Journal of Sustainable Agriculture and Biosystems Engineering

Journal homepage: https://talenta.usu.ac.id/jsabe

The Study of Erosion on Various Land Use in Paluh Besar Sub Watershed Using Geographic Information System

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ARTICLE INFO

Article history:
Received 12 December 2023
Revised 29 February 2024
Accepted 29 February 2024

E-ISSN : 3026-4065

How to cite :
S. Tarigan and D.L.S. Nasution, "The Study of Erosion on Various Land Use in Paluh Besar Sub Watershed Using Geographic Information System", Journal of Sustainable and Biosystems Engineering, Vol. 02, No. 01, 2024.

http://doi.org/10.32734/jsabe.v2i01.146720

ABSTRACT

Erosion could be a sign of natural resources damage. It's important to prevent the erosion that had to predict in each land cover to sustainability of natural resources. This study aimed to predict the erosion value in each land cover unit using Universal Soil Loss Equation (USLE) Method with Geographic Information System. The study showed that the highest erosion occurs in residential area which valued 138.11 ton/ha/year and the lowest occur in pond that valued 0.3 ton/ha/year. The highest erosion hazard level occur in residential area that classify moderate (III) and the lowest erosion hazard level is pond that classify low hazard level (I).

Keywords: Erosion, Universal Soil Loss Equation (USLE) Method, Geographic Information System, Land Use

1. Introduction

Erosion is one of land degradation. Yudhistira (2011) explain that erosion could be a sign of natural resources damage. Erosion is the process of detachment and transportation of soil that causing of water energy [1].

Several watersheds in Sumatera Utara Province have been affected by erosion impact. Deli Watershed is one of critical watershed that flows through Medan City. Deli Watershed have seven catchment area around Deli Serdang Regency include Paluh Besar Sub Watershed. One of big problem that Paluh Besar Sub Watershed facing was decreasing of vegetation around the river as impact of the increasing of settlement and forest conversion to settlement and plantation [2]

The direct erosion measurement in the field requires a lot of time, energy and cost. As an alternative to assess erosion on a watershed, it requires a system application. Therefore, it needs a system to assist as the Geographic Information System (GIS) became an alternative to resolve this problem which was then assisted by an erosion estimation method, namely the Universal Soil Loss Equation (USLE) Method. Universal Soil Loss Equation (USLE) is one of popular erosion estimation methods that recently used in many watershed because of its simplycity, effectivity and its efficiency.

In the USLE equation, several factors influence such as land use, slope, climate, and conservation. Land use or land cover has an important effect on increasing the amount of erosion because it will affect the physical properties of the soil, the availability of organic material, and the ability to absorb water on a land. The USLE prediction model can be used to predict erosion rates in the Paluh Besar sub-watershed as well as input and considerations for handling soil erosion problems in Deli Serdang Regency.

2. Methods

This study conducted at Paluh Besar Sub Watershed, Sumatera Utara Province that located on $03^0$34’12’’ - $03^0$45’50’’ (North Latitude) dan $98^0$35’55’’ - $98^0$40’25’’ (East Longitude). There are some data needed to collect such as rainfall data that collected from Climatological, Meteorological, and Geophysical Agency to determine the erosivity (R) factor. Landuse SHP Map and Slope SHP Map is made using Arc GIS (Geographic Information System) to determine vegetation (C) dan slope (LS) factor. The sample of soil should been taken to analyze soil physical properties in determining soil erodibility factor. The sample of soil taken by analyze landuse map to specify the location and the coordinate of soil sample could be taken using ArcGIS and Ground Check point (GCP).

