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IDENTIFICATION OF EROSION RATE USING UNIVERSAL SOIL LOSS EQUATION (USLE) METHOD IN KOTO TANGAH DISTRICT PADANG CITY IN 2024

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ABSTRACT: This study aims to analyze the erosion rate in Koto Tangah District, which is an area with varied topography and high rainfall. The area of this area reaches 232.25 square kilometers, this area faces an increased risk of erosion due to human activities such as land clearing for agriculture and settlements. This study aims to: (1) calculate the erosion rate using the USLE method, and (2) map the distribution of areas with the potential for erosion in 2024. The formulation of the problem is focused on identifying the magnitude of the erosion rate and the distribution pattern of areas prone to erosion in Koto Tangah District. The research method uses the Universal Soil Loss Equation (USLE) approach integrated with the Geographic Information System (GIS). The data used include: rainfall data from CHIRPS 2024, soil type data from the Digital Soil Map of the World (DSMW) 2007, slope data from DEM, and land use data from the interpretation of Landsat imagery on October 8, 2024 using the Maximum Likelihood Classification method. The results of the analysis are expected to provide important information for the government and the community in disaster mitigation efforts and natural resource management. The study shows variations in erosion rates from <15 tons/ha/year to >480 tons/ha/year, with steep mountainous areas (>45%) showing the highest erosion rates. The discussion reveals that the interaction of slope factors, soil type, and land cover are the main determinants of the magnitude of erosion. Through a better understanding of erosion conditions in Koto Tangah, it is hoped that proactive steps can be taken to reduce the negative impacts of soil erosion and increase environmental resilience.

Keywords: Erosion, USLE, Koto Tangah

1. INTRODUCTION

Padang City is the capital city of West Sumatra Province with an area of 695km^2. Koto Tangah District is one part of Padang City and is the largest district in Padang City with an area of 232.25 square kilometers. Astronomically, Koto Tangah District is located between 0°58' South Latitude and 100°21'11" East Longitude. Based on its geographical location, to the east Koto Tangah borders the Indonesian Ocean. To the west it borders directly on Solok Regency and Pauh District. To the south it borders on Padang Utara District and Nanggalo District. To the north it borders on Padang Pariaman Regency. The environmental conditions of Koto Tangah District have generally become residential areas but still give the impression of a shady area. With sufficient natural landscapes, it greatly influences its spatial planning patterns. The topography and shape of the area will greatly determine the development and structure of a large-scale residential area (housing built by developers) (Badan Pusat Statistik Kota Padang, 2024).

Factors that influence the danger of erosion are rain, low vegetation levels, soil types, and conservation measures. These are the factors that greatly influence the occurrence of erosion. (Morgan dan Rickson,2005). Along with the development of Padang City according to the dynamics of society, it has automatically created greater pressure on the environment and is feared to exceed its carrying capacity. This will certainly give rise to various environmental problems/issues in this area (SLHD Kota Padang Tahun 2009).

In conducting analysis on areas that are easily eroded in Koto Tangah District, the utilization of the Universal Soil Loss Equation (USLE) method developed by Wischmeier and Smith (1978) seems to be able to be used to find out the level of erosion hazard in a very long period of time (per year) in an area with a Geographic Information System (GIS) approach. The approach with a method to predict the level of erosion hazard spatially which is obtained from overlays in rainfall data, soil type data, slope gradient data, and land use (Aprizon Putra dkk, 2018). The results of data processed with spatial data can produce the erosion rate value of the erosion rate and the level of erosion danger based on the USLE (Universal Soil Loss Equation) method by using an overlay on existing factors (Rusnam dkk, 2013).

The level of erosion hazard in the Koto Tangah District area was analyzed by considering various factors such as topographic conditions, land use, slope, soil type and average annual rainfall (2024) in the Koto Tangah District. This research is expected to be used as a reference, especially in studies in the field of remote sensing technology, in an effort to provide or create information related to erosion hazard level maps. Which is useful for describing the level of erosion that occurs in an area. Erosion analysis can also be used as a guideline in preparing disaster mitigation, one of which is to estimate or identify areas that may be affected by erosion disasters (Rusnam dkk, 2013).

