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Evaluation of Erosion Potential and Determination of The Causes of Erosion Using A Geographic Information System

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ABSTRACT

The purpose of this study was to determine the magnitude of the erosion class and too determine the cause distribution area in the Upper Serang Sub-watershed. In this study using combinatian of quantitative and qualitative descriptive methods. While the tools used are GPS, soil sampling tools, laboratory test equipment such as permeability analysis tools, organic materials tools, texture analysis tools, data analysis tools using Arc Gis 10.4.1 and SPSS. Erosion potential analysis using USLE (Universal Soil Loss Equation) method. Based on the research results, the Upper Serang Sub-watershed has 5 erosion class categories, i,e very light class (0.5-10.11 t·ha–1·y–1). Light grade (15.26-48.52 t·ha–1·y–1). Medium class (70.55-164.51 t·ha–1·y–1). Heavy class (208.95–388.41 t·ha–1·y–1). Very heavy class (697.47–2241.14 t·ha–1·y–1). While the Erosion Hazard Index is divided into 4 classes, i,e low class with a value of <1. Medium class with a score of 1.001-4.00. High class with a value of 4.01–10.0. Very high grade with a score of > 10. The dominant factor influencing the high and low erosion value is the slope factor and the length of the slope at the location of the Upper Serang Sub-watershed based on the closeness value with a value of 0.935 with a very strong closeness class.

1. INTRODUCTIOIN

According to Kartasapoetra (2005) erosion is the process of washing away the soil by the pressure or force of water and wind, either occurring naturally or as a result of human actions. According to (Lesmana *et al.*, 2020) argues that erosion is three successive processes, namely the release, transport, and deposition of soil materials by erosion (Mihi *et al*., 2020). The allocation of land from forest to agricultural land results in an increase in the value of land loss. Inappropriate land management also causes land loss (Eisenberg & Muvundja, 2020). At least cover crops can also increase the erosion value (Andriyani *et al*., 2019). The high value of erosion is also closely related to land use that is not in accordance with the power and ability of the land itself (Sidik, 2019).

A watershed is an area bounded by high points where water from falling rainwater collects in the area and then distributes it to the sea via the main river. The Serang Upper sub-watershed is one of the upstream areas of the Jratunseluna watershed which is one of the super-priority watersheds, administratively with the areas of Boyolali Regency and Semarang Regency, Central Java. The Serang Upper sub-watershed is at an elevation of 130-2400 masl and is located on the slopes of Mount Merbabu with diverse physiography with a slope of 8% to > 40%, consisting of highlands and mountains/hills, as well as lowlands. The Upper Serang Sub-watershed has rainfall ranging from 2500-3500 mm/year with soil types including: Alfisols, Histosols, Inceptisols.

The Serang Hulu sub-watershed is experiencing rapid changes in land use, especially for clearing gardens, fields and residential areas which continue to grow and even large -scale industrial buildings are built. Knowing that there are changes in land use that are carried out continuously and the geographical and climatic conditions in the Serang Hulu Sub-watershed are varied, there is the potential for erosion. Erosion also has an impact on the economy and the environment (Khairunnisa *et al*., 2020; Srinivasan *et al*., 2019). Soil erosion is a problem because it can affect soil productivity, agricultural land fertility, siltation in water bodies, and a decrease in water quality (Benavidez *et al*., 2018; Singh & Panda, 2017), as well as landslides occurred (Agustina & Dewi, 2020). Knowing the existence of these events, it is necessary to assess the potential for erosion in the Serang Hulu Sub-watershed area. One method that can be used to determine the amount of erosion is the Universal Soil Loss Equation (USLE) (Fan *et al*., 2021; Tsegaye *et al*., 2020). The USLE method developed by Wischmeir and Smith in 1978 is a method that is often used to determine the amount of erosion (Alie, 2015; Pamungkas, 2020). The USLE method can be used as a tool in predicting the average erosion over a long period of time from a farming area with a certain cropping system and land management (Lesmana *et al*., 2020).

The Serang Hulu sub-watershed has an area of about 8409.83 hectares with an agricultural land area of around 4102.71 hectares and to find out the spatial distribution or location of the magnitude of erosion that occurs can use the Geographic Information System (GIS). According to Aronoff (1989) GIS is a computer-based system that provides the ability to handle geographically referenced data including input, management, manipulation and analysis as well as data output. Utilizing GIS technology to evaluate erosion potential can determine, calculate, analyze, map and describe the physical condition of the area spatially more quickly. According to Prayitno *et al*. (2015) the USLE method combined with GIS is very efficient for calculating the level of erosion hazard in a large area. Therefore, an evaluation of the potential for erosion in the Upper Serang Sub-watershed is carried out using GIS technology to estimate the potential for soil erosion, determine the factors causing soil erosion, and prepare recommendations for appropriate treatment to reduce erosion hazards in order to increase soil productivity. The purpose of this study was to determine the magnitude of the erosion class and its distribution area in the Upper Serang Sub-watershed and to determine the dominant factors that influence the occurrence of erosion.

2. MATERIALS AND METHODS

The research was conducted in June – August 2021 in the Serang Upper sub-watershed which is spread out in the administrative area of Ampel District, Boyolali District and Tengaran District, Semarang Regency. The research materials used were composite soil samples, intact soil in iron rings, distilled water, $K_2Cr_2O_7$, H_2SO_4, Calgon solution. The research tools used are GPS for surveys, soil sampling equipment, laboratory test equipment such as permeability analysis tools, organic matter analysis tools, texture analysis tools, data analysis tools using ArcGIS 10.4.1 software and SPSS to analyze data correlations.

