

Determination of the most dominant cause factors due to erosion in the farmland of Sibolangit sub-district

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Abstract. Solving erosion problems is often inefficient and effective because of lack a deep understanding of the most dominant causal factors. It really depends on how the results of our research of the factors that influence and relate to each other. Erodibility, slope and crop management are three factors that influence the amount of erosion. Each of these factors has a different index value indicating differences in the magnitude of the effect on erosion. The erosion model designed to predict long-term erosion is the USLE Method. The formula for the USLE equation is as follows: $A = R.K.L.S.C.P$ where A=the amount of eroded soil in $\text{tonsha}^{-1} \text{ year}^{-1}$; R=rainfall factor; K=soil erodibility factor; L= slope length factor; S=slope factor; C=crop management factors; P=soil conservation factor. The statistical analysis used to answer the most dominant factor is multiple linear regression analysis. The results of this research showed that the highest erosion was 11,302.79 $\text{tons ha}^{-1} \text{ year}^{-1}$ in SPT-24, followed by SPT-5 of 3192.88 $\text{tons ha}^{-1} \text{ year}^{-1}$ and SPT-25 of 2408.33 $\text{tonsha}^{-1} \text{ year}^{-1}$ while the lowest erosion on SPT-26 is 21.06 $\text{tons ha}^{-1} \text{ year}^{-1}$. Based on the analysis results obtained the most dominant factor is soil erodibility with a coefficient of determination (R^2) of 61.4% so that the focus on erosion handling offarmland in Sibolangit Sub-District is minimum and contour tillage, optimize use of green manure and compost, land cover with plant litter. All of the aim is to improve each factor that affects erodibility, namely texture, structure, permeability and soil organic matter.

1. Introduction

Sibolangit is one of the sub-districts in Deli Serdang Districts. This area is dominated by steep topography to very steep with altitude of 350 - 700 meters above sea level. The area of Sibolangit Sub-District is 173.32 km^2 (BPS Sibolangit Sub-District, 2018). Most of the people's livelihoods are farming, but their farmland is generally vulnerable to erosion due to unstable soil, steepness topography and inadequate of crop management. Soil erosion refers to the wearing away of a field's topsoil. Nutrients and organic matter that are important for plants have lost of the farmland. Arsyad (2010) explains that the loss of one or several nutrients from the region of the roots causes decreasing of soil fertility, so that the soil is

unable to provide sufficient and balanced nutrients to support normal plant growth. As a result the productivity of the soil becomes very low.

There are three factors that influence the magnitude of erosion that occurs on farmland in Sibolangit Sub-District, namely the factors of soil erodibility (the ability of soil from destroyed by rainfall or run off that causes erosion), slope and crop management. These three factors together and partially influence the magnitude of erosion. However, each factor has different effects on erosion. Hardjowigeno (2010) suggests that soil sensitivity to erosion (soil erodibility) is influenced by soil texture, organic matter, structure, and soil permeability. The higher the erodibility value of the soil, the more resistant to erosion. The next factor is the steepness of the slope. Arsyad (1989) explains that aside from increasing the amount of run off, the steeper the slope also increases speed of the run off, thereby increasing the energy of water. In addition, with the slope steepness increasing, the amount of soil granules splashed down by the impact of raindrops is increasing. The last is crop management factors, according to Asdak (2004), crop management factors show all influence of vegetation, litter, soil surface conditions, and land management on erosion. The amount of erosion is determined by the intensity and form of land and crop management activities, so the estimated amount of erosion due to land management activities is necessary.

These three factors essentially have a big role, but this research needs to find out what factors most influence the magnitude of erosion that occurs at the study site. By knowing the most dominant factors it will improve the quality of solving erosion problems. This is due to the handling of erosion problems based on priority which is very urgent considering the high cost of implementing soil conservation so that ultimately an efficient and effective solution.