2. METHOD

2.1. Tools and materials used

The following are the tools and materials used in the research.
For the tools, namely:

1. Laptop HP ProBook 440 G1 Intel i7-4702MQ @2.20 GHz up to 3.20 GHz, RAM 12 GB Dual Chanel DDR3L.
2. Software ArcGIS 10.8
3. Microsoft Office Word 2013.

The materials used are:

1. Landsat 8 OLI image of Padang City area on 10-29-2024.
2. DEM (Digital Elevation Model) image of Padang City area in 2024.
3. CHIRPS image data for 2024 from January to December in the Padang City area.
4. Shp Soil types around the world (Digital Soil Map of the World).
5. Indonesian administrative shp for Koto Tangah District area.

2.2. Research stage

This research in the initial stage was carried out by downloading all data online, the downloaded data in the form of Landsat 8 image data downloaded through the United States Geological Survey (USGS) website, Digital Elevation Model (DEM) image data through the Ina-Geoportal website, Climate Hazards InfraRed Precipitation with Station data (CHIRPS) data, and Digital Soil Map of the World (DSMW) shape files downloaded through the Indonesia Geospatial website.

At the Pre-Processing stage of data, the data is processed into a parameter data of erosion constituents in the form of land use data, rainfall data, slope data, and soil type data. After all the parameter data is obtained, proceed to the Processing stage. At this stage, all data is given an index that describes the influence of the data on erosion. All data will later be calculated by multiplying the index values of all parameters used to obtain the erosion rate value and erosion hazard level and erosion hazard class that occurs in the study area.

Based on the data of erosion rate value and erosion hazard level and erosion hazard class obtained, mapping of areas with potential erosion hazard in the study area will be carried out. This mapping will later be given a color that describes how erosion occurs in the study area such as green for areas with very light erosion, light green for areas with light erosion, yellow for areas with moderate erosion, orange for areas with heavy erosion, and red for areas with very heavy erosion.

2.3. Map analysis techniques

The map analysis techniques in this research are:

1. Pra-Processing Data
   This initial stage is the first stage in research to find USLE (Universal Soil Loss Equation) based data, because raw data obtained from various sources such as Landsat 8 satellite imagery, DEM data, CHIRPS data, and soil type shp files (DSMW) cannot be used directly for analysis.

2. Processing
   This stage is the processing stage of all data used as parameter data to calculate the erosion rate to determine the level of erosion hazard based on the USLE components, namely A = R * K * LS * CP. Where all data is given an index that describes its influence on the erosion rate in the research area.

2.5. USLE Parameter Processing

a) Rainfall Erosivity Value (R).

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This factor is used to measure the potential of rain that can cause erosion. The R value can be calculated using the Lenvain 1975 formula using the average rainfall value. To find the erodibility value, use the following calculation:

$$Rm = 2{,}21\ (Rain)m^{1,36}$$

Explanation:
Rm = rainfall erosivity index (unit/year).
$(Rain)m^{1,36}$ = Average rainfall amount (cm/year).

Table 1. R value index

No	Annual rainfall data (mm)	Average annual rainfall (mm)	R Value
1	2.800-3.300	3.050	5284,94
2	3.300-3.700	3.500	6372,72
3	3.700-4.200	3.950	7512,15
4	4.200-4.600	4.400	8699,37

Source: Research results.

b) Soil Type Erodibility Value (K)
The K factor indicates how easily the soil can be eroded. This value is determined based on the physical and chemical properties of the soil, such as texture and structure. The K value is adjusted to the Bogor Irrigation Research and Development Center, 1985 as a guideline for the K Value.