The research method uses quantitative and qualitative descriptive methods. According to Sugiyono (2013) combination of quantitative and qualitative descriptive is a method used to examine objects with data obtained in the form of numbers which then the data is described or translated in a sentence. The data used were annual rainfall data obtained in the last 10 years 2011-2020 in the Upper Serang Sub-watershed, soil type maps, DEM (Digital Elevation Model) maps to make slope maps, land use data and data from the interviews with farmers around Serang Upper sub-watershed area.

The analysis of erosion potential using the USLE empirical method developed by Wischemeier and Smith in 1978, where the erosion potential value is obtained from the multiplication of the values of the erosivity (*R*), erodibility (*K*), combination is the rasio of soil loss from a particular slope to reference slope (*LS*), cover management factor (*C*) and (*P*) is supporting practices factor. The use of the USLE method is very useful for providing recommendations and planning related to the agronomic sector because it can be used as a basis for land use selection and soil conservation measures aimed at reducing on-site effects of soil erosion.

Analysis of the tolerable erosion of the Upper Serang Sub-watershed using the Hammer formula Arsyad (2010). Tolerable erosion is not only used to maintain soil productivity but can also be used as a simulation of watershed management planning. The distribution of the erosion value and the erosion value is tolerated using spatial analysis with ArcGIS 10.4.1 software with the stages as shown in Figure 1.

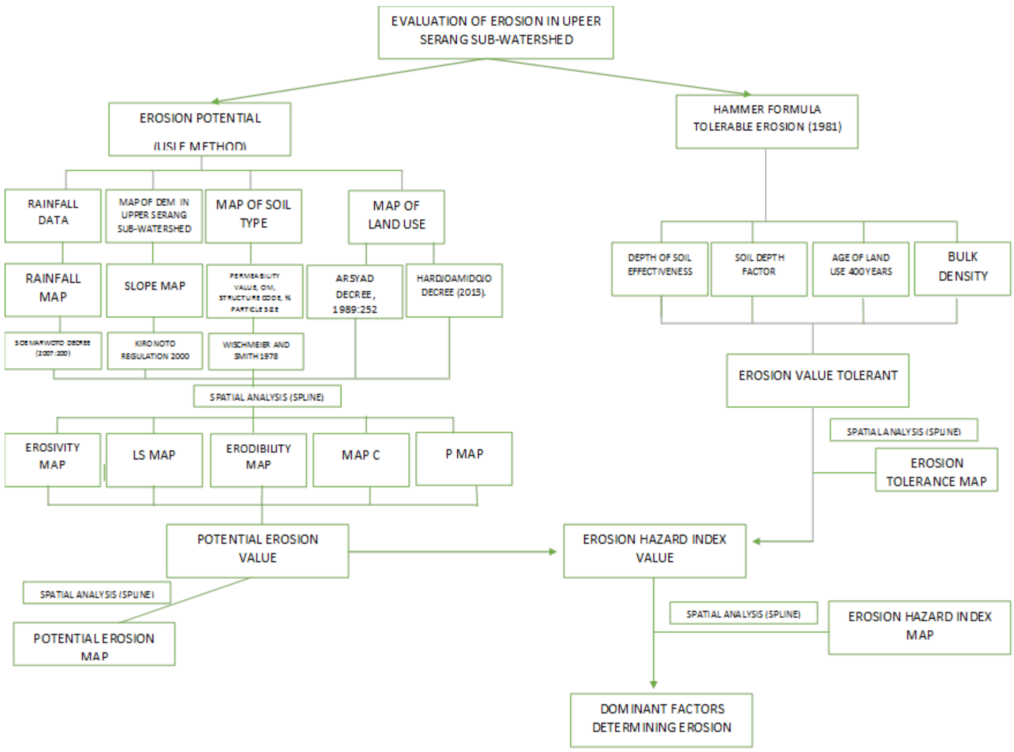

Figure 1. Data erosion analysis stage

Analysis of determining the dominant factor of erosion using Pearson Correlation analysis which results in the Pearson correlation classed based on Sugiyono (2010). Correlation analysis using SPSS version 20 software, with the variables used are erosivity (*R*), erodibility (*K*), slope length/slope (*LS*), and land cover/conservation directions (*CP*) in the Serang Upper Sub-watershed area.

3. RESULTS AND DISCUSSION

3.1. Erosion Potential in Serang Upper Sub-watershed

3.1.1. Rain Erosivity Index (R)

Rain is an important contributor to erosion (Liu *et al*., 2018), because it can produce kinetic energy to the soil which can break down soil aggregates, rain can also produce surface runoff by eroding the soil through which the stream flows. The raindrops can cause soil particles to splash in to the air which then fall back to the ground surface due to the earth's gravity and some fine particles that cover the soil pores. Erosivity data in this study was obtained from rainfall data for the past 10 years in the area around the Upper Serang Sub-watershed and then calculated using the Soemarwoto (2007) formula, namely *R* = 0.41x *H* 1.09, where *H* is the result of the average annual rainfall in an area. In the Serang Upper Sub-Watershed has two *H* values, namely 2500-3000 mm/y and 3000-3500 mm/y. The results of rainfall erosivity in the Serang Upper Sub-watershed have a medium category with an *R* value of 1228.98 mm/month and a high category with an R value of 1452.43 mm/month, as for the regional distribution of the rain erosivity value (*R*) can be seen in Table 1.