2.1. Erosion Measurement

The calculation of erosion was conducted using USLE Method. The equation of USLE Method is: [3]

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

Where
A = Erosion (tons/ha/year)
R = Erosivity (kJ/ha)
K = Soil Erodibility (tons/kJ)
LS = Slope
CP = Landuse

2.2. Erosivity

Erosivity measurement was conducted by collect daily rainfall data for year 2000 - 2022 from Agency of Meteorology, Climatology, and Geophysics. The rainfall data analyzed was the average of monthly rainfall, maximum rainfall in month and the amount day of rainfall in month then calculate using the erosivity equation Bols [4].

$$R = \sum_{i=1}^{12} (EI_{30})i \quad (2)$$

Where

$$EI_{30} = 6{,}119\ (R)^{1,21}.(RD)^{-0.47}.\ (R.Max)^{0.53} \quad (3)$$

R = The average of monthly rainfall (cm/month)
R max = Monthly maximum rainfall (day)
RD = Amount of rainy day in a month (cm/month)

2.3. Erodibility

The soil erodibility of the Paluh Besar sub-watershed is determined by analyzing soil components such as soil texture, organic matter, soil structure and soil permeability in the Research and Technology Laboratory. The sample of soil was taken in each land cover. The determination of erodibility using equation 4, and for several land use such as water bodies the value of erodibility is determined using Table 1.

$$K = \frac{M^{1,14}\ (10)^{(-4)}(12-a)+3{,}25(b-2)+2{,}5(c-3)}{100} \quad (4)$$

K = Soil Erodibility (tons/kJ)
M = Particle size (% silt + % very fine sand) (100 - % clay) If the available texture data is only the sand, silt and clay fraction, then the % very fine sand can be estimated with 20% of the sand fraction
a = organic matter (% C x 1,724)
b = Soil structure (determine by Table 2)
c = Permeability index (determine by Table 3)

Table 1. Soil erodibility value based on soil type [5]

Soil Type	Erodibility (K)
Aluvial	0.47
Latosol	0.31
Podzolic red yellow	0.32

2.4. Slope Factor

Slope factor was analyzed by slope map using Arc GIS 10.0 and valued using Table 2.

Table 2. LS index based on slope magnitude [6]

Slope Class	Slope	LS Index
I	0 - 8 %	0.4
II	8 – 15 %	1.3
III	15 – 25 %	3.1
IV	25 - 40 %	6.8
V	>40 %	9

2.5. Landcover unit factor

The index of plant type and management is assessed based on land unit mapping and then scoring by the landuse (CP) value using Table 3.

Table 3. Landuse (CP) index in varity landcover [7]

Landuse	CP
Plantation	0.5
Shrub	0.3
Secondary Dryland Forest	0.01
Dryland Farming	0.28
Settlement	0.95
Mixed dryland farm	0.19
Plantation forest	0.05
Bare Land	1

2.6. Erosion Hazard Level

The value of erosion then categorized using Table 4 for the assessment of Erosion Hazard Level.

Table 4. Erosion Hazard Level [8]

Class	Erosion (ton/ha/yr)	Categorized
I	<15	Very low
II	15-60	Low
III	61-180	Moderate
IV	181-480	High
V	>480	Very High

3. Results and Discussion

3.1. Paluh Besar Sub Watershed

Paluh Besar Sub-watershed area has an area of 11040.42 hectares which includes six sub-districts, each of which is in Deli Serdang Regency with Labuhan Deli District and Hamparan Perak District and Medan City with Medan Sunggal District, Medan Helvetia District, Medan Belawan District and Medan Marelan District.

