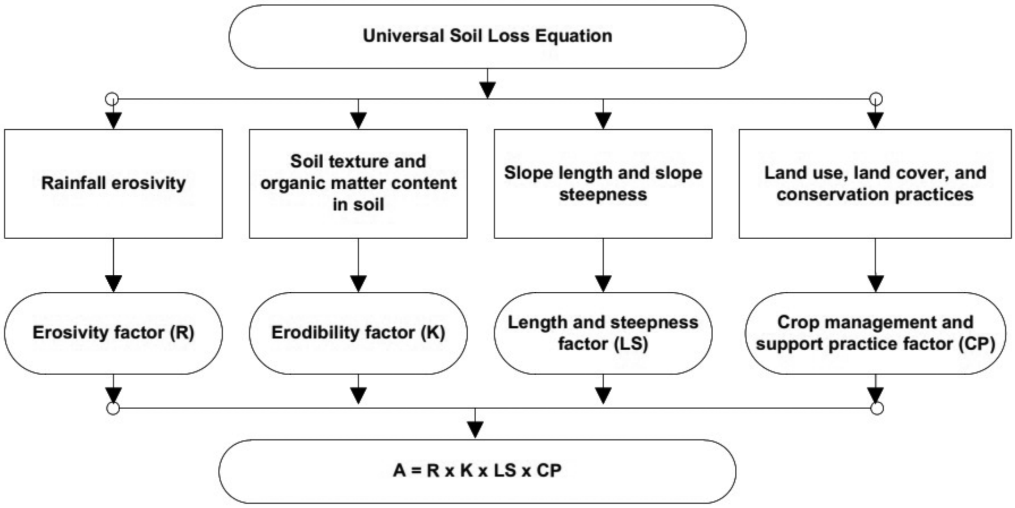


**Fig. 2. Methodology Flowchart (Azmeri et al., 2022; Azmeri et al, 2020)**

$$A = R \,.\, K \,.\, LS \,.\, CP \tag{1}$$

This study used satellite rainfall data from CHIRPS (Climate Hazards Group InfraRed Precipitation with Station). Katsanos et al. (2016) conducted a study on the frequency of CHIRPS rainfall in Cyprus and obtained the CHIRPS data feasibility. Meanwhile, in Indonesia, Narulita et al. (2021) conducted a study that concluded that the CHIRPS data is feasible to use if there are limitations in accessing station rainfall data. The data being used is the ten-year monthly rainfall data. The rainfall erosivity is determined using Equation 2 and P is the monthly rainfall total (cm). The result is entered into the ArcGIS 10.4 calculator tool and processed as an R factor to obtain the soil erosion rate.

$$R = 2.21 \,.\, P^{1.36} \tag{2}$$

Soil has a vulnerability, or sensitivity to erosion, known as the soil erodibility factor (Roy, 2019; Pham et al., 2018; El Jazouli et al., 2017). The LS factor consists of two components, i.e., the slope length and steepness obtained based on the topographic data (Fijałkowska, 2021; Bekele & Gemi, 2021; Azmeri et al., 2020). The coordinates in the topographic data of the Krueng Mane watershed were projected into UTM; the steepness data was created using slope tools from DEM. The C factor is the ratio between the level of erosion in specifically managed planted soil and the level of erosion in soil not managed. Meanwhile, P factor is a human action factor in physical and mechanical soil management (Azmeri, 2020; C. Huang et al., 2020). The CP value was determined based on the watershed Krueng Aceh's land cover map.

**Classification of spatial erosion hazard**

Soil erosion hazard estimates the hazard magnitude posed by erosion on land (Azmeri, 2020). This parameter needs to be determined to decide the conservation strategies required in the area (Azmeri et al., 2022 and Azmeri et al., 2020). The hazard of soil erosion description can be observed from actual erosions, as presented in Table 1.