Table 1. Rain erosivity value of upper Serang Sub-watershed

Rainfall (mm/ month)	R Value	Category	Area (ha)	Region
2500 - 3000	1228.98	Medium	3402.84	Candisari, Ngargoloka, Sampetan, Ngadirojo, Jlarem, Patemon, Kembang, Butuh, Ngagrong, Tegalrejo,
3000 - 3500	1452.43	High	3398.44	Kali Gentong, Jlarem, Kembang, Tegalrejo, Sruwen, Cukil, Kembang, Patemon, Butuh, Ngadirojo, Karangduren, Gondang Slamet, Candi, Urut Sewu, Ngampon, Sugihan, Cukil, Regunung, Klero,Tengaran, Tegalwaton, Duren, Barukan,

Source: The value of *R* is based on the formula from Soemarwoto (2007).

The high value of erosivity will have a major effect on the crushing power of soil aggregates and surface runoff. The higher the erosion value of rain, the stronger the ability of rainwater to destroy soil aggregates. The falling rain will fill the macro pore space as a result the infiltration rate will be hampered, and surface runoff will increase (Widianto & Damen, 2014). However, high erosivity values do not necessarily cause high erosion if it occurs on land that has low erodibility values or is located on land with gentle slopes and in areas that have good land management. However, high erosivity values can be minimized by covering the soil surface, so the soil flooded by rainwater does not diminish too quickly.

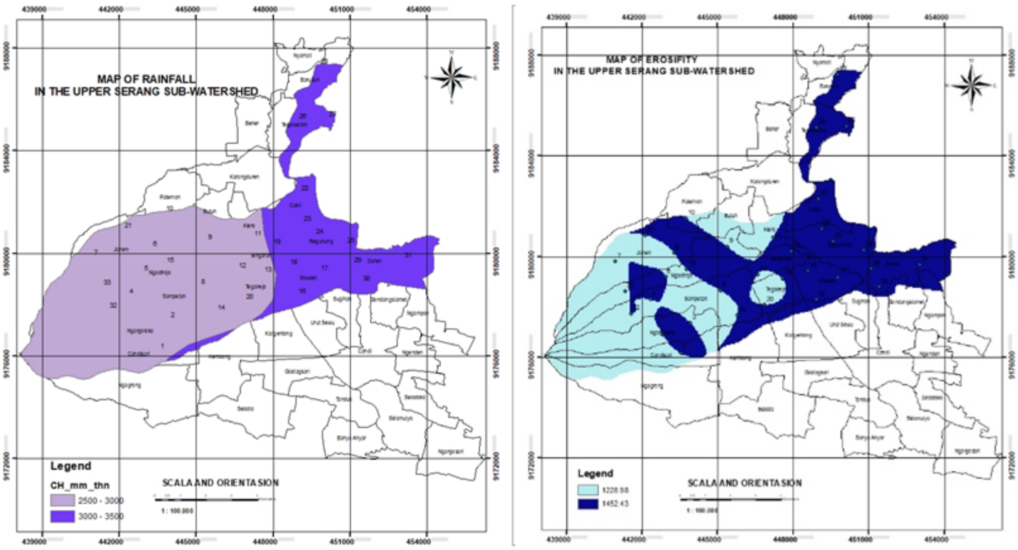

Figure 2. Rainfall and rain erosivity (R) map of upper Serang Sub-watershed

3.3.2. Soil Erodibility (K)

Soil erodibility value shows the ability/resistance of soil particles to peeling and removal of soil due to the kinetic energy of rain. The value of soil erodibility (*K*) can be calculated using the formula developed by Wischmeier & Smith (1978), i,e :

$$K = \frac{\{2.71M^{1.14} - (10^{-4})(12 - OM) + 4.20(s-2) + 3.23(p-3)}{100} \quad (1)$$

where : *K* is Soil erodibility, *OM* is percentage of organic matter, *s* is soil structure code, *p* is soil sectional permeability class code, and *M* is percentage of soil texture class.

The basic data used are the percentage of organic matter, soil structure, soil cross-sectional permeability class and the percentage of particle size. The value of soil erodibility in the Upper Serang Sub-watershed is shown in Table 3.

Table 2. Soil erodibility (*K*) value of upper Serang Sub-watershed

K value	Class	Category	Area (ha)	Region
0.0774 – 0.0980	1	Very low	12.98	Cukil, Karangduren.
0.1320 – 0.2124	2	Low	600.16	Duren, Cukil, Karangduren, Klero, Regunung, Sruwen, Sugihan, Karangduren, Patemon, Butuh, Gondang Slamet, Candi, Kembang, Sampetan, Candisari, Ngargoloka, Ngagrong.
0.2183 – 0.3220	3	Medium	4074.77	Duren, Gondangslamet, Duren, Sugihan, Tegalrejo, Regunung, Butuh, Cukil, Sruwen, Karangduren, Klero, Tegalwaton, Tengaran, Patemon, Kaligentong, Urut Sewu, Jlarem, Kembang, Ngadirojo, Ngargoloka, Candisari, Ngagrong, Sampetan.
0.3317 – 0.4077	4	Slightly High	1807.63	Duren, Gondang Slamet, Duren, Tegalwaton, Regunung, Tegalrejo, Sruwen, Barukan, Tengaran, Butuh, Ngampon, Jlarem, Ngadirojo, Sampetan, Urut Sewu, Kembang,
0.4393 – 0.5369	5	High	298.71	Duren, Gondangslamet, Duren, Barukan , tegalwaton, Ngampon, Ngadirojo, Jlarem,

Based on Table 2 The level of soil erodibility ranges from very low to high. The high value of soil erodibility indicates that the soil is more prone to erosion. The high and low value of soil erodibility in an area is influenced by several factors, such as soil texture (clay, loamy loam, sandy loam, clay loam, dusty loam, sandy loam, large loam, and medium loam), where the soil has a low percentage of clay, but has a high percentage of sand and silt. Based on research by Morgan & Rickson (2005), the higher the erodibility, the greater the ability of the soil to erode. Soil with high erodibility will be sensitive to erosion compared to low erodibility soil which has strong resistance to erosion.