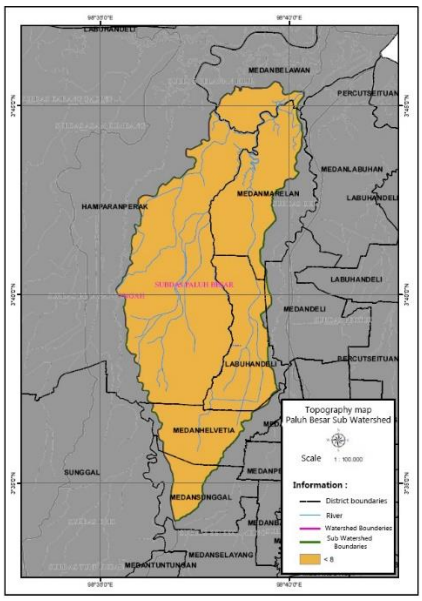

Figure 1. Paluh Besar Sub Watershed administration map

3.2. Erosivity

Erosivity factor calculated using equation 2 [4]. The average of monthly rainfall, maximum rainfall and amount day of rainfall monthly calculated to obtain the erosivity value. The value of erosivity can be seen at Table 5.

Table 5. Erosivity factor of Paluh Besar Sub Watershed

Month	Precipitation (cm)	Day of Precipitation (day)	Max Precipitation (cm)	EI_{30}
Jan	13.59	11.4	5.34	11.36
Feb	9.57	7.7	3.96	62.18
Mar	6.16	8.1	2.33	32.34
Apr	8.89	8.5	3.39	60.12
May	12.14	12.1	3.82	79.1
Jun	14.78	11.5	4.67	114.34
July	16.47	11.1	4.73	133.43
Aug	21.53	14.1	4.93	168.55
Sept	25.36	16.2	5.85	210.78
Oct	31.76	18.2	6.29	272.28
Nov	18.59	17.8	4.53	120.93
Dec	27.76	15	6.47	257.18
			$\sum EI_{30}$	1622.49

The total value of erosivity was 1622.49 ton/kJ. The erosivity value get in low value of erosivity. Rainfall was one of crucial factor that causing erosion. The average rainfall analyze in this area classified dry condition.

3.3. Soil Erodibility

Soil erodibility (K) is the soil's ability to withstand the impact of rain. Organic matter, soil texture, and permeability influence to soil erosion [3]. The soil erodibility was obtained using equation 4 by taking soil sample in each land use cover to obtain the components which influence the erodibility value such as soil texture, organic matter, and permeability that the soil sample was

taken in each landcover unit for settlement, sugarcane plantation, banana dry farming, and corn dry farming. The expectance for shrub, water bodies, and pond that erodibility was determined by soil types map (Figure 2) and scoring using Table 1. Soil erodibility value could be seen in Table 6.

Table 2. Erodibility in Paluh Besar Sub Watershed

Land Cover	K
Settlement	0.224
Sugarcane Plantation	0.231
Banana Farming	0.402
Corn Farming	0.245
Shrub	0.47
Water Bodies	0.47
Pond	0.47