**Table 1. The soil erosion hazard classes**

| Class | Soil erosion hazard ($Mg \cdot ha^{-1} \cdot y^{-1}$) | Classification |
|---|---|---|
| I | < 15 | Low |
| II | 15 – 60 | Low-Moderate |
| III | 60 – 180 | Moderate |
| IV | 180 – 480 | High-Moderate |
| V | > 480 | High |

*Source*: The Regulation of the Director-General of Watershed Management and Social Forestry of the Republic of Indonesia, 2013

**Sediment Delivery Ratio (SDR)**

Sediment transfer to the watershed outlet is conducted by estimating the SDR value in equation 3 (Tsegaye & Bharti, 2021; Roy, 2019; Singh & Panda, 2017; Hui et al., 2010; Boyce, 1975). This parameter estimates the amount of sediment in the catchment area, compared to erosion in the entire watershed (Azmeri et al., 2022).

$$SDR = 0{,}41 \times A^{-0.3} \tag{3}$$

where: A = watershed area (ha).

## Results and Discussion

### Rainfall erosivity

Rainfall erosivity is rainfall's ability to cause erosion in an area. A higher rainfall erosivity value leads to a higher ability to cause erosion.

Table 2 shows that the rainfall in the Krueng Mane watershed falls under the mild (0–100 mm) and moderate (101–300 mm) categories. Calculations using equation 2 result in monthly rainfall erosivity value between 46.342 and 161.095. The lowest rainfall erosivity occurred in July and the highest in December. The total ten-year rainfall erosivity is 1,057.05.

**Table 2. Rainfall erosivity value**

| Month | Rainfall (mm) | R value |
|---|---|---|
| January | 210.45 | 139.27 |
| February | 96.03 | 47.92 |
| March | 104.,86 | 54.01 |
| April | 150.90 | 88.59 |
| May | 145.86 | 84.59 |
| June | 95.20 | 47.35 |
| July | 93.70 | 46.34 |
| August | 94.46 | 46.85 |
| September | 113.47 | 60.12 |
| October | 193.40 | 124.15 |
| November | 229.55 | 156.74 |
| December | 234.22 | 161.09 |
| **Total** | | 1,057.047 |

### Soil Erodibility Factor (K)

The soil erodibility factor was determined by grouping based on the soil type in the Krueng Mane watershed. The soil distribution was then analyzed using ArcGIS 10.4. A high soil erodibility value indicates that the soil is more susceptible to erosion (X. Huang et al., 2022). The K value of the Krueng Mane watershed soil is presented in Table 3 and Figure 3.

**Table 3. Soil erodibility (K) factor distribution**

| Soil Type | Area (ha) | K value | Persentage (%) |
|---|---|---|---|
| Inceptisol | 3,331.40 | 0.23 | 8.01 |
| Andisol | 3,307.74 | 0.07 | 7.95 |
| Ultisol | 34,959.77 | 0.16 | 84.04 |
| **Total** | **41,598.92** | | 100.00 |

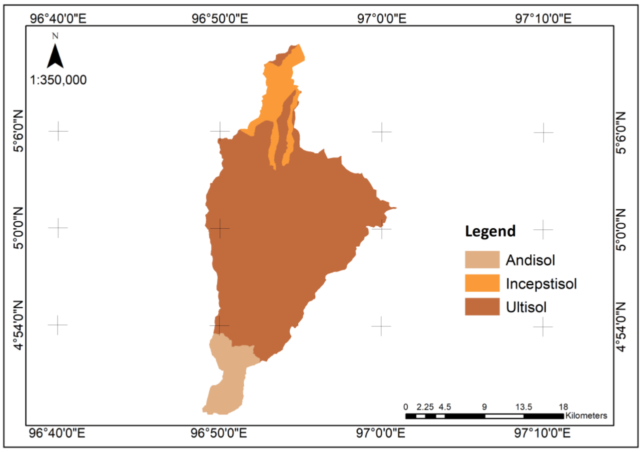


**Fig. 3. The K map**
*Source*: own study

Three types of soil at the Krueng Mane watershed have varying K values. Ultisols dominate as much as 84.04% of the Krueng Mane watershed area. This soil type has relatively stable aggregate stability, but it also has an argillic layer that can inhibit interception (Dariah et al., 2004). Inceptisol soil has the highest K value among other soil types due to its dusty clay texture that is susceptible to erosion. Dusty soil is more easily transported by water flow (Hardiana et al., 2019). Meanwhile, andisol has high infiltration properties, good aggregate stability, and high water holding capacity; these properties can reduce erosion risks (Bekele & Gemi, 2021; Suprayogo et al., 2020).