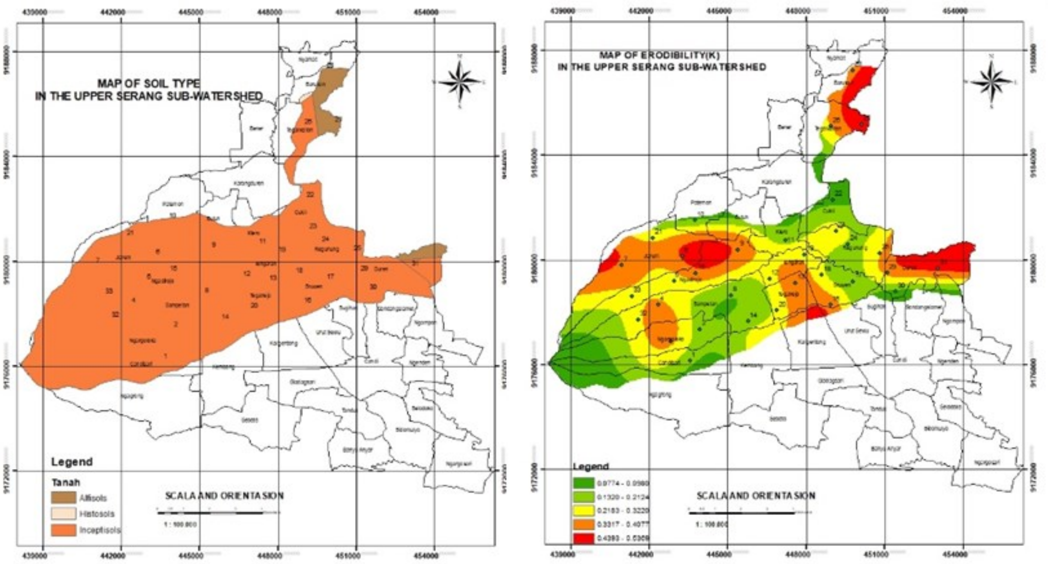

Figure 3. Map of soil types and erodibility (*K*) of upper Serang Sub-watershed

3.1.3. Land Length and Slope Factor (LS)

Determination of the value of land length and slope (*LS*) used secondary data in the form of a slope map of the Serang Upper Sub-watershed which was then converted to the *LS* value based on the provisions of the Ministry of Forestry developed by Kironoto (2000) as shown in Table 3.

Table 3. *LS* value based on Kironoto (2000)

Slope Class	Slope	*LS* value
1	0-8	0.40
2	8-15	1.40
3	15-25	3.10
4	25-40	6.80
5	>40	9.50

Based on the slope data in Table 4, the Serang Hulu Sub-watershed area has LS values with varied categories, from very low to very high categories. The slope and length of the slope are two topographical properties that greatly affect surface runoff and erosion (Arsyad, 2010). Slope factors consist of different slope shapes (convergent, parallel, and divergent) and different curvatures (straight, concave, and convex)

(Sabzevari & Talebi, 2019). The longer the slope, the more volume of soil that is carried away by runoff and the steeper the slope, the faster the runoff transports the soil. Soil loss can be caused by long steep slopes and damaged vegetation cover (El-Jazouli *et al*., 2017).

Table 4. LS value of Serang upper Sub-watershed

Slope Value	Class category	*LS* value	Area (ha)	Region
< 8%	Very Low	0.40	0.17	Ngadirojo.
8 – 15 %	Low	1.40	3243.80	Gondangslamet, Kaligentong, Ngampon, Ngargoloka, Urutsewu, Candisari, Jlarem, Kembang, Ngadirojo, Sampetan,Sugihan, Tegalrejo, Patemon, Barukan, Regunung, Butuh, Cukil, Duren, Sruwen Karangduren,Klero, Tegalwaton, Jlarem, Kembang, Tengaran,
15 – 25 %	Medium	3.10	1347.81	Gondangslamet, Ngampon, Ngargoloka, Candi, Candisari, Jlarem, Kembang, Ngadirojo, Sampetan, Sugihan, Patemon, Regunung, Duren, Sruwen, Kembang,.
25 – 40 %	high	6.80	1821.35	Ngargoloka, candisari, Jlarem, Ngadirijo, Ngagrong, Sampetan, Candisari, Jlarem, Ngadirojo, Ngagrong,
> 40%	Very high	9.50	387.81	Ngadirojo, Sampetan, Ngargoloka, Jlarem, Ngargoloka.