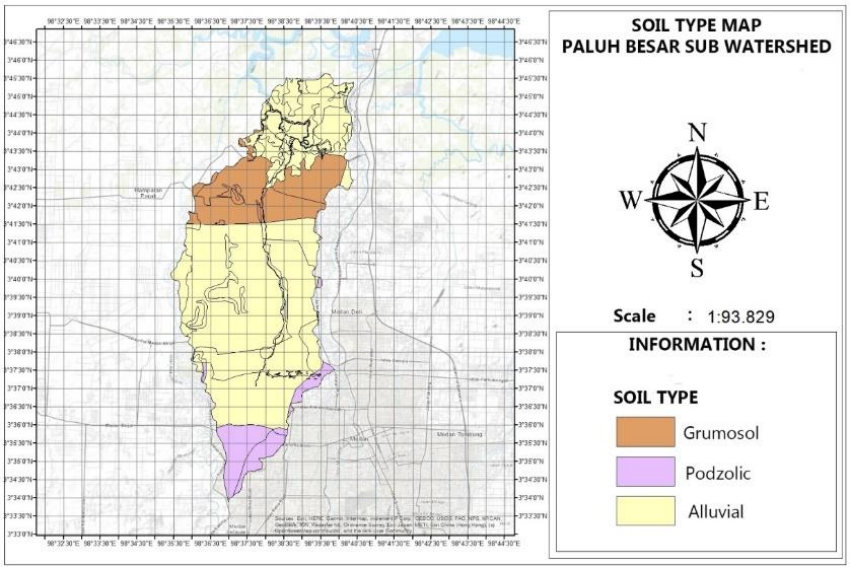

Figure 2. Soil Type Map

It can be seen that the lowest erodibility value is found in settlements with a value of 0.224, while the highest soil erodibility is found in swamp thickets, water bodies and ponds with a value of 0.47. According to Wischmeier and Smith [3], the area of soil destruction is the release and transport which is influenced by organic content, permeability, soil structure and texture. Erodibility and erosion value in each land cover have a relationship, namely the higher the erodibility, the easier it is for the soil to be eroded.

3.4. Slope Factor (LS)

The value of slope factor was asses by made the map slope of Paluh Besar Sub Watershed using Arc GIS and then scoring the value using Table 2. The map slope of Paluh Besar Sub Watershed can be seen in Figure 2 and the score of land slope can be seen in Table 7.

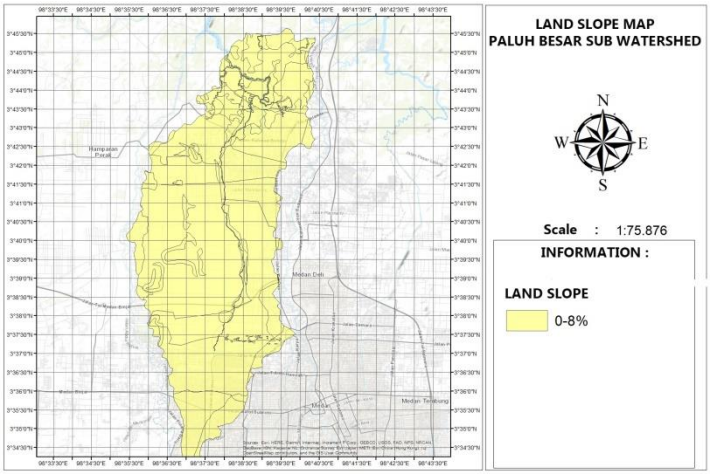

Figure 3. Slope Map

Table 3. Land Slope Score of Paluh Besar Sub Watershed

Land use	Slope	LS Score
Settlement	0-8%	0.4
Sugarcane Plantation	0-8%	04
Banana dry land farming	0-8%	0.4
Corn dry land farming	0-8%	0.4
Shrub	0-8%	0.4
Water bodies	0-8%	0.4
Pond	0-8%	0.4

Table 7 that shown score of land slope for all indicated the slope of Paluh Besar Sub Watershed which categorized to flat slope (class I) that get in low score. This condition rendering slope factor doesn't impact in aggravate the erosion value. According to Arshad in Arham et al., [9] describe that slope affects erosion through runoff. The steeper the slope, the greater the rate and amount of surface flow and the greater the erosion will occured.

3.5. Land Use Factor (CP)

The value of land cover factor was asses using Table by observing landuse map. The map of land cover unit could be seen in Figure 3 and the score of land use could be seen in Table 8.

