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SOIL NUTRIENT LOSS THROUGH EROSION CAUSES ECONOMIC LOSS IN THE DELI WATERSHED UPSTREAM

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Abstract

Soil erosion generally occurs in areas with steep slopes, especially in mountainous regions, such as the upstream of Deli Watershed located in the administrative area of Karo Regency and Deli Serdang Regency, North Sumatra Province, Indonesia. Apart from the biophysical form of the land, this area also tends to have a higher rainfall level than other lower sites. In addition, the condition of the land surface that lacks green vegetation, such as forests, may lead to erosion. The loss of soil particles, in turn, has the potential to eliminate soil nutrients that act as inputs for agricultural production. Therefore, this study aimed to calculate the average erosion upstream of the Deli watershed and estimate the value of the economic loss of soil nutrient loss due to erosion. The Universal Soil Loss Equation (USLE) Method and the Replacement Cost Method were used. The analysis results showed that the average erosion of the Deli Watershed upstream was 583.02 tonnes/ha/year, which is classified as very heavy erosion. At the same time, the economic loss value for replacing soil nutrients was Rp 2,072,636,100 per ha. Hence, it shows the application of Soil and Water Conservation (KTA) is needed to reduce economic losses due to environmental degradation.

Key words : erosion, nutrient loss, replacement cost, USLE

INTRODUCTION

A watershed is a container that functions to capture rainwater, store some rainwater into the ground through the infiltration process or channel the other part to the outlet (estuary) in the form of surface water to meet the water needs of the people living around the watershed. A watershed starts with a hilly and mountainous topography, commonly called upstream. Then, it ends in a site with an elevation that tends to be sloping or flat below, referred to as downstream.

The upstream of watershed has a vital role as a conservation site to determine the quality and sustainability of the environment. The upstream watershed protects the function of the water system because every activity in this area will have an impact in other locations in the form of (a) changes in flow rate fluctuations and sediment transport, including nutrients and dissolved materials in the water flow system; (b) affect the production system; (c) water quality; and (d) energy production (Asdak, 2010; Springgay, 2017; Suprayogi et al., 2018; Kironoto et al., 2020). Then, the upstream area also offers ecosystem services as a source of water supply for agricultural, domestic, and environmental purposes and the protection of biodiversity, so that this area can be considered the primary life support (Springgay, 2017).

Furthermore, the upstream of a watershed is an ecosystem with the main constituents consisting of forests, rice fields, rivers, and humans (Asdak, 2010). However, this area is prone to environmental degradation, such as critical land, due to the loss of soil nutrient content carried away by rainwater and

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surface water runoff. This process is usually referred to as soil erosion.

Erosion is the process of releasing soil particles in the topsoil at the source site/water catchment area (on-site), which is brought to the sedimentation basin/downstream area (off-site), resulting in a thin layer of soil up to leaving the bedrock (Asdak, 2010; Anasiru, 2015; Hendro et al., 2015; Alewell et al., 2019). Generally, topsoil with a thickness of 15 – 30 cm has better chemical and physical properties than the subsoil, so that the loss of the topsoil containing nutrients and organic carbon finally results in the loss of potential for agricultural, forestry, and water production (Kironoto et al., 2020; Hendro et al., 2015).

Areas classified as erosion-prone areas include: (a) areas with steep slopes, especially mountain ridges with shallow soil depths; (b) lands with low soil permeability; and (c) lands with inadequate amounts and conditions of vegetation (Asdak, 2010). Based on this explanation, the upstream of the Deli watershed is included in an area prone to erosion.

The upstream of Deli Watershed has these characteristics, known to have a relatively steep slope (> 16%) with the highest land height of 1,680 meters and the lowest of 50 meters (Arli, 1998; Simbolon et al., 2020). Then, the types of land cover in the upstream of Deli Watershed is dominated by dryland agriculture. The upstream area has the role of protection, absorption, and distribution for water planted with strong-rooted woody plants (forests). Each type of land cover in the upstream area of Deli Watershed can be seen in Table 1.