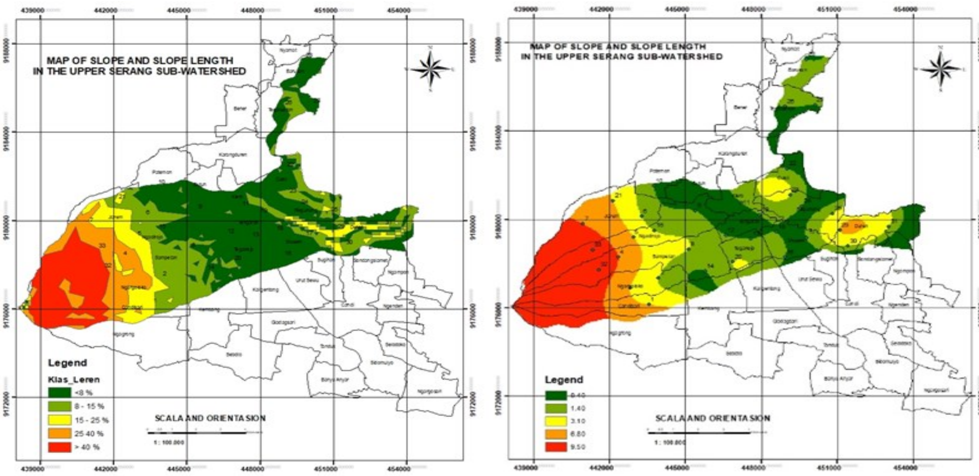

Figure 4. Map of slope and slope length (LS) of Serang upper Sub-watershed

3.1.4. Plant Management Factor (C)

The value of plant management Factor (C) is obtained from secondary data from land use maps which are then ascertained by conditions in the field, the more intensive protection to soil conditions by plants, the lower the erosion that occurs. The Ministry of Forestry in 2006 had categorized the C value from types of crop management or land use as shown in Tabel 5 (Arsyad, 1989). Based on the conversion data of crop management types, the value of crop management in the Upper Serang Sub-watershed is shown in table 6. Based on Table 6, the value of the C factor of paddy fields, gardens and dry fields obtains a varied value because the plants that are cultivated in each region are different. Vegetation is very crucial in the value of erosion, the canopy of vegetation is very good at reducing the amount of rain crushing power while the roots and stems of vegetation can help bind soil and water, thereby reducing the rate of erosion (Munandar & Jayanti, 2016). Based on the research of Bhan & Behera (2014) vegetation has a great influence on erosion because vegetation blocks rainwater from falling directly on the ground surface, so that the power to destroy the soil can be reduced. it is also necessary to consider the height and the density of the canopy that affects the intensity of rain drops on the ground. In addition, plant roots play a very important role in stabilizing aggregates and increasing soil porosity. Lack of cover crops can also increase erosion rates (Andriyani *et al*., 2019).

Table 5. The value of factor *C* for several crop management

Types of crop management	Annual *C* value
Open land without plants	1
Natural forest	0,001
Production forest	0,5
Shrubs/grasslands	0,3
Plantation / mixed garden	0,2
Moor (not specified)	0,7
Meadow	0,02
Cassava	0,8
Corn	0,7
Soya bean	0,399
Potato	0,4
Peanuts	0,2
Sugarcane	0,2
Banana	0,6
Pure reed	0,001
Tobacco	0,7

Table 6. The value of crop management of upstream Serang Sub-watershed

Land Use	*C* Value	Area (ha)	Region
Ricefield	0.01	0.328	Sruwen, Regunung, Tegalwaton, Duren
Garden	0.2	1908.49	Ngargoloka, Patemon, Klero, Sruwen, Tengaran, Jlarem, Cukil, Regunung, Tegalwaton, Barukan, Duren
Moor	0.7	3224.69	Candisari, Ngargoloka, Sampetan, Ngadirojo, Jlarem, Tengaran, Tegalrejo,
Shrubs	0.7	304.0	Jlarem, Sampetan, Duren, Candi, Ngadirojo, Ngagrong
Meadow	0.7	211.89	Jlarem, Sampetan, Naggrong, Candisari, Patemon, Regunung, Kali Gentong
Settlement	0.2	1152.70	Candosari, Tegalwaton, Ngadirojo, Sampetan, Jlarem, Ngadiroto , Regunung, Urut Sewu, Cukil, Tengaran, Cukil, Duren

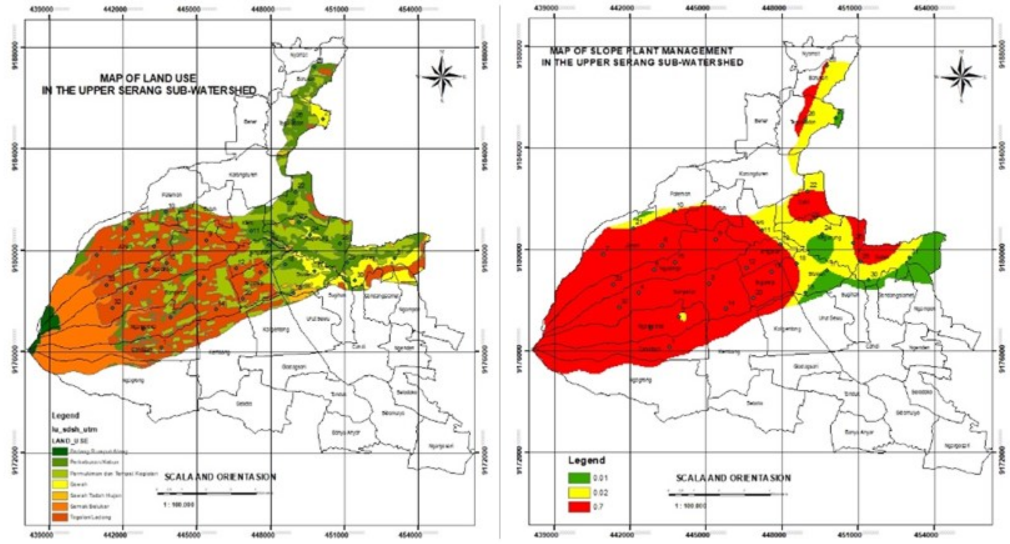

Figure 5. Map of Land Use and Plant Management of Upper Serang Sub-watershed

3.1.5. Land Management Factor (P)

Land management factors in erosion are highly dependent on human activities where the amount of soil loss can be minimized by good land management or conservation treatment. The high and low values of erosion are caused by the different land management and soil conservation based on the slope (Handayani *et al*., 2006). Changes in land use/cover and erosivity of rainfall runoff have a significant influence on soil erosion (Fu *et al*., 2021). The value of land management (*P*) can be obtained by using topographic map converted to slope data categorized by Arsyad (1989) as presented in Table 7. Based on the conversion data of slope, the value of land management in the Upper Serang Sub-watershed is shown in Table 8.