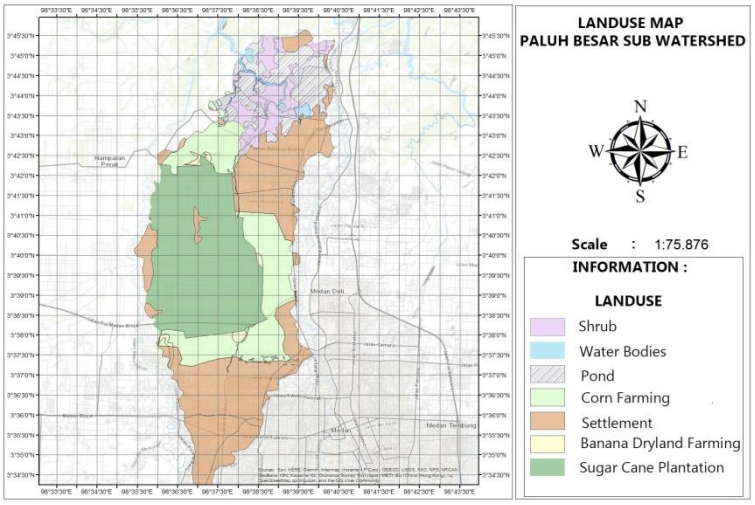

Figure 4. Land Use Map

Table 4. Crop Factor value of Sub DAS Paluh Besar

Land use	Score (CP)	Percentage (%)
Settlement	0.950	35.43
Sugarcane Plantation	0.500	30.19
Banana dry land farming	0.190	0.79
Corn dry land farming	0.280	17.85
Shrub	0.010	6.09
Water bodies	0.025	0.71
Pond	0.001	8.94

The highest value of land use occurs in settlement landcover that the rural area that the most sensitive area to flood and erosion because of the lack of vegetation. The high score increasing the erosion hazard. Vegetation is the most important factor in reducing erosion hazard level. Crop factor could be as an alternative in conservation effort.

3.6. Erosion

The value of erosion was assessing using USLE Methods by put and multiply all factors causing erosion such as erosivity, erodibility, and land use, the value of erosion shown in Table 9.

Table 5. Erosion Value and Categorize of Sub DAS Paluh Besar

Land Use	R	K	LS	CP	Erosion	Category
Settlement	1622.49	0.224	0.4	0.950	138.11	Moderate (III)
Sugarcane Plantation	1622.49	0.231	0.4	0.500	74.96	Moderate (III)
Banana dry land farming	1622.49	0.402	0.4	0.190	49.57	Low (II)
Corn dry land farming	1622.49	0.245	0.4	0.280	44.52	Low (II)
Shrub	1622.49	0.47	0.4	0.010	3.05	Very Low (I)
Water bodies	1622.49	0.47	0.4	0.025	7.63	Very Low (I)
Pond	1622.49	0.47	0.4	0.001	0.31	Very Low (I)

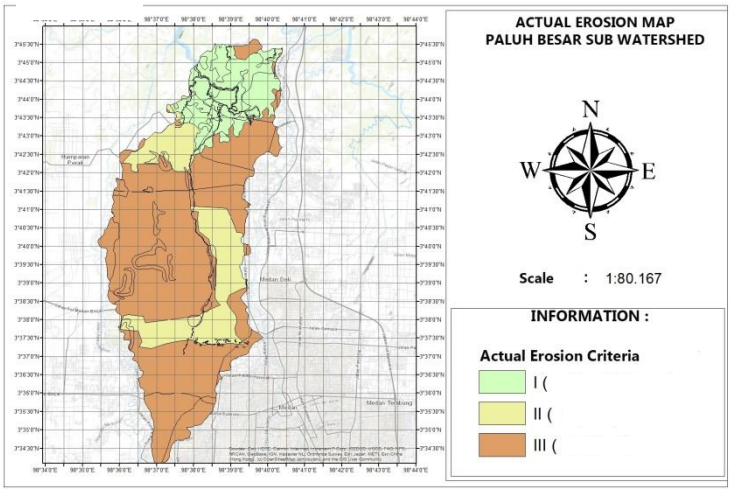

Figure 5. Erosion Class of Sub DAS Paluh Besar Map

Table 9 shown the various erosion value from various land use. It can be seen that there are a very large gap between each variry of land use. This indicates landuse hold important role in reducing or aggravate the erosion hazard level. Hardjowigeno [10] state that vegetation has a big influence on erosion because vegetation blocks rainwater from falling directly on the surface of the land, so that the power to destroy the soil can be reduced. In this case, to reduce the erosion value, conservation actions can be carried out according to Arsyad [11] explains that carrying out

conservation actions in improving of crop will reduce the conservation value (P < 1). Otherwise, without carrying out conservation actions the conservation value will be (P = 1).