Table 1. Land Cover Area of the Deli Watershed Upstream

No.	Land Cover	Area (ha)
1.	Primary forest (*Hutan lahan kering primer*)	2,005.22
2.	Secondary forest (*Hutan lahan kering sekunder*)	175.05
3.	Shrubland (*Belukar*)	542.7
4.	Settlement (*Permukiman*)	117.6
5.	Bareland (*Lahan terbuka*)	81.8
6.	Cropland (*Pertanian lahan kering*)	12,048.3
7.	Paddy field (*Sawah*)	131.01
	Total (ha)	15,101.6

Source: Watershed and Protected Forest Management Center Wampu Sei Ular (BPDASHL WSU) (2021)

Furthermore, the upstream land of Deli Watershed is also intensively processed by the community as agricultural land without applying the concept of Soil and Water Conservation (KTA). Around 82% of the people living near the Deli Watershed upstream work as farmers (Hutapea, 2012). As a result, erosion has become a routine disaster every year, especially during the rainy season or high rainfall.

Research on the average amount of erosion in the Deli Watershed has been conducted previously by Hutapea (2012) and Isma (2014), and the results showed that there had been an increase in the average amount of erosion in two years. The average erosion of the Deli Watershed increased from 27.08 tonnes/ha/year or equivalent to a loss of 1.3 millimeters of soil layer to 138.808 tonnes/ha/year (Hutapea, 2012; Isma, 2014).

However, previous studies that have calculated the average erosion of the Deli Watershed have never specifically analyzed the watershed according to the watershed section, such as upstream, middle, and downstream. Instead, the previous studies were conducted by Sub-Watershed or the Deli Watershed as a whole.

The increased average erosion was caused by the biophysical conditions of the

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land accompanied by an increasing annual average rainfall (climate). These two factors are variables for calculating soil erosion estimation using the Universal Soil Loss Equation (USLE) Method. The USLE Method is an erosion modeling designed to predict the long-term average annual soil loss (erosion) from sheet and furrow erosion under certain conditions (factors) (Regulation of the Forestry Minister of the Republic of Indonesia Number P.32/Menhut-II/2009). The calculation of the erosion level using the USLE method has been widely used in Indonesia because it is easy to manage, relatively simple, can be used in the tropics, and has relatively few parameters compared to other methods (Isma, 2014).

Then, this erosion has the potential to incur costs that are seen as economic losses, such as the costs of preventing damage or improving environmental quality. For example, the flood and erosion control costs incurred by the Medan City Government to build a canal on the Deli River amounted to Rp 727,896,854,487.00 with a service life of 50 years (Department of Public Works, 2009 in Sulistiyono et al., 2018). As another example, the cost of the Forest and Land Rehabilitation Movement (Gerhan) located in Deli Serdang Regency was Rp 2,357,820,600.00/year with an area of 977 ha out of 10,794 ha of the area included in the Gerhan program (Deli Serdang District Forestry Service, 2007 in Sulistiyono et al., 2018). The greater costs incurred by the government show the greater environmental damage level. Therefore, the cost can be assumed as a form of government effort as a managing actor to maintain, increase, and restore the benefits of natural resources and the environment of the (upstream) Deli Watershed. Based on the explanations above, this study aimed to calculate the average amount of erosion upstream of the Deli Watershed and estimate the value of the economic loss of soil nutrient loss due to erosion.

MATERIAL AND METHODS

This research was conducted in upstream of the Deli Watershed (DAS) in North Sumatra Province, Indonesia. The location was chosen because it has a very high level of vulnerability to erosion (BPDASHL WSU, 2013), so it becomes a priority area for land management and conservation activities (Fadhlan, 2020). This research was conducted in October 2021.

Table 2. The Upstream Area of the Deli Watershed

District	Subdistrict	Area (ha)
Karo	Berastagi	602.08
	Merdeka	731.9
	Dolat Rayat	21.06
Deli Serdang	Sibolangit	8,250.8
	Biru-biru	2,109.4
	Namorambe	3,378.5
	Kutalimbaru	7.9
Total (ha)		15,101.6

Source: BPDASHL WSU (2021)

Furthermore, the predictive analysis of the soil erosion level (tonnes/ha/year) in the upstream of Deli watershed was calculated using the USLE (Universal Soil Loss Equation) formula. The components of the USLE equation were obtained from BPDASHL WSU through secondary data, namely shp (shape) files and rainfall data. Then, the shp file was processed using ArcGIS 10.3 software to generate spatial data of the upstream Deli Watershed.