Table 2. K value index

No	Soil type	Soil texture	K Factor
1	Humic Andosols	Volcanic, clay, humus	0.278
2	Dystric Cambisols	Clay, humus	0.25
3	Humic Glaysols	Clay, Humus, Swampy	0.205

Source: Bogor Irrigation Research and Development Center, 1985

c) Slope Length and Gradient Index (LS)
The LS factor measures the effect of slope length and slope on the rate of water flow that contributes to erosion. To determine the value of the slope length and slope index, I use references from Hengki Simanjuntak et al., 2017.

Table 3. LS value index

No	Slope class (%)	Information	LS Factor
1	<8%	Flat	0.40
2	8-15%	Sloping	1.40
3	15-25 %	A bit steep	3.10
4	25-45%	Steep	6.80
5	>45%	Very Steep	9.50

Source: Hengki Simanjuntak et al., 2017

d) Crop Management and Soil Conservation (CP) Index.
The CP factor reflects the impact of land use management on the possibility of soil erosion. For the CP value, I use the measurement data issued by BPDAS (2012) contained in a journal by Purnama et al., 2022.

Table 4. CP value index

No	Land use	CP Value
1	Dry land forest	0,010
2	Check the bushes	0,300
3	Settlement	0,950
4	Irrigated rice fields	0,01430
5	Open land	0,950

Source: Purnama et al., 2022

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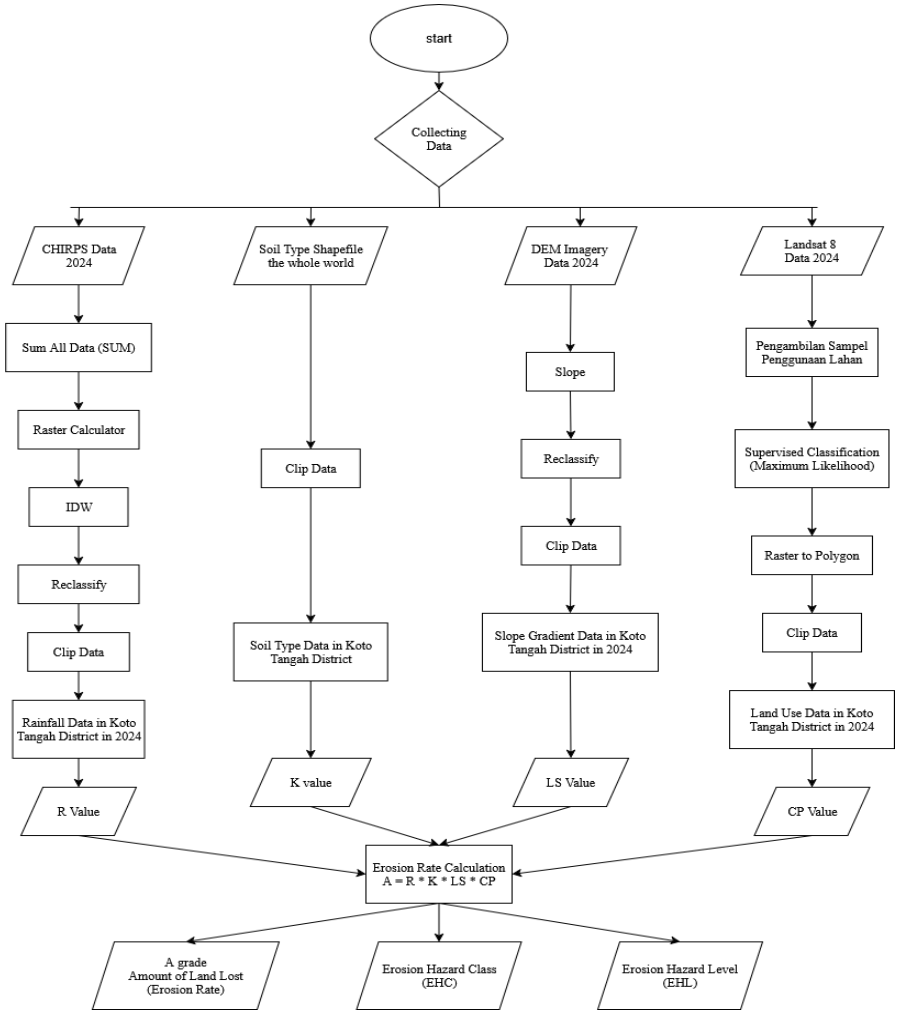
e) Perhitungan Laju Erosi (A)
After all the data from the values that make up the erosion rate, namely the R, K, LS, and CP factors, are created, the data is then calculated using the following formula:

$$A = R*K*LS*CP$$

To calculate the erosion rate (A value), all data must be Intersect first. The A value obtained will be adjusted to the Erosion Hazard Class (EHC) and Erosion Hazard Level (EHL).

2.4. Flow diagram

This research uses a flow diagram as follows:



3. RESULTS AND DISCUSSION

3.1 Rainfall data occurred in Koto Tangah District during 2024 according to calculations from CHIRPS data.

Rainfall data was obtained or obtained through processing of all CHIRPS image data in Koto Tangah District from January to December in 2024. Rainfall data that occurred in Koto Tangah District in 2024 can be seen in Figure 3.1.

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3.2 Data on the distribution of soil types in Koto Tangah District according to the Digital Map of the World (DSMW) published by FAO-Unesco in 2007.

In obtaining the distribution of soil types in the entire study area in Koto Tangah District, this study refers to the Shape File Digital Soil Map of the World (DSMW) in 2007. Based on these data, it can be seen how the distribution of soil types in Koto Tangah District is, which data is very useful for obtaining results from the erosion rate in Koto Tangah District. In Koto Tangah District, based on data from the Digital Soil Map of the World (DSMW) in 2007, there are 3 types of soil, namely humic androsols, dystric cambisols, and humic glaysols. The soil type data can be seen clearly in Figure 3.2.

3.3 Slope gradient data in Koto Tangah District in 2024 based on DEM image data processing

Slope data in Koto Tangah District in 2024 was obtained through DEM image data processing. This slope data is used as one of the main ones in calculating the erosion rate, because the slope level has a significant influence on surface water flow and the possibility of erosion in an area or region. All the slope data results in the Koto Tangah District in 2024 can be seen in Figure 3.3.

3.4 Land use data in Koto Tangah District in 2024 based on processing of Landsat 8 imagery

Land use data in Koto Tangah District in 2024 was obtained from processing Landsat 8 image data on October 29, 2024 using the Maximum Likelihood Classification method by taking 5 samples in the study area, namely dry land forests, bushes, settlements, open land, and irrigated rice fields. Land use data obtained based on Landsat 8 image processing in the study area can be seen in Figure 3.4