### Slope Length and Steepness Factor (LS)

Table 4 and Figure 4 show the distribution of steepness level against the LS value, which is required to determine the soil erosion rate of the Krueng Mane watershed.

Table 4 shows that the steepness of the Krueng Mane watershed is mostly 0–8% (36.03%), covering an area of 14,988.88 Ha spread from upstream to downstream of the watershed. Meanwhile, 3.91% (the lowest percentage) has

**Table 4. The LS value distribution**

| Slope (%) | Area (ha) | LS value | Persentage (%) |
|---|---|---|---|
| 0 – 8 | 14,988.88 | 0.4 | 36.03 |
| 8 – 15 | 11,852.06 | 1.4 | 28.49 |
| 15 – 25 | 8,255.00 | 3.1 | 19.84 |
| 25 – 40 | 4,876.71 | 6.8 | 11.72 |
| > 40 | 1,626.27 | 9.5 | 3.91 |
| Total | **41,598.92** | | 100.00 |

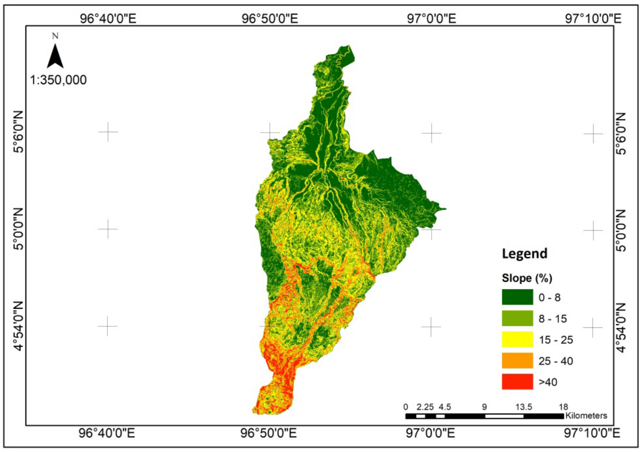


**Fig. 4. The LS map**
*Source*: own study

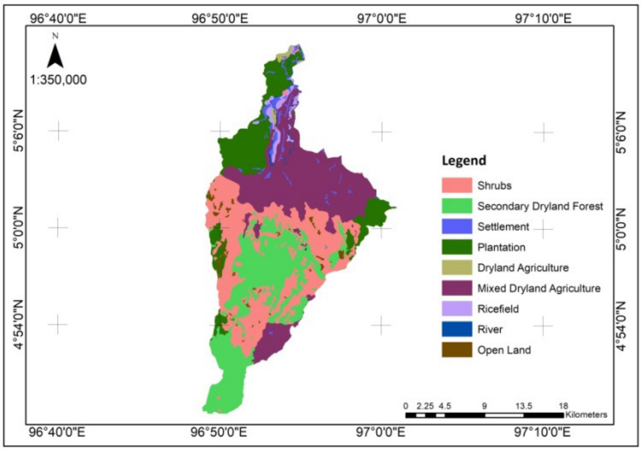


**Fig. 5. The CP map**
*Source*: own study

a steepness of more than 40% in the upstream area of the Krueng Mane watershed. The slope steepness affects the surface runoff velocity that triggers erosion. A steeper and longer slope has a higher risk of erosion due to increased surface runoff velocity and volume (Allafta & Opp, 2022). According to X. Huang et al. (2022), land with various soil types tends to have varying levels of erodibility.

**Crop Management and Support Practice (CP) Factor**

The CP value distribution in the Krueng Mane watershed is provided in Table 5 and Figure 5.

The land cover of the Krueng Mane watershed is dominated by 11,621.52 Ha of mixed dryland agriculture with a CP value of 0.013. Land cover with low CP values has a good canopy and plant density and strong roots that withstand rainfall erosivity (A. Putra et al., 2018). Table 5 shows that plantations and settlements have higher CP due to the lack of canopy density and strong roots. The absence of cover crops gives a very high CP value, resulting in a lack of soil's ability to withstand rainwater that can damage the soil layer.