Alewell et al. (2019) explained that the USLE type modeling does not address larger rill or gully erosion (linear structures with a depth of > 30 centimeters). However, it is limited to sheet/interrill and small rill erosion

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only, i.e., a few centimeters fewer depths, generally defined as structures that may be removed by planting activities. Furthermore, USLE expresses soil mass loss per unit area and time (Alewell et al., 2019).

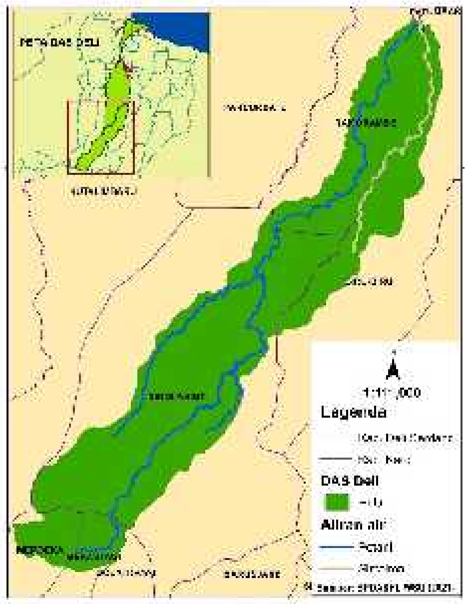

Figure 1. The Map of Upstream of Deli Watershed
Source: BPDASHL WSU (2021) and INA Geospatial

USLE formula is known to have been proposed firstly by Wischmeier and Smith in 1965 (Wischmeier and Smith, 1978). The USLE formula is as follows:

$$A = R \times K \times LS \times CP \quad (1)$$

Description:

- A: The amount of soil loss or soil erosion per unit area (tonnes/ha/year),
- R: The mean erosivity of annual rainfall,
- K: The soil erodibility factor or soil quality,
- LS: The slope length and slope-steepness factor, and
- CP: The cropping management and the conservation efforts factor.

The next step was to calculate the economic loss caused by the loss of soil nutrients in the eroded topsoil. This calculation was carried out using the replacement cost method based on the USLE calculation results for the analysis.

The eroded soil nutrients were converted into inorganic fertilizers, including Urea fertilizer, SP-36 fertilizer, and KCl fertilizer. These fertilizers were used to assist farmers in increasing agricultural land productivity after topsoil erosion. The equation for calculating the replacement cost of soil nutrients is as follows:

$$RC = NEr \times (70\% N, 20\% P, 10\% K) \times P \quad (2)$$

Description:

- RC: Replacement cost of soil nutrient content
- NEr: Erosion value where the soil content generally consists of 70% N elements, 20% P elements, and 10% K elements (Suparmoko and Waluyo, 2004)
- Q: Fertilizer price per kilogram at the research site

RESULT AND DISCUSSION

1. Factors for the Calculation of Erosion in the Upstream of Deli Watershed

a. Rainfall Erosivity Factor (R)

The impact of rainwater on soil is the leading cause of soil erosion that originates from the rate and distribution of raindrops (Asdak, 2010; Isma, 2014). Meanwhile, rain erosivity (R) is the driving force that causes

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peeling and transport of soil particles to lower places (Asdak, 2010). The higher the R factor value, the greater its ability to cause erosion (Isma, 2014).

The R factor value in this study was the results of monthly Rainfall (CH) analysis of the Deli Watershed, delivered at the workshop on preparing the general plan for the management of the Deli watershed at the BPDASHL WSU Office (2021). Monthly CH data were obtained from ten rain stations, including Kuta Gadung, Biru-Biru, Klambir, Pancur Batu, Saintis, Tuntungan, Helvetia, Belawan, Tongkoh, and Semayang during the period of 2011 to 2020 (BPDASHL WSU, 2021). The value of the R factor is shown in Table 5.

The formula for the rain erosivity index (R) used was the formula proposed by Lenvain (Asdak, 2010), as follows:

$$R = 2,2 \times P^{1,3} \quad (3)$$

Description:
R: Erosivity factor
P: Monthly Rainfall (centimeters).