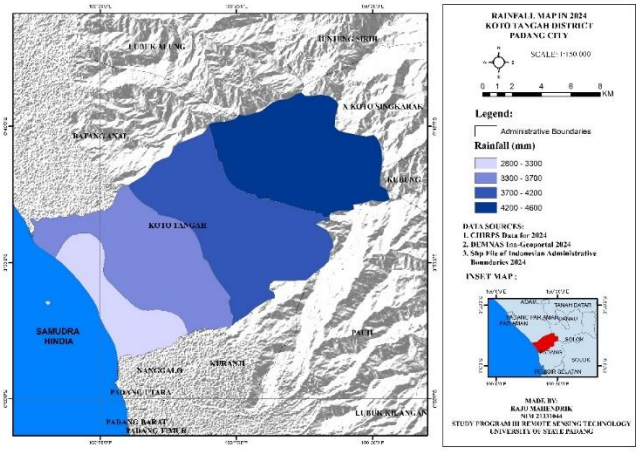

Figure 3.1 Map of rainfall in Koto Tangah District during 2024

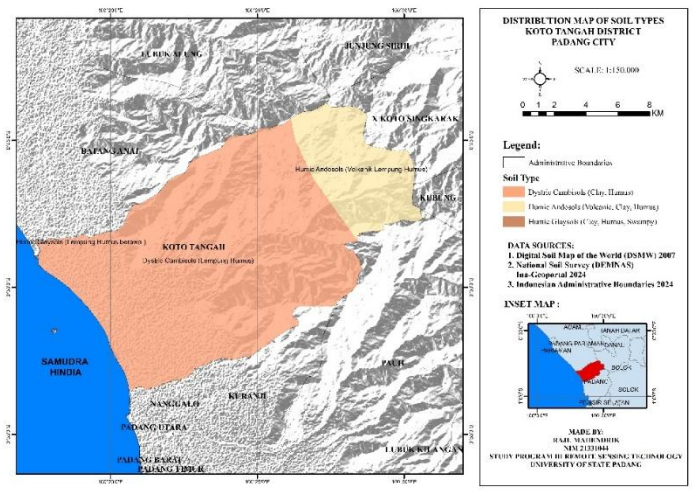

Figure 3.2 Map of soil type distribution according to the Digital Soil Map of the World (DSMW) in Koto Tangah

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District.

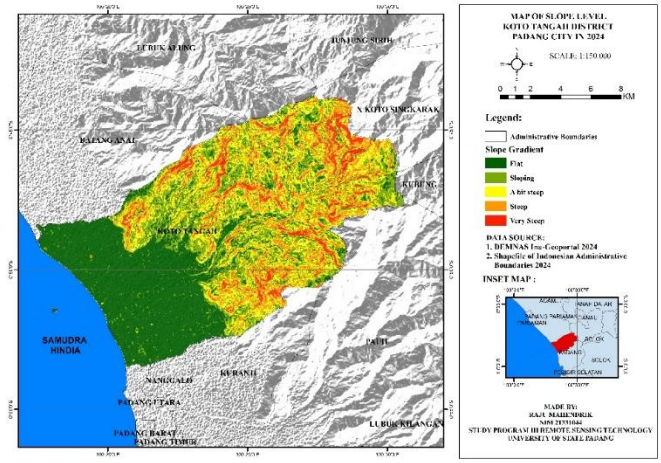

Figure 3.3 Slope gradient map in Koto Tangah District in 2024 based on DEM-Nas image processing.

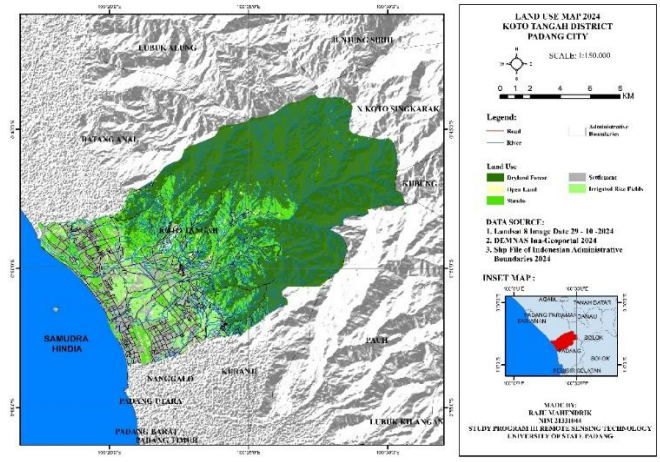

Figure 3.4 Land use map in Koto Tangah District in 2024 based on Landsat 8 image processing

3.5 Mapping of erosion areas

The value of the erosion rate in Koto Tangah District in 2024 can be obtained from the multiplication of each erosivity index factor on each parameter used. Namely the R value for rainfall data, the K value for soil type distribution data, the LS value for slope data, and the CP value for land use data. All of these data are multiplied to obtain the A value or erosion rate value which will later affect the level and class of erosion hazard in Koto Tangah District. Based on these data, it will be possible to map which areas have the potential for erosion. Data on all erosion rates in Koto Tangah District can be seen in table 3.1 and figure 3.5.