**Table 5. The CP value distribution**

| Land Use | Area (ha) | CP value | Persentage (%) |
|---|---|---|---|
| Shrubs | 11,485.58 | 0.3 | 27.61 |
| Secondary dry land forest | 10,029.23 | 0.01 | 24.11 |
| Settlement | 769.25 | 0.5 | 1.85 |
| Plantation | 6,041.34 | 0.5 | 14.52 |
| Dryland farm | 197.30 | 0.048 | 0.47 |
| Mix dryland farm | 11,621.52 | 0.013 | 27.94 |
| Paddy field | 687.19 | 0.02 | 1.65 |
| River | 237.73 | 0 | 0.57 |
| Open land | 529.76 | 1 | 1.27 |
| Total | 41,598.92 | | 100.00 |

**Estimate of Annual Soil Erosion**

The soil erosion hazard map at the Krueng Mane watershed was obtained by overlaying USLE factors (Table 6 and Figure 6). The Krueng Mane watershed erosion is classified as low to high. The erosion hazard level is dominated by low category (53.58%), while the lowest is in high category (1.08%).

From the calculation, the total soil erosion rate at the Krueng Mane watershed was 17,614.82 Mg·ha$^{-1}$·y$^{-1}$, with the lowest erosion rate of 0.269 Mg·ha$^{-1}$·y$^{-1}$. This soil erosion rate occurred in secondary dryland forests with andisol soil on a slope of less than 8%. It happened, because the land had good canopy density and roots, supported by andisol soil, which is highly stable. The land is on a gentle slope; therefore, the soil erosion hazard is very mild.

The highest erosion rate was 1,606.71 Mg ha$^{-1}$ y$^{-1}$, which occurred in open land with ultisol soil at more than 40%

**Table 6. The Hazard of Soil Erosion**

| Class | Soil erosion hazard | Area (Ha) | Persentage (%) |
|---|---|---|---|
| I | Low | 22,287.46 | 53.58 |
| II | Low-Moderate | 7,046.45 | 16.94 |
| III | Moderate | 9,567.00 | 23.00 |
| IV | High-Moderate | 2,248.09 | 5.40 |
| V | High | 449.92 | 1.08 |
| **Total** | | 41,598.92 | 100.00 |

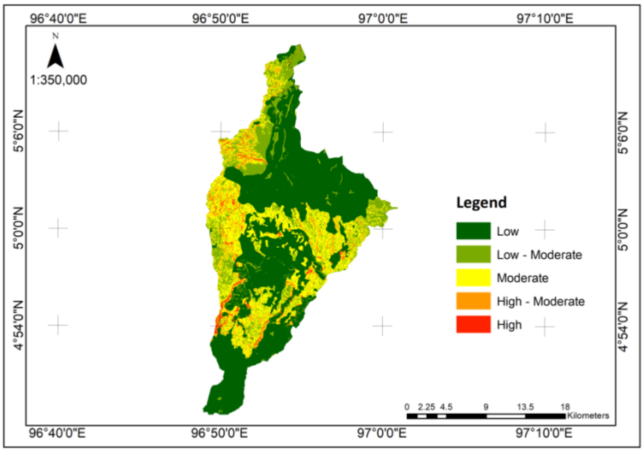


**Fig. 6. The hazard of Soil erosion map**
*Source*: own study

steepness. Because vegetation cover is absent in open lands, rain energy falls directly on the soil particles. A land steepness of more than 40% increases the surface runoff velocity and volume. Ultisol soil has a layer that can inhibit water from penetrating the soil and has a high dust content; thus, the soil is easilyeroded. Azmeri et al. (2022) stated that open land contributes the most to the number of soil erosion. In line with the calculation, most open lands are at risk of severe to extreme erosion rates.

The sedimentation level of the Krueng Mane watershed was determined based on the SDR value from equation (3). Based on the SDR, the Krueng Mane watershed delivers sediment downstream of 0.092. This SDR value indicates that 9.2% of the eroded soil is carried to the river, while 90.8% of the erosion yield is retained and settles in the soil surface basins and land in the Krueng Mane watershed.

Based on the SDR value, the total sediment yield of the Krueng Mane watershed is 67,412,186.16 $Mg \cdot y^{-1}$, because not all eroded soil entered the river. Some of the soil settled in particular areas in the watershed (Bekele & Gemi, 2021; Tatipata et al., 2015). The particular places are basins on the ground surface and locations where the flow slows down. Sediment yield that settles in the river trench will reduce the river's storage capacity and potentially lead to river silting.