Table 3. Rainfall Erosivity Factor (R) from 2011 to 2020

Months	Average Monthly Rainfall (CH) (millimeters)	Average Monthly Rainfall (CH) (centimeters)	R
January	197.5	19.75	127.75
February	130.9	13.09	73.02
March	192.3	19.23	123.20
April	180	18	112.61
May	366	36.6	295.62
June	207.2	20.72	136.36
July	206.2	20.62	135.46
August	231.4	23.14	158.46
September	356	35.6	284.68
October	335.8	33.58	262.94
November	301.6	30.16	227.21
December	297.9	29.79	223.42
Annual Rainfall Erosivity			2,160.73

Description: CH (*Curah Hujan*) is a Rainfall, R is a Rainfall Erosivity Factor
Source: BPDASHL WSU (2021) and analysis results

Based on the R results, the monthly rainfall erosivity value for ten years ranged from 73.02 to 295.62. The lowest monthly rainfall erosivity value occurred in February, whereas the highest was in May. Then, the annual rainfall erosivity value was obtained from the sum of the monthly erosivity values from January to December, which was 2,160.73. The rain characteristics of the upstream of the Deli Watershed obtained from BPDASHL WSU are illustrated in Figure 2.

In general, Figure 2 illustrates that the highest monthly rainfall in the Deli Watershed occurs from September to December. It means that at the end of the year, the Deli Watershed is at risk of experiencing hydrometeorological disasters, such as floods and landslides/soil erosion, if it is not accompanied by good management of the drainage system and water catchment area.

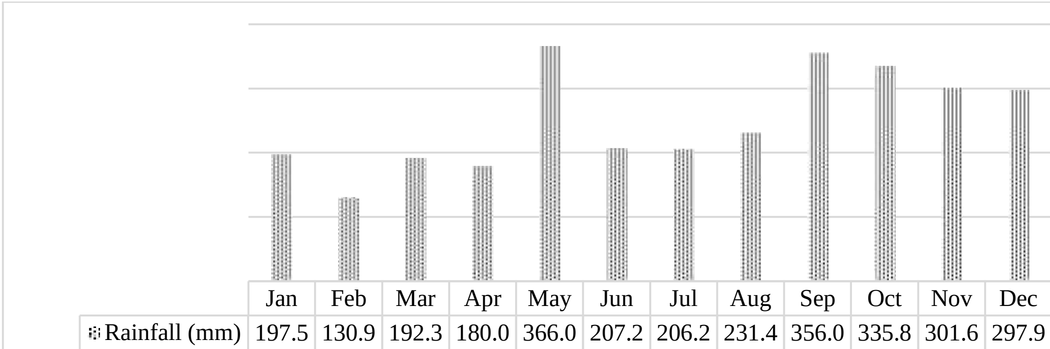

Figure 2. Average Monthly Rainfall at Sibolangit Rainfall Post (PCH) from 2011 to 2020
Source: BPDASHL WSU (2021)

By knowing the monthly rainfall trend, the relevant actors must anticipate disasters. One of them is applying agricultural land processing, an activity through the vegetative method. For example, farmers can: (1) develop a cropping plan by determining the type of crop (seasonal/permanent) and planting time to control soil infiltration during the rainy season; (2) planting in strip cropping, crop rotation, agroforestry systems; and (3) utilize crop residues (Suprayogi et al., 2018).

b. Soil Erodibility Factor (K)

Soil erodibility (K) indicates the level of sensitivity of the soil to erosion or the ability of the soil to resist erosion based on the physical properties of the soil, including soil texture (percentage of very fine sand, silt, and clay), soil organic matter content, soil structure, soil permeability, and other soil properties, such as cohesion and particle size distribution (Asdak, 2010; Edriani, 2014; Kironoto et al., 2020). The mean value of the K factor in the Deli watershed upstream was calculated with the study of soil taxonomy, which is soil great groups.

Each great group has a level of sensitivity to erosion (soil erodibility), where the greater the K factor, the smaller the resistance to erosion and vice versa (Isma, 2014). The following is the K factor average value for each great group in the upstream of Deli Watershed.