Table 7. Value for *P* based on Arsyad (1989)

Conservation Measures	*P* value
Slope 0-8%	0.50
Slope 9-20%	0,75
Slope >20	0,90

Table 8. The value of land management in the upper Serang Sub-watershed

P value	Area (ha)	Region
0.5	0.33	Tegalrejo
0.75	3726.16	Gondangslamet, Kaligentong, Ngampon, Ngargoloka, Urut Sewu, Candi, Candisari, Jlarem, Kembang, Ngadirojo, Sampetan, Sugihan, Tegalrejo, Patemon, Barukan, Regunung, Butuh, Cukil, Duren, Sruwen, Karangduren, Klero, Tegalwaton,
0.9	3074.51	Ngargoloka, Candisari, Jlarem, Ngadirojo, Sampetan, Regunung, Sugihan, Duren, Sruwen,

Based on Table 6 Land in the Serang Hulu Sub-watershed area has different management based on the slope and its use so that the P value obtained also varies. The more intensive the agricultural pattern and the higher the slope, the more intensive land management will be. Vice versa, if in managing the land in the wrong way, it can cause the intensity of erosion to increase. Intensive cultivation activities and climate change can cause an increase in soil erosion (Djoukbala *et al*., 2019; Zhang *et al*., 2019). For example, forest clearing, forest allocation into industrial or residential areas. Land management in the Serang Hulu Sub-watershed area varies from terracing, to intercropping based on the slope of the land (Figure 5).

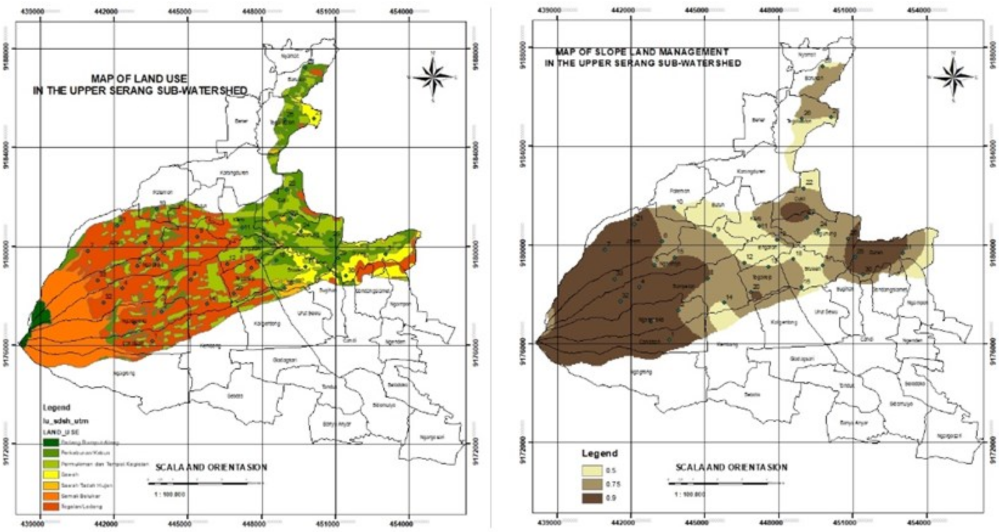

Figure 5. Map of land use and land management in the upper Serang Sub-watershed

3.1.6. Erosion Potential (A) in the Upper Serang Sub-watershed

According to Suripin (2001), the erosion hazard is categorized in 5 classes, as shown in Table 9. The amount of erosion potential (*A*) in the Upper Serang Sub-Watershed which is the result from the multiplication of the *R*, *K*, *LS*, *CP* data, are shown in Table 10. Calculation of the erosion hazard level by comparing the predicted erosion results (*A*) with the tolerable erosion (*TE*).

Table 9. Class erosion category according to Suripin (2001)

Erosion Hazard Class	Erosion Rate (ton·ha·y)	Category
I	<15	Very light
II	15-60	Light
III	60-180	Medium
IV	180-480	Heavy
V	>480	Very heavy

Erosion can cause loss of nutrients that plants need to grow and thrive. Sudirman *et al*. (1986) stated that the loss of topsoil could result in a decrease in organic matter content, an increase in soil compaction, a decrease in the stability of soil aggregates, a high aluminum saturation value and a decrease in soil CEC. This can reduce the quality of the soil which in turn decreases the productivity of the soil.

Erosion that occurs in the Upper Serang Sub-watershed area has a value of very light to very heavy which is dominated by heavy to very heavy erosion in the upstream part. The contributing factors are less dense land cover, steep slopes, and high erodibility values.