## Conclusion

The study reveals that the GIS-based USLE method provided accurate spatial distribution estimations. The tool built a soil erosion model to assess the potential erosion hazard and risk for the Krueng Mane watershed. This model is based on land access, which accommodates challenging land use changes in the future. The modeling shows that the erosion rate of the Krueng Mane watershed varied spatially. The USLE overlay affected the average annual soil loss rate. The erosion rate of the Krueng Mane watershed is 17,614.82 $Mg \cdot ha^{-1} \cdot y^{-1}$, and the total sediment yield of the Krueng Mane watershed is 67,412,186.16 $Mg \cdot y^{-1}$. Several soil erosions in the Krueng Baro watershed are spatially classified as very mild (22,287.46 Ha or 53.58% of the total area of the Krueng Mane watershed). A small portion of the watershed is categorized as High (449.92 Ha, or 1.08% of the total Krueng Mane watershed area). The very mild soil erosion hazards occur on land with good canopy density, low erodibility soil, and gentle slopes. Meanwhile, extreme soil erosion hazards happen on land with high steepness and open land due to the absence of vegetation that can inhibit runoff and the transport of soil particles. The soil erosion hazard classification shows that land cover significantly affects the erosion index and the erosion hazard level.

## References

**Alalwanya, A. A. M., Abdel Ghani, E. T., Ali, K. A. & Al-Bayati, A. H. I.** (2021). Use of Revised Universal Soil Loss Equation (RUSLE) Model to Estimate Soil Erosion in Jibab Wadi Basin West of Iraq. IOP Conference Series: Earth and Environmental Science, *904*(1). https://doi.org/10.1088/1755-1315/904/1/012004.

**Allafta, H. & Opp, C.** (2022). Soil Erosion Assessment Using the RUSLE Model, Remote Sensing, and GIS in the Shatt Al-Arab Basin (Iraq-Iran). Applied Sciences, *12*(15), 7776. https://doi.org/10.3390/app12157776.

**Azmeri, A.** (2020). Erosi, Sedimentasi, dan Pengelolaannya. (Erosion, sedimentation, and the management). Banda Aceh. Syiah Kuala Universitas Press. (Indonesian).

**Azmeri, A., Nurbaiti, N., Mawaddah, N., Yunita, H., Jemi, F. Z. & Sundary, D.** (2022). Surface erosion hazard and sediment yield for Keuliling Reservoir in Indonesia. *Journal of Water and Land Development*, 52 (I-III), 108–118. https://doi.org/10.24425/jwld.2022.140380.

**Azmeri, L. S. & Rezkyna, N.** (2020). Interphase Modeling of Soil Erosion Hazard Using a Geographic Information System and the Universal Soil Loss Equation. *Journal of Chinese Soil and Water Conservation, 51*(7), 65–75. https://doi.org/10.29417/JCSWC.202006.

**Bekele, B. & Gemi, Y.** (2021). Soil Erosion Risk and Sediment Yield Assessment With Universal Soil Loss Equation And GIS: In Dijo Watershed, Rift Valley Basin Of Ethiopia. *Modeling Earth Systems and Environment, 7*(1), 273–291. https://doi.org/10.1007/s40808-020-01017-z.

**Boyce, B.** (1975). Sediment Routing and Sediment Delivery Ratios. In Present andProspective Technology for Predicting Sediment Yield and Sources, USDA.

**Brahmanto, P. D., Sulistyo, B. & Barchia, M. F.** (2020). Analysis of the Level of Erosion Hazard by Using Remote Sensing and

Geographic Information System in the Sub - Watershed of Rindu Hati. *Journal of Land Restoration, 3*(2), 32–38.

**Dariah, A., Subagyo, H., Tafakresnanto, C. & Marwanto, S.** (2004). Kepekaan Tanah Terhadap Erosi. Teknologi Konservasi Tanah Pada Lahan Kering Berlereng (Soil Sensitivity to Erosion, Soil Conservation Technology on Dry Land Slopes), 7–30 (Indonesian).