Table 4. The Soil Erodibility Factor (K) in the Upstream of Deli Watershed

Great Groups	K	Area (ha)	A	K * A
Dystropepts; Dystrandepts; Tropudults	0.073	3,145.59	0.208	0.015
Dystropepts; Troporthents; Tropudults	0.073	2,423.63	0.160	0.012
Dystrandepts; Eutrandepts; Dystrandepts	0.32	3,950.39	0.262	0.084
Dystropepts; Dystrandepts; Haplorthox	0.073	3,571.53	0.237	0.017
Dystropepts; Tropudults; Troporthents	0.073	652.45	0.043	0.003
Hydrandepts; Eutropepts; Troporthents	0.32	1,357.97	0.090	0.029
Total (ha)		15,101.6	Mean K-value	0.160

Description: K is the soil erodibility factor value, A is the area of the great groups divided by the area of the Deli Watershed upstream, Mean K-value is the sum of K times A (K*A)
Source: BPDASHL WSU (2021) and analyzed using ArcGIS 10.3

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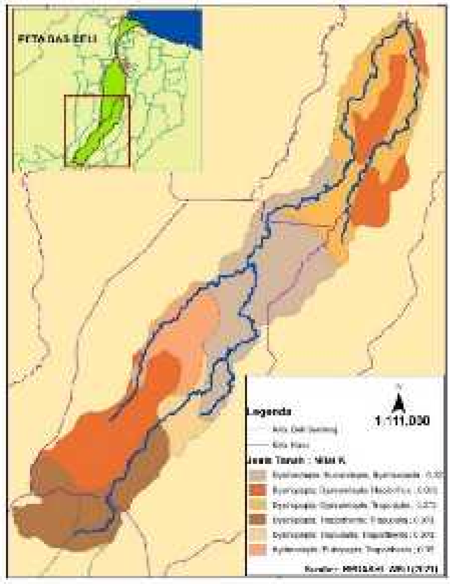

Figure 3. Map of Soil Great Group (K)
Source: BPDASHL WSU (2021)

c. Slope Length and Slope-Steepness Factor/Topography (LS)

The slope length factor (L) is measured from the initial place where the water flow occurs above the ground surface to the place where the deposition begins, which is caused by a decrease in the steepness of the slope or where the water flow on the ground surface enters a river or channel (Arsyad, 2012). Meanwhile, the slope-steepness factor (S) is the ratio between the amount of erosion in a plot of land with a particular slope to the amount of erosion from the soil (Kironoto et al., 2020).

The L and S value can be calculated simultaneously in the LS factor, which means the ratio between the amount of erosion from a plot of land with a certain slope length and steepness to the amount of erosion from the soil (Arsyad, 2012). The calculation of the LS factor average value in the upstream of the Deli watershed can be seen in Table 5.

Table 5. The LS Factor in the Upstream of Deli Watershed

Class	Slope (%)	Description	LS	T	Area (ha)	A	T * A
1	0 – 8	Flat	0.4	4	4,142.39	0.275	1.10
2	8 – 15	Moderate	1.4	11.5	3,047.91	0.202	2.32
3	15 – 25	Steep	3.1	20	2,977.81	0.197	3.94
4	25 – 45	Steeper	6.8	35	3,091.31	0.205	7.17
5	> 45	Steepest	9.5	72.5	1,822.21	0.121	8.76
				Total (ha)	15,081.63	1.000	23.31
						Mean LS-value	6.8

Description: LS is the slope length and slope-steepness factor value, T is the median value of each slope (%), A is the area of the slope divided by the area of the Deli Watershed upstream, Mean LS-value is the sum of T times A (T*A) then adjusted for the degree of Slope (%) and LS factor

Source: Rahmawaty *et al*. (2011), BPDASHL WSU (2021), and analyzed using ArcGIS 10.3

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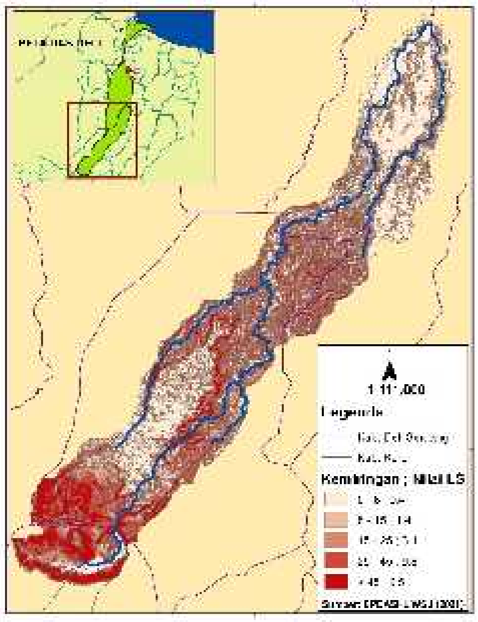