Table 10. Erosion value in the upper Serang Sub-watershed

A (t·ha^{-1}·y^{-1})	Category	Area (Ha)	Percentage	Region
0.5 – 10.11	Very light	1608,49	23,72 %	Gondangslamet, Ngampon, Ngargoloka, Urutsewu, Candi, Candisari, Jlarem, Kembang, Ngadirojo, Sampetan, Sugihan, Tegalrejo, Patemon, Barukan, Regunung, Butuh, Cukil Duren, Sruwen, Karangduren, Tegalwaton, Tengaran.
15.26 – 48.52	Light	861,57	12,70 %	Gondangslamet, Kaligentong, Ngargoloka, Urutsewu, Candisari, Jlarem, Kembang, Ngadirojo, Sampetan, Sugihan, Tegalrejo, Patemon, Barukan, Regunug, Butuh, Cukil, Duren, Sruwen, Karangduren, Klero, Tegalwaton, Tengaran
70.55 – 164.51	Medium	1142,12	16,84 %	Gondangslamet, Kaligentong, Ngargoloka, Urutsewu, Candisari, Klarem, Kembang, Ngadirojo, Sampetan, Sugihan, Tegalrejo , Patemon, Regunung, Butuh, Cukil, Duren, Sruwen, Karangduren, Klero,Tengaran.
208.95 – 388.41	Heavy	1033,29	15,24 %	Kaligentong, Ngargoloka, Candisari, Jlarem, Kembang, Ngadirijo, Sampetan, Tegalrejo, Patemon, Regunung, Butuh, Duren.
697.47 – 2241.14	Very heavy	2134,50	31,48 %	Ngargoloka, Candisari, Jlarem, Ngadirojo, Ngagrong, Sampetan.

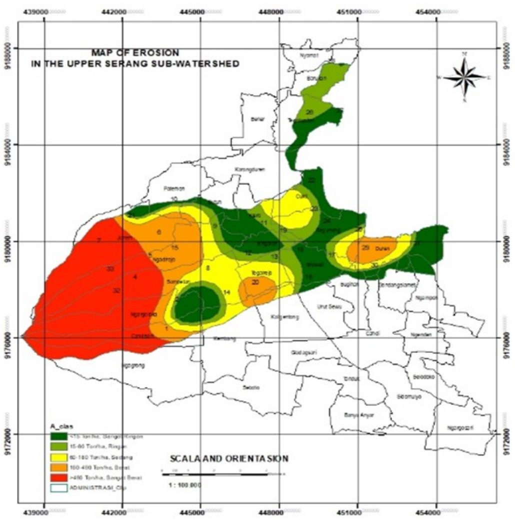

Figure 7. Erosion map in Serang Upper Sub-watershed

3.2. Tolerable Value Soil Erosion Potential in the Upper Serang Sub-watershed.

Erosion in general cannot be eliminated up to zero, but erosion can be prevented or reduced or there is still erosion but with the value or limit of the allowable erosion estimation number. Tolerable erosion is the estimated amount of erosion that can still be tolerated and does not interfere with productivity. The value of tolerable soil in the Upper Serang Sub-watershed is shown in Table 11.

Table 11. The Upper Serang Sub-Watershed Tolerable Erosion (ET) Rate

TE class	*TE* ($t{\cdot}ha^{-1}{\cdot}y^{-1}$)	Area (Ha)	Percentage	Region
Low	12-60	4570,89	67,20 %	Cukil, Karangduren, Jlarem, Ngadirojo, Gondangslamet, Kaligentong, Ngampon, Ngargoloka, Urutsewu, Candi, Candisari, Jlarem, Kembang , Ngadirpjp, Ngagring, Sampetan, Sugihan, tegalrejo, Patemon, Barukan, Regunung, Butuh, Cukil, Duren, Sruwen, karangduren, Klero, Tegalwaton, Tengaran.
High	60-300	2230.39	32.80 %	Kaligentong, Candisari, Jlarem, Kembang, Sampetan, Tegalrejo, Butuh, Klero, Gondangslamet, Sugihan, Regunung, Cukil, Duren, Sruwen, Karangduren,

In Indonesia, there are various methods for determining the amount of erosion potential that can be tolerated. The value of tolerable erosion is calculated using the formula developed by Hammer (1981):

$$TE = \frac{DE \times fd}{t} \times Bulk\ density \times 10 \qquad (2)$$

where *TE* is tolerable erosion, *DE* is effective depth of soil, *fd* is depth factor of the sub-order of soil, and *T* is useful life of soil (300-400 years)

Based on Table 11, The Serang Upper Sub-watershed area has different tolerable erosion values for each location. The calculation of tolerable erosion is not only intended to maintain soil productivity, but can also aim to control the rate of siltation of reservoirs, or to anticipate pollution of river water quality which is often used for public consumption.

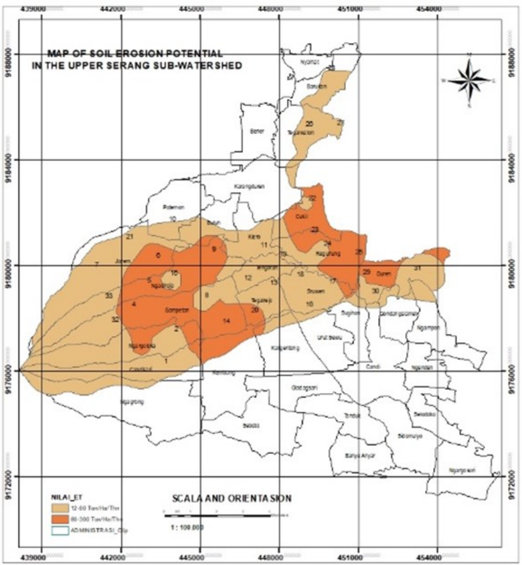

Figure 8. Tolerable erosion map

The results of the erosion analysis using the USLE method are then divided by the results of the tolerable erosion to obtain the value of the Erosion Hazard Index (*EHI*). The calculation results are as shown in Table 12.