4. Conclusion

The result of this study shown the highest erosion occurs in settlement land use. The value is 138.11 ton/ha/year which categorized moderate and the lowest erosion hazard level occurs in Pond landuse which is 0.30 ton/ha/year and categorized as very low. The result shown that land cover unit was the very impactful factor in erosion that shown there are very large gap erosion occurs in between each land use unit.

References

[1] Y. Yudhistira, W. K. Hidayat, A. Hadiyarto, "Kajian Dampak Kerusakan Lingkungan Akibat Kegiatan Penambangan Pasir di Desa Keningar Daerah Kawasan Gunung Merapi [The Study of Environment Damage Causing Sand Mining at Keningar Village Mount Merapi Area],' Jurnal Ilmu Lingkungan, vol. 9, pp. 76-84, 2011.

[2] S. Hutapea, "Kajian Konservasi Daerah Aliran Sungai Deli dalam Upaya Pengendalian Banjir di Kota Medan [The Study of Deli Watershed as an Efforts to Flood Control]," thesis, Faculty of Agriculture, UGM, Yogyakarta, 2012.

[3] W. H. Wischmeier and D. D. Smith, "Predicting rainfall erosion losses – A guide to conservation planning," Department of Agriculture, Agriculture Handbook No.537, US, 1978.

[4] P. L. Bols, "The Iso-Erodent Map of Java and Madura," Belgian Technical Assistance Project ATA 105, Soil Research Institute, Bogor, 1978.

[5] B. Ristanto, E. R. Indrayatie, K. Nisa, "Analisa Tingkat Bahaya Erosi Di Das Asam-Asam Kabupaten Tanah Laut Dengan Sistem Informasi Geografis (Sig) [Analyze of Erosion Hazard Level at Asam Watershed tanah Laut Regency using Geographic Information System]," Undergraduate Thesis, Universitas Lambung Mangkurat, Banjarmasin, 2019.

[6] Departemen Kehutanan [Foresty Department], "Pengetahuan Dasar Pengelolaan Daerah Aliran Sungai. **[**Basic Knowledge of Watershed Management]", Direktorat Rehabilitasi dan Konservasi Tanah [Directorate of Soil Rehabilitation and Conservation], Jakarta, 1998.

[7] Departemen Kehutanan [Foresty Department], Peraturan Direktur Jendral Bina Pengelolaan Daerah Aliran Sungai dan Perhutanan Sosial No. P.3/V-Set/3013 Mengenai Pedoman Identifikasi Karakteristik Daerah Aliran Sungai **[**Regulation of the Director General of Watershed Management and Social Forestry No. P.3/V-Set/3013 Regarding Guidelines for Identification of Watershed Characteristics]," Departemen Kehutanan RI [Indonesian Department of Forestry], Jakarta, 2013.

[8] A. S. Purba, "Aplikasi Sistem Informasi Geografis (Sig) Untuk Menganalisa Potensi Erosi Pada Das Ular [Application of Geographic Information System to analyze Erosion Risk at Ular Watershed]," Undergraduate Thesis, Universitas Sumatera Utara, Medan, 2012.

[9] Arham, R. T. Lopa, B. Bakri, "Pengaruh Hubungan Intensitas Curah Hujan dan Kemiringan Lahan Terhadap Laju Erosi [The Influence of rain Intensity and Land Slope to Erosion]," Undergraduate Thesis, Universitas Hasanuddin, 2013.

[10] S. Hardjowigeno, "Ilmu Tanah [Soil Science]," Penerbit Akademia Pressindo, Jakarta, 2007.

[11] S. Arsyad, "Konservasi Tanah dan Air .Edisi Kedua [Water and Soil Conservation Second Edition]," IPB Press, Bogor, 2012.