Figure 4. Map of Slope-steepness (LS)
Source: BPDASHL WSU (2021)

The topography of the Deli watershed upstream varies from a slope of 0% to > 45%. Generally, land with a slope of > 45% is designated as a protected area by the government to restore and improve the quality of natural resources (Asdak, 2010). In more detail, the slope in percent (%) found in the upstream of Deli watershed is dominated by flat land with a slope of 0% - 8% covering an area of 4,142.39 ha. Meanwhile, the smallest land area is very steep land with a slope level of > 45% covering an area of 1,822.21 ha.

d. Cropping Management and Conservation Efforts Factor (CP)

The value of plant management factor (C) in USLE shows the overall effect of vegetation, leaf litter, soil surface conditions, and particular land management on the amount of soil erosion that is processed clean and not planted (Asdak, 2010; Arsyad, 2012). Furthermore, the effects of ground cover vegetation on erosion include: (a) protecting the soil surface from rainwater collisions (reducing terminal velocity and reducing rainwater diameter); (b) reducing the speed and volume of running water; (c) holding soil particles in place through the root system and resulting litter; and (d) maintaining the stability of the soil's capacity to absorb water (Asdak, 2010). Meanwhile, the P factor is the ratio between the average soil eroded from land that received particular conservation treatment to land cultivated without conservation action and according to the direction of the slope, assuming that other erosion-causing factors do not change (Asdak, 2010; Arsyad, 2012).

The data used in calculating the value of the CP factor is secondary data from the remote sensing analysis results that have been widely used by researchers in the study of mapping the CP factor (Kironoto et al., 2020). The secondary data is in a digital land cover map of the Deli Watershed upstream. The calculation of the CP factor average value can be seen in Table 6.

Based on the table above, there are seven types of land cover in the upstream of Deli Watershed, ranging from natural vegetation such as primary forest to built-up land such as settlements. Furthermore, dryland agriculture (cropland) has the most significant area among other land cover types, while the smallest is bareland.

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Table 6. The CP Factor in the Upstream of Deli Watershed

Land Cover	CP	Area (ha)	A	CP * A
Primary forest	0.01	2,005.21	0.133	0.0013
Secondary forest	0.01	175.04	0.012	0.0001
Shrubland	0.3	542.68	0.036	0.0108
Settlement	0.95	117.55	0.008	0.0074
Bareland	0.95	81.77	0.005	0.0051
Cropland	0.28	12,048.29	0.798	0.2234
Paddy field	0.01	131.01	0.009	0.0001
Total (ha)		15,101.6	Mean CP-value	0.2482

Description: CP is the cropping management and conservation efforts factor value, A is the total land cover area divided by the total area of the Deli Watershed upstream
Source: BPDASHL WSU (2021) and analyzed using ArcGIS 10.3

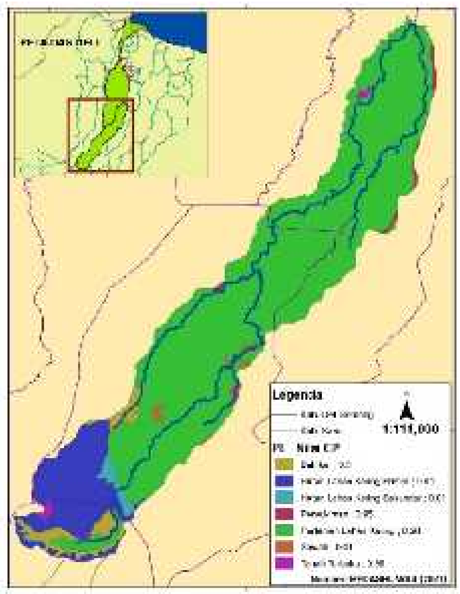

Figure 5. Map of Land Cover (CP)
Source: BPDASHL WSU (2021)

The land cover type determines the CP factor value used in the calculation. The CP factor value was informed, along with a digital landcover map obtained from BPDASHL WSU (2021). Furthermore, the CP factor value adjusts to the type of land cover so that the analysis can be carried out after knowing the area of each type of land cover.