Table 3.1 Erosion rate, class, and level of erosion hazard and the total accumulated value of erosion rate in Koto Tangah District in 2024

No	Erosion Hazard Class	Erosion Rate (ton/Ha/year)	Erosion Hazard Level	Colors on the map	Total erosion rate value (ton/Ha/year)
1	I	<15	Very low	Green	93,22
2	II	15 – 60	Low	Light green	765,1
3	III	60 – 180	Moderate	Yellow	2.532,72
4	IV	180 – 480	High	Orange	4.373,68
5	V	>480	Severe	Red	31.4727,15

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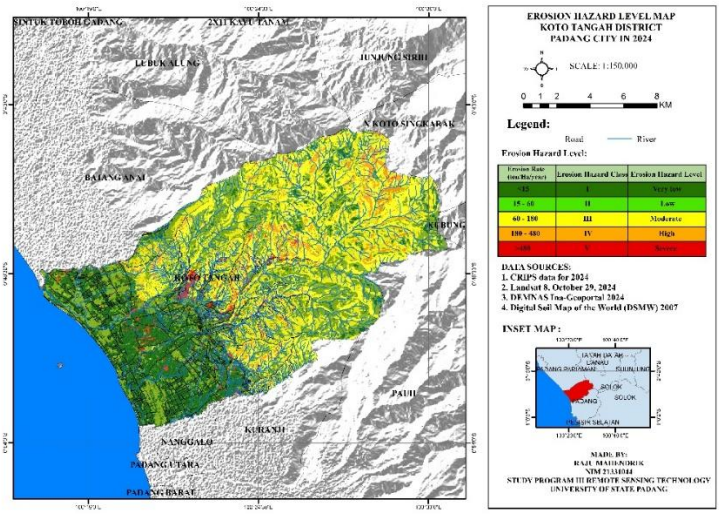

Figure 3.5 Map of erosion hazard levels in Koto Tangah District in 2024.

3.6 Calculating Erosion Rate Using Universal Soil Loss Equation (USLE) Method to Determine Erosion Hazard Level in Koto Tangah District in 2024.

The results of the erosion rate calculation using the Universal Soil Loss Equation (USLE) method in Koto Tangah District in 2024 showed significant variations in erosion hazard levels in various regions. Based on the analysis of four main parameters, namely rainfall (R), soil type (K), slope gradient (LS), and land use (CP), a comprehensive picture of the erosion distribution pattern in the study area was obtained. The distribution of erosion rates shows that areas with very severe hazard levels (>480 Tons/Ha/Year) despite having the smallest area, actually make the largest contribution to the total erosion in the study area, reaching 314,727.15 Tons/Ha/Year. This is in accordance with the research findings of Prasannakumar et al. (2012), which states that areas with very steep slopes (>45%), high rainfall, and open land use tend to produce very high erosion rates. These results are also in accordance with the USLE theory which states that the interaction between the LS (slope) and CP (land cover) factors has an exponential effect on the magnitude of erosion.

Areas with severe erosion hazard levels (180-480 Ton/Ha/Year) contributed 4,373.68 Ton/Ha/Year, mainly found in areas with Dystric Cambisols soil types that have less stable structures. This is in line with the findings of research by Gelagay and Minale (2016), which showed that soil with low organic matter content and high acidity is more susceptible to erosion, especially when exposed to high rainfall in the Koto Tangah mountainous area. Spatial analysis shows an interesting pattern where areas with moderate erosion hazard levels (60-180 Ton/Ha/Year) actually have the widest distribution, but with a lower total erosion accumulation (2,532.72 Ton/Ha/Year) compared to the severe category. This phenomenon can be explained by the characteristics of its land use which is dominated by shrubs that provide partial protection against erosion. Areas with very light erosion hazard levels (<15 Ton/Ha/Year), and light erosion hazard levels (15 – 60 Ton/Ha/Year) which are areas with flat and gentle slopes only contribute an accumulated erosion rate value of 93.22 Ton/Ha/Year for erosion hazard levels, and 765.1 Ton/Ha/Year for light erosion hazard levels. This proves the effectiveness of vegetation in suppressing erosion rates.