Table 12. Erosion Hazard Index (*EHI*) scores in Serang Upper sub-watershed

EHI score	EHI class	Area (ha)	Percentage	Regions
0.81 – 0.17	Low	2537.61	37.31 %	Ngargoloka, Candisari, Kembang, Sampetan, Gondangslamet, Kaligentong, Ngampon,, Urutsewu, Candi, Jlarem, Ngadirojo, Sugihan, Tegalrejo, Patemon, Barukan, Regunung, Butuh, Cukil, Duren, Sruwen, Karangduren, Klero, Tegalwaton, Tengaran.
1.01 – 3.26	Medium	1548.37	22.76%	Barukan, tegalwaton, Regunung, Cukil, Gondangslamet, Sugihan, Duren, Sruwen, Kaligentong, Ngargoloka, Urutsewu, CAndisari, Jlarem, Kembang, Ngadirojo, Sampetan, Tegalrejo, Patemon, Butuh, Sruwen, Tengaran.
5.34 – 9.69	High	724.39	10.65 %	Regunung, Duren, Ngagrogoloka, Candisari, Jlarem, Ngadirojo, Sampetan
13. 57 – 57.54	Very high	1990.92	29.27 %	Ngargoloka, Candisari, Jlarem, Ngadirojo, Ngagrong, Sampetan.

Based on Table 12, the value of *A* is compared with the value of the tolerable erosion (*TE*), if the value of *A* < *TE* then the management of soil and water conservation in general, both plants and conservation techniques in the Serang Upper Sub-watershed area is good. If *A* > *TE* the management of plants and soil in the Sub-watershed is not good and the management of conservation techniques is not good, so that conservation improvements are needed in the Serang Upper Sub-watershed area.

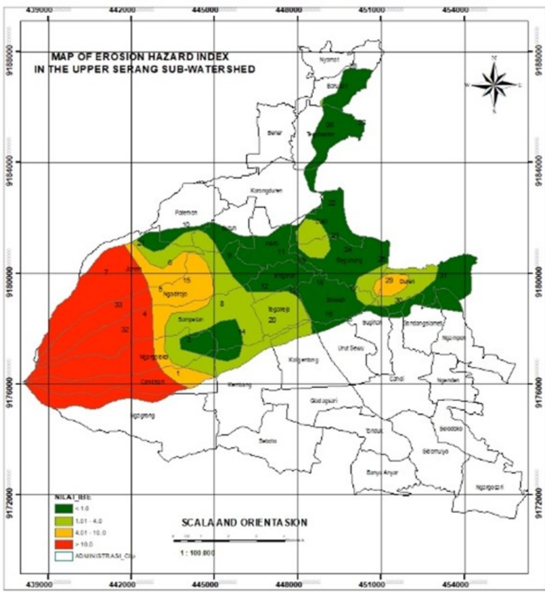

Figure 9. Erosion Hazard Index (EHI) Map

3.3. Dominant Erosion Factors in the Upper Serang Sub-watershed

The analysis used to determine the dominant parameter affecting the erosion value using the Pearson Correlation method which calculated the closeness of the relationship. The level of the correlation coefficient closeness class is based on the closeness coefficient class stated by Sugiyono (2010), namely the value of 0.00 – 0.1999 very low, 0.20 – 0.399 low, 0.40 – 0.5999 moderate, 0.60 – 0, 7999 Strong and 0.80 – 1.00 very strong. Based on table 3.7, the factor that has a very strong relationship with the magnitude of soil erosion is the LS factor (Length and slope) with a closeness coefficient of 0.935. Category is very strong. This is also stated by Triwanto (2012) that the dominant factors affect erosion are the length and slope of the land, where these factors affect the speed and volume of surface water to the extent that surface runoff water enters the channels (rivers) or the flow has decreased due to changes in slope (flat) so that the velocity and volume are scattered in various directions.

Table 13. Erosion parameter relationship closeness value

Parameter	Pearson Correlation	Closeness Criteria
Rain Erosivity	-0.445	Very low
Soil Erodibility	0.089	Very low
Length and Slope	0.935	Very strong
Plant management	0.550	Medium
Land Management	0.652	Strong

4. CONCLUSION

Based on the research results, the Upper Serang Sub-watershed has 5 erosion class categories, namely very light class (0.5-10.11 $t \cdot ha^{-1} \cdot y^{-1}$) which has an area of 1608.49 ha or 23.72% of the total area. Light grade (15.26-48.52 $t \cdot ha^{-1} \cdot y^{-1}$) which has an area of 861.57 ha or 12.70% of the total area. Medium class (70.55-164.51 $t \cdot ha^{-1} \cdot y^{-1}$) which has an area of 1142.12 ha or 16.84% of the total area. Heavy class (208.95 – 388.41 $t \cdot ha^{-1} \cdot y^{-1}$) which has an area of 1033.29 ha or 15.24% of the total area. Very heavy class (697.47 – 2241.14 $t \cdot ha^{-1} \cdot y^{-1}$) which has an area of 2134.50 ha or 31.48% of the total area. While the Erosion Hazard Index (*EHI*) is divided into 4 classes, namely low class with a *EHI* score of < 1 which has an area of 2537.61 ha or 37.31% of the total area. Medium class with a *EHI* score of 1.001 – 4.00 which has an area of 1548.37 ha or 22.76% of the total area. High class with a value of 4.01 – 10.0 which has an area of 724.39 ha or 10.65% of the total area. Very high grade with a score of > 10 which has an area of 1990.92 ha or 29.27% of the total area. The dominant factor influencing the high and low erosion value is the slope factor and the length of the slope at the location of the Upper Serang Sub-watershed based on the closeness value with a value of 0.935 with a very strong closeness class.

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