The CP factor value, also known as the land cover factor, affects the amount of land erosion in the upstream of Deli watershed (Isma, 2014). The greater the land cover factor, the greater the possibility of soil erosion.

In addition, Table 6 also shows that residential land cover and bareland have an immense CP factor value, which was 0.95. It means that the rainwater that falls will not be absorbed into the soil because no canopy or root system can withstand the kinetic energy and absorb the rainwater. This condition causes the rainwater that falls will immediately turn into surface runoff and follow the nature of the water flowing to a lower area. Therefore, during the rainy season, the water flow from upstream to downstream will be high. Meanwhile, the smallest CP factor value was

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found in primary forest, secondary forest, and paddy field with 0.01.

2. Estimation of Soil Erosion in the Upstream of Deli Watershed

The estimated erosion value in Deli Watershed upstream was calculated using the Universal Soil Loss Equation (USLE) Method. This method requires average values for factors such as rain erosivity (R), soil erodibility (K), slope length and slope-steepness (LS), and the cropping management and conservation efforts (CP). This analysis can be seen in Table 7.

Table 7. Calculation of Erosion Prediction for Upstream of Deli Watershed with the USLE Method

The average value of the factors that cause erosion				**Predicted mean erosion (tonnes/ha/year)**	**Predicted total erosion (tonnes/year)**
R	**K**	**LS**	**CP**	**A**	
2,160.73	0.16	6.8	0.248	583.02	8,804,534.8

Source: analysis results

Based on the USLE results, the average erosion or symbolized by A is 583.02 tonnes/ha/year. Then, A's value is multiplied by the upstream area of the Deli watershed (15,101.6 ha) to calculate the predicted total upstream erosion of the Deli watershed. The value obtained is 8,804,534.8 tonnes/year.

Moreover, the USLE results can be classified into class 5, which is very heavy with a value of >480 tones/ha/year. The classification of soil erosion is shown in Table 8.

Table 8. The Classification of Soil Erosion

Class	**Soil Erosion (tonnes/ha/year)**	**Description**
1	< 15	Very low
2	15 – 60	Low
3	60 – 180	Medium
4	180 – 480	High
5	> 480	Very high

Source: Rahmawaty *et al*. (2011)

3. The Replacement Cost of Soil Nutrient Content

The loss of fertile and good soil layers containing one or more nutrients decreases soil fertility. Thus, the soil cannot provide sufficient and balanced nutrients to support normal plant growth (Arsyad, 2012). One of the causes of this nutrient loss is soil erosion. Erosion is the process of releasing or eroding soil grains from a place caused by the movement of water or wind (Arsyad, 2012; Suprayogi et al., 2018).

Furthermore, agricultural areas are most vulnerable to erosion (Suprayogi et al., 2018), especially on steep slopes with intensive farming systems. This explanation describes the condition of land resources in the upstream of Deli watershed, dominated by dryland agriculture with varying slope class intervals.

Suprayogi et al. (2018) explained that the loss of topsoil, a fertile layer of soil and a medium for root growth due to erosion, will cause a decrease in soil fertility. It will further reduce soil productivity due to physical, chemical, and biological decline in soil properties. Therefore, the eroded soil requires input in the form of fertilizer to restore soil fertility. The amount of fertilizer needed depends on soil erosion which means that the

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greater the erosion that occurs, the more soil nutrients are carried.

The replacement costs incurred to restore land productivity are generally experienced and borne by upstream actors, especially farmers who cultivate land resources. The farmers carry out permanent dryland farming with seasonal crops such as eggplant, chili, mustard greens, bananas, and annual crops such as coffee.

Hence, economic losses need to be calculated to see the impact of environmental degradation on economic aspects. The greater the value of the economic loss indicates the need for immediate action to anticipate erosion in the upstream of Deli watershed. If not, money and time will be wasted in repairing soil damage through fertilizer application and not treating the leading cause of erosion (Arsyad, 2012).