**El Jazouli, A., Barakat, A., Ghafiri, A., El Moutaki, S., Ettaqy, A. & Khellouk, R.** (2017). Soil erosion modeled with USLE, GIS, and remote sensing : a case study of Ikkour watershed in Middle Atlas ( Morocco ). *Geoscience Letters, 4*(25), 1–12. https://doi.org/10.1186/s40562-017-0091-6.

**Fijałkowska, A.** (2021). Analysis of the Influence of DTM Source Data on the LS Factors of the Soil Water Erosion Model Values with the Use of GIS Technology. *Remote Sensing, 13*(4), 1–38. https://doi.org/10.3390/rs13040678.

**Ganasri, B. P. & Ramesh, H.** (2016). Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin. *Geoscience Frontiers, 7*(6), 953–961. https://doi.org/10.1016/j.gsf.2015.10.007.

**Gocić, M., Dragićević, S., Radivojević, A., Bursać, N. M., Stričević, L. & Đević, M. Đ.** (2020). Changes in soil erosion intensity caused by land use and demographic changes in the jablanica river basin, Serbia. *Agriculture, 10*(8), 345. https://doi.org/10.3390/agriculture10080345.

**Gusma, F., Azmeri, A., Jemi, F. Z. & Rahmatan., H.** (2023). Soil erosion rate and hazard level at the Sianjo-anjo reservoir watershed in Indonesia. *Journal of Water and Land Development*, 57 (IV-VI), 181–187. https://doi.org/10.24425/jwld.2023.145348.

**Hardiana, E., Kadir, S. & Nugroho, Y.** (2019). Analisis Tingkat Bahaya Erosi (TBE) di DAS Dua Laut Kabupaten Tanah Bumbu (Analysis of Erosion Hazard in Dua Laut Watershed Tanah Bambu Regency). *Jurnal Sylva Scienteae, 2*(3), 529–539 (Indonesian).

**Huang, C., Zhou, Z., Teng, M., Wu, C. & Wang, P.** (2020). Effects of climate, land use and land cover changes on soil loss in the Three Gorges Reservoir area, China. *Geography and Sustainability, 1*(3), 200–208. https://doi.org/10.1016/j.geosus.2020.08.001.

**Huang, X., Lin, L., Ding, S., Tian, Z., Zhu, X., Wu, K. & Zhao, Y.** (2022). Characteristics of Soil Erodibility K Value and Its Influencing Factors in the Changyan Watershed, Southwest Hubei, China. *Land, 11*(1), 1–14. https://doi.org/10.3390/land11010134.

**Hui, L., Xiaoling, C., Lim, K. J., Xiaobin, C. & Sagong, M.** (2010). Assessment of soil erosion and sediment yield in Liao watershed, Jiangxi Province, China, Using USLE, GIS, and RS. *Journal of Earth Science, 21*(6), 941–953. https://doi.org/10.1007/s12583-010-0147-4.

**Katsanos, D., Ratalis, A. & Michaelides, S.** (2016). Period, Validation of A High-Resolution Precipitation Database (CHIRPS) Over Cyprus for A 30-Year. Atmospheric Research, 169(Part B), 459–464. https://doi.org/10.1016/j.atmosres.2015.05.015.

**Kim, I. & Arnhold, S.** (2018). Mapping environmental land use conflict potentials and ecosystem services in agricultural watersheds. *Science of the Total Environment, 630*, 827–838. https://doi.org/10.1016/j.scitotenv.2018.02.176.

**Lintern, A., Webb, J. A., Ryu, D., Liu, S., Bende-Michl, U., Waters, D., Leahy, P., Wilson, P. & Western, A. W.** (2018). Key factors influencing differences in stream water quality across space. *Wiley Interdisciplinary Reviews: Water, 5*(1), 1–31. https://doi.org/10.1002/WAT2.1260.

**Naharuddin, N., Malik, A. & Ahyauddin, A.** (2021). Soil Loss Estimation for Conservation Planning in the Dolago Watershed Central Sulawesi, Indonesia. *Journal of Ecological Engineering, 22*(7), 242–251.

**Narulita, I., Fajary, F. R., Mulyono, A., Kusratmoko, E. & Djuwansah, M. R.** (2021). Application of Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) satellite data for drought mitigation in Bintan island, Indonesia. *IOP Conference Series: Earth and Environmental Science, 789*(1). https://doi.org/10.1088/1755-1315/789/1/012052.