2. Methodology

2.1. Research Description

The tools used in soil survey and soil sampling are soil auger, Abney level, GPS (Global Positioning System), tape rule (metric scale), ring sample, etc. Soil sample taken from the location of the research that has been determined based on the Land Map Unit called SPT in this research, various maps (Rupa Bumi Indonesia Map on a 1: 25,000 scale map, Topographic Map on a 1: 25,000 scale map, Slope Map on a 1: 25,000 scale map and Soil Types Map on a 1: 25,000 scale map and chemicals used in the laboratory.

2.2. Data Required

Primary data in the form of soil physical and chemical properties were obtained from soil surveys and observations and the results of laboratory analysis at the Laboratory of Soil Research Institute (Balittanah), Bogor and the PPKS RISPA Chemical and Physical Laboratory, Medan. Secondary data in the form of climate data were obtained from the Meteorology, Climatology and Geophysics Agency (BMKG), Sampali Medan, various maps were obtained from the BP Wampu Sei Ular Watershed (BP DAS Wampu).

2.3. Implementation of Research

The research implementation consists of two stages. The first stage is the determination of the SPT. Determining the location of sampling points is based on SPT resulting from overlapping several maps (overlay), namely making a Basic Map of the location on a 1: 25,000 scale map. After the SPT is determined on the Basic Map, soil sampling is carried out at each SPT at the research location. The method of soil sampling is Stratified Random Sampling and the number of soil samples taken for the purpose of analyzing the physical and

chemical properties of the soil is adjusted to the number of SPT (17 SPT). Then, soil samples are taken to the laboratory for analysis. The next stage is erosion prediction. Prediction of erosion is based on the approach stated in The Universal Soil Loss Equation (USLE). All of the data obtained from variables that affect erosion are processed using the USLE equation so that it can be estimated the amount of erosion that occurs at the study site.

2.4. Research Data Analysis

Analysis of erosion prediction data used in this study is the Universal Soil Loss Equation (USLE) method. The USLE equation is as follows: $A = R.K.L.S.C.P$ where A = the amount of soil eroded in $\text{tons ha}^{-1} \text{ year}^{-1}$; R = rainfall and surface flow factors; K = soil erodibility factor; L=slope length factor; S=slopesteeptness factor; C=crop management factors; P=specific factors of soil conservation measures (Arsyad, 2010). The statistical analysis used to answer the most dominant factor is multiple linear regression analysis. In mathematics multiple regression analysis is formulated as follows (Trianto, 2016): $Y = a + b_1X_1 + b_2X_2 + \dots + b_nX_n + e$, where Y = independent variable; a = constant; X_1 = first independent variable; X_2 = second independent variable; X_n = n^{th} independent variable; e=disturbing variable. The dependent variable is the amount of erosion,while the independent variables are erodibility, slope, and crop management.

3. Results and Discussion

Based on the results of the study, Table 1 shows that the highest erosion that occurred in the farmland of Sibolangit Sub-District was $11,302.79 \text{ tons ha}^{-1} \text{ year}^{-1}$ on SPT-24, followed by SPT-5 of $3192.88 \text{ tons ha}^{-1} \text{ year}^{-1}$ and SPT- 25 amounting to $2408.33 \text{ tons ha}^{-1} \text{ year}^{-1}$ while the lowest erosion was at SPT-26 which was equal to $21.06 \text{ tons ha}^{-1} \text{ year}^{-1}$.

One of the effects of erosion in thefarmland of Sibolangit Sub-District is the appearance of the rocks on the soil surface that directly harm to the farmers because in addition to eroding the soil surface layer which is a source of mineral nutrients, organic matter and living sites of microflora and soil microfauna, it also reduces the total area of planting of farmers as shown in Figure 1. Sitorus et al. (2010) explain that erosion causes erosion of soil in the soil surface layer so that finally it will cause the appearance of rocks on the surface. This phenomenon occurs because of the topsoil has been lost. This will affect land use and crop management. In addition, soil tillagerequires excessive energy. The more percentage of rock on the soil surface shows the more critical land conditions.