Furthermore, the USLE results were used as the basis for calculating the estimated economic costs to replace the missing nutrient content. The economic loss was calculated assuming that the soil component generally consists of 70% N elements, 20% P elements, and 10% K elements (Suparmoko and Waluyo, 2004). The price of each fertilizer type in this analysis refers to the Regulation of the Minister of Agriculture of the Republic of Indonesia Number 49 of 2020 concerning the Allocation and Highest Retail Price of Subsidized Fertilizer in the Agricultural Sector for the 2021 Fiscal Year. The calculation is depicted in Table 9.

Table 9. The Economic Calculation of Soil Nutrients Replacement

Fertilizer Types	**Kilogram lost per ha per year**	**Cost (Rp) per kilogram**	**Cost (Rp) per ha**
Urea (*nitrogen*)	408,114	2,250	918,256,500
SP-36 (*phospor*)	116,604	2,400	279,849,600
KCl (*kalium*)	58,302	15,000	874,530,000
Total	**583,020**		**2,072,636,100**

Source: analysis results

The replacement cost calculation was performed in several steps. First, after obtaining the amount of soil eroded in the upstream of Deli Watershed, 583.02 tonnes/ha/year, soil erosion was converted into kg (kilograms). It is because Urea, SP-36, and KCl fertilizers units are sold in the market in kg. Thus, the total soil eroded was 583,020 kg/ha/year.

Second, each nutrient element (N, P in the form of P2O5, and K in the form of K2O) was calculated for each kg of eroded soil using the approach by Suparmoko and Waluyo (2004), in which the amount of element N 70%, element P 20 %, and the K element was 10%. Thus, the value of each macronutrient content is written as shown in Table 4.

Third, the Regulation of the Agriculture Minister of the Republic of Indonesia Number 49 of 2020 concerning the Allocation and Highest Retail Price of Subsidized Fertilizers in the Agriculture Sector for the 2021 Fiscal Year set about the price of those fertilizers. Urea and SP-36 fertilizers, single subsidized fertilizers and KCl fertilizers, are Rp 2,250/kg, Rp 2,400/ kg, and Rp 15,000/kg, respectively.

Fourth, the last step in this calculation was to multiply the previously obtained nutrient values with the prices of the three types of fertilizers. The results produced a number that showed the cost of replacing nutrients that need to be spent by actors, which was Rp 2,072,636,100/ha/year. In general, the greater the agricultural output that farmers want to receive, the greater the intake of nutrients (fertilizers) that farmers need to provide (Suprayogi et al., 2018).

Furthermore, one aspect that should be considered is the replacement of soil nutrients

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by using a single inorganic fertilizer. Each of these three fertilizer types has its advantages, which are taken from the official website of PT Petrokimia Gresik. For example, the nutrient *Nitrogen* in Urea fertilizer plays a role in making plant parts greener and fresher, accelerating plant growth, and increasing the protein content of crop yields. Meanwhile, the *Phosphorus* content in SP-36 fertilizer helps promote root growth with a good root system, promoting flower formation and fruit or seed ripening, accelerating harvesting, and increasing plant resistance to pests, diseases, and drought. Finally, the *Potassium* element in KCl fertilizer has the advantage of making plants more upright and sturdy, increasing plant resistance to pests, diseases, and drought, increasing sugar and starch formation, and increasing yield resistance during transportation and storage.

Although the output from using inorganic fertilizers is not as good as organic fertilizers, such as manure, people in the upstream of Deli Watershed still depend on this type of fertilizer during the planting period until the harvest period. Meanwhile, organic fertilizers are used by farmers only during the land preparation process.

CONCLUSION

Soil erosion in the upstream of Deli Watershed is classified into class 5 or very heavy. The predicted average erosion in the upstream of Deli Watershed is 583.02 tonnes/ha/year with the very heavy classification threshold > 480 tonnes/ha/year. Meanwhile, the economic loss value is obtained from converting the amount of eroded soil into nutrients N 70%, P 20%, and K 10% multiplied by the price of each fertilizer. The estimated cost to be incurred by farmers as actors affected by the degradation of land resources in the upstream of Deli Watershed is Rp 2,072,636,100 per ha.

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