**Pham, T. G., Degener, J. & Kappas, M.** (2018). Integrated universal soil loss equation (USLE) and Geographical Information System (GIS) for soil erosion estimation in A Sap basin: Central Vietnam. *International Soil and Water Conservation Research, 6*(2), 99–110. https://doi.org/10.1016/j.iswcr.2018.01.001.

**Putra, A., Triyatno, Syarief, A. & Hermon, D.** (2018). Penilaian Erosi Berdasarkan Metode Usle Dan Arahan Konservasi Pada DAS Air Dingin Bagian Hulu Kota Padang-Sumatera Barat (Erosion Assessment based on the USLE Method and Conservation Guidelines in Upstream Air Dingin Padang City-Watershed West Sumatera). *Jurnal Geografi, 10*(1), 1–13. http://jurnal.unimed.ac.id/2012/index.php/geo (Indonesian).

**Raditya, F. T. & Suhastyo, A. A.** (2020). Implementasi Model Spasial Erosi Lahan di Kecamatan Pagentan Kabupaten Banjarnegara (Implementation of Land Erosion Spatial Model in Pagentan District, Banjarnegara Regency). *Jurnal Ilmiah Media Agrosains, 6*(1), 20–26 (Indonesian).

**Roy, P.** (2019). Application of USLE in a GIS environment to estimate soil erosion in the Irga watershed, Jharkhand, India. *Physical Geography, 40*(4), 361–383. https://doi.org/10.1080/02723646.2018.1550301.

**Singh, G. & Panda, R. K.** (2017). Grid-cell based assessment of soil erosion potential for identification of critical erosion prone areas using USLE, GIS and remote sensing: A case study in the Kapgari watershed, India. *International Soil and Water Conservation Research, 5*(3), 202–211. https://doi.org/10.1016/j.iswcr.2017.05.006.

**Suprayogo, D., Van Noordwijk, M., Hairiah, K., Meilasari, N., Rabbani, A. L., Ishaq, R. M. & Widianto, W.** (2020). Infiltration-Friendly Agroforestry Land Uses on Volcanic Slopes in the Rejoso Watershed, East Java, Indonesia. *Land, 9*(8), 240.

**Tatipata, W. H., Soekarno, I., Sabar, A. & Legowo, S.** (2015). Analisis Volume Sedimen yang Mengendap Setelah T-Tahun Waduk Beroperasi (Studi Kasus: Waduk Cirata) (Analysis of Sediment Volume that Settles after T-Year of Reservoir Operation (Case Study: Cirata Reservoir). *Jurnal Teknik Sipil., 22*(3), 235–242 (Indonesian).

**Tsegaye, L. & Bharti, R.** (2021). Soil Erosion and Sediment Yield Assessment Using RUSLE and GIS-Based Approach in Anjeb Watershed, Northwest Ethiopia. *SN Applied Sciences, 3*(5), 1–19. https://doi.org/10.1007/s42452-021-04564-x.

**Tundu, C., Tumbare, M. J. & Onema, J. M. K.** (2018). Sedimentation and its impacts/effects on river system and reservoir water quality: Case study of Mazowe catchment, Zimbabwe. *Proceedings of the International Association of Hydrological Sciences, 377*, 57–66. https://doi.org/10.5194/piahs-377-57-2018.

**Turner, B. L., Fuhrer, J., Wuellner, M., Menendez, H. M., Dunn, B. H. & Gates, R.** (2018). Scientific case studies in land-use driven soil erosion in the central United States: Why soil potential and risk concepts should be included in the principles of soil health. *International Soil and Water Conservation Research, 6*(1), 63–78. https://doi.org/10.1016/j.iswcr.2017.12.004.

**Zhu, C. & Li, Y.** (2014). Long-Term Hydrological Impacts of Land Use/Land Cover Change from 1984 to 2010, in the Little River Watershed, Tennessee. *International Soil and Water Conservation Research, 2*(2), 11–21. https://doi.org/10.1016/S2095-6339(15)30002-2.

***Received***: Mart, 06, 2023; ***Approved***: June, 12, 2023; ***Published***: August, 2023