Figure 1. The appearance of the rocks on the soil surface as an indicator critical land due to erosion in Sibolangit Sub-District.

Table 1. Value of Erodibility, Slope, Crop Management and Erosion

SPT	Erodibility * (X1)	Slope** (X2)	Crop Management ** (X3)	Erosion Prediction* (Y)
SPT - 1	0,56	4,25	0,1	527,71
SPT - 4	0,48	1,20	0,5	638,58
SPT - 5	0,5	12,0	0,2	3192,88
SPT - 8	0,56	0,25	0,7	144,86
SPT - 9	0,19	1,20	0,5	134,81
SPT - 10	0,13	12,0	0,1	415,07
SPT - 13	0,26	1,20	0,2	138,36
SPT - 18	0,34	1,20	0,7	633,25
SPT - 20	0,31	4,25	0,5	1460,63
SPT - 21	0,14	9,50	0,2	707,75
SPT - 22	0,45	0,25	0,7	116,41
SPT - 23	0,52	1,20	0,7	645,67
SPT - 24	0,59	12,0	0,6	11302,79
SPT - 25	0,35	9,50	0,7	2408,33
SPT - 26	0,57	0,25	0,1	21,06
SPT - 27	0,65	1,20	0,1	115,3
SPT - 28	0,48	12,0	0,1	1532,58

Information :

* Results of data processing; ** Soil surveys and observations

The phenomenon of erosion that occurs on this farmland, often involves two or more variables (influential factors) that are correlation with each other. This correlation can be investigated by multiple regression statistical analysis.

Table 2. Table of ANOVA

Model	Sum of squares	Degree of freedom (df)	Mean Square	F	Significance
Regression	71410832,59	3	23803610,86	6,905	0,005
Residual	44814393,5	13	3447261,038		
Total	116225226,1	16			

Source: Results of processing statistical analysis data (2019)

In Table 2, Anova Table produces sig = 0.005 or F calculate ($F_{cal.}$) is greater than F table so it can be concluded that the independent variables (X1, X2 and X3) simultaneously (together) have a significant effect on the dependent variable (\hat{Y}). This means that the erodibility factor (X1), slope (X2) and crop management (X3) together affect the magnitude of erosion. This can be proven in SPT-21 where erodibility is 0.14 (classified as low) on slope of 40% (classified as steep) with crop management i.e mixed garden with medium density (value C= 0.20) is very heavy erosion namely amounting to 707.75 tons ha⁻¹ year⁻¹ while the opposite in SPT-26 with erodibility of 0.57 (classified as very high) on the slope of 4% with the management of high density mixed garden plants (C=0.10) then the erosion there is a medium which is only 21.06 tons ha⁻¹ year⁻¹. This phenomenon is suitable with the opinion of Arsyad (1989) who explained that a land with low sensitivity might heavy erosion which

means if the farmland is located on steep slope. Conversely, the soil that has a high erosion sensitivity, may show light erosion if there is a low steepness.

Table 3. Coefficient, Significance and Coefficient of Determination.

Model	coefficients	Significance	Coefficient of correlation (r)	Coefficient of determination (R ²)
Erosion (Y)	-5034,822	0,011	0,784	0,614
Soil Erodibility (X1)	6565,675	0,041		
Slope (X2)	417,314	0,001		
Plant Management (X3)	4241,524	0,041		

Source: Results of processing statistical analysis data (2019)

Based on the results of multiple linear regression statistical analysis (Table 3), the linear regression equation is as follows: $\hat{Y} = -5034,822 + 6565,675X_1 + 417,314X_2 + 4241,524X_3$ with R square (R²) of 0.614 which means there is a strong correlation between independent variables (X1, X2 and X3) to the dependent variable (\hat{Y}). The contribution of X1, X2 and X3 to variations \hat{Y} is 61.4%, while the remaining 38.6% is caused by other factors not included in the study. The results of the analysis explain the individual influence of each independent variable on the dependent variable and the magnitude of the effect is shown by each regression coefficient value. The magnitude of the coefficient of Y is -5034,822. A negative sign explains that without erodibility, slope and soil management that affect erosion, erosion will still occur. This is in accordance with the opinion of Rahim (2006) which explains that the soil naturally to erode. This erosion is often called geological erosion. This type of erosion is not dangerous because the rate is balanced with the formation of soil at the site of the erosion.