3.7 Mapping Potential Erosion Hazard Areas in Koto Tangah District in 2024.

Based on the results of erosion data processing using the Universal Soil Loss Equation (USLE) method, it shows significant spatial variations. Rainfall data (R), soil type distribution data (K), slope gradient data (LS), and land use data (CP) all of these data are the main data that can be used in mapping areas with potential for erosion in Koto Tangah District in 2024. Rainfall data (R) in the research area with the highest intensity observed in the mountainous area, namely with a value of >3700 mm/year increases the possibility of erosion. This condition is in accordance with the findings of Prasannakumar et al. (2012) who said that high rainfall can increase erosion. The volume of rainfall, rainfall intensity, and duration of rain increase the erosivity of erosion in the research area, especially on bare land/open land surfaces. Soil type data (K) shows the dominance of Dystric Combisols soil with low organic matter (<2%) and unstable structure, especially in areas with steep to very steep slopes increasing the erosivity of erosion in the research area.

Analysis of slope gradient (LS) data shows that the mountainous areas in the research location have a fairly

steep slope gradient with a slope of >15% to very steep (>45%) making the potential for erosion increase. Furthermore, land use (CP) data is also a crisis factor where forest conservation becomes open land, especially in areas with a fairly steep to very steep slope gradient, increasing the potential for erosion to increase.

In the application of mapping potential areas with potential erosion hazards, there are 5 erosion classifications that produce clear spatial patterns, namely:

3.7.1 Green color (<15 Ton/Ha/Year) is dominant in the lowlands at the research location.
3.7.2 Light green (15 – 60 Tons/Ha/Year) is still found in lowland areas with flat to gentle slopes.
3.7.3 The yellow color (60 – 180 Tons/Ha/Year) shows that this area is located in an area that is heading towards the highlands with a rather steep slope.
3.7.4 The orange color (180 – 480 Tons/Ha/Year) shows that this area shows the potential for erosion which is already quite active, where this area is already in a mountainous area and has a steep to very steep slope.
3.7.5 The red color (>480 Ton/Ha/Year) in this area indicates very large erosion potential, located in a mountainous area with a very steep slope (>45%).

4. CONCLUSION

Based on the research results using the Universal Soil Loss Equation (USLE) method in Koto Tangah District in 2024, it can be concluded: This study successfully calculated the erosion rate and erosion hazard level in Koto Tangah District in 2024 using the Universal Soil Loss Equation (USLE) method. This method considers rainfall data (R), soil type data (K), slope data (LS), and land use data (CP). The erosion rate in the study area varies from <15 Ton/Ha/Year, which is a very light hazard level, to >480 Ton/Ha/Year, which is a very severe erosion hazard level. Erosion with a very light hazard level occurs mainly in lowland areas with an accumulated total erosion rate of 93.22 Ton/Ha/Year. This condition is influenced by the flat slope (<8%), relatively low rainfall (2,800 - 3,300 mm/year) and the dominance of land use in the form of irrigated rice fields that have a regular water management system.

The mountainous area in Koto Tangah District with very steep slopes (>45%), high rainfall (42,000 - 4,600 mm/year), and the dominance of fragile Dystric Cambisols soil contributes to the erosion rate with a very high level of danger (>480 Tons/Ha/Year) especially in open land areas. This area has the largest total value of accumulated erosion rates in Koto Tangah District in 2024, namely with a total value of accumulated erosion rates of 314,727.15 Tons/Ha/Year, although the distribution of the area is quite narrow.

Through spatial analysis, this study successfully mapped the distribution of areas with potential for erosion in Koto Tangah District. The mapping results show that areas with high erosion hazards are concentrated in mountainous areas with steep to very steep slopes, high rainfall, and little vegetation land use or areas with open land. Areas with moderate erosion hazards are spread across the transition between mountainous and lowland areas in Koto Tangah District. Areas with low erosion hazards are located in the lowlands in Koto Tangah District with flat to gentle slopes, relatively low rainfall, and controlled land use.

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