Regression coefficients for each independent variable are X1 of 6565,675, X2 is 417,314 and X3 is 4241,524. From the magnitude of the coefficient it can be seen that the highest coefficient value is the erodibilitaas factor coefficient (X1) which is equal to 6565,675 followed by the crop management coefficient (X3) and finally the slope coefficient (X2).

This means that the most dominant factor affecting the magnitude of erosion is erodibility factor (X1). The high erodibility coefficient shows the resistance of soil particles that are high to erosion caused by rainfall kinetic energy. The amount of soil erodibility is determined by soil characteristics such as soil texture, soil aggregate stability, soil permeability and *organic matter content*. According to Asdak (2004), the four properties of soil that are important in determining soil erodibility are: (1) soil texture, soil with the main elements of dust and sand and organic matter, giving a greater possibility of erosion; (2) soil organic matter, soil organic matter tend to improve soil structure and have the character of increasing soil permeability, groundwater capacity and soil fertility thereby reducing erosion potential; (3) soil structure, affects the ability of soil to absorb ground water; (4) soil permeability, indicating the ability of the soil to flow water. Soils with high permeability increase the rate of infiltration thereby reducing the amount of the runoff. Therefore, handling erosion problems, these factors should be the main focus for improving degradation of farmland through the application of soil conservation so that the amount of soil erosion can be reduced. Soil conservation strategies that can be done in this area that through minimum and contour tillage, optimize use of green manure and compost, land cover with plant litter. All of the aim is to improve each factor that affects erodibility, namely texture, structure, permeability and soil organic matter.

Furthermore, crop management factors (X3) affect the magnitude of erosion where the coefficient value is 4241,524. Basically, crop management factors must consider the nature of plant protection against erosivity (the ability of rain to cause erosion). Plants have an important role and are very influential on erosion. The role described by Kartasapoetra, et al. (1985) as follows: (a) the durability of leaves and plant branches on the raindrops will have a role, among others, to resist the impact of raindrops, to hold back and slow down the flow of run off; (b) humus with its absorption power plays a role in reducing run off that has slowed down; (c) plant roots have a role in binding to the soil so it is difficult to destroy, the porosity will become larger so that it will reduce erosion; (d) microorganisms have a role in the humification process (forming crumb structure so that the ability to absorb and infiltrate water is greater; (e) transpiration causes water to be absorbed by plant roots so that the soil is more porous and absorbs water smoothly.

The results of statistical tests, the effect of the slope factor (X2) with erosion based on the results of the analysis obtained a positive effect. The regression coefficient of the slope factor (X2) is 417,314. There is a correlation between the magnitude of erosion and the steepness slope factor. The difference in topography will affect the amount of erosion. The steeper the slope it will increase the volume, speed, energy of carrying water from run off and increase the number of granules of soil splashed down the slope due to the impact of rainfall kinetic energy on the soil surface. This phenomenon causes erosion to occur which is getting bigger. In general, the slope of more than 45% is no longer suitable for farmland.

4. Conclusion

1. The most dominant factor affecting the magnitude of erosion on farmland in Sibolangit Sub-District is erodibility factor (X1), followed by crop management factors (X3) and slope factors (X2).
2. Soil erodibility factors are the main focus for the improvement of land that has been damaged by erosion through the application of soil conservation so that the amount of soil erosion can be reduced on farmland in Sibolangit Sub-District
3. There is a correlation between the independent variables of erodibility, slope and crop management (X1, X2 and X3) on the variation of the dependent variable the magnitude of erosion (\hat{Y}).

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