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ANALYSIS OF EROSION AND SEDIMENTATION RATES AT KEBUN RAYA BANUA RESERVOIR AND KAMPUNG BANJAR RESERVOIR USING THE USLE METHOD

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ABSTRACT

The Kebun Raya Banua Reservoir and Kampung Banjar Reservoir serve as water retention areas and tourist attractions within the South Kalimantan Provincial Government office complex. Erosion and sedimentation can have detrimental impacts on these reservoirs, necessitating this study to determine the erosion and sedimentation rates of both. This research utilizes various data, including rainfall data, soil type data, topographic data, crop management data, and soil conservation data. The Universal Soil Loss Equation (USLE) method was employed to calculate erosion and sedimentation rates. Analysis results indicate that the Kebun Raya Banua Reservoir experiences an erosion rate of 79,486 tons/ha/year and a sedimentation rate of 25,980 tons/ha/year. Conversely, the Kampung Banjar Reservoir exhibits an erosion rate of 8,779 tons/ha/year and a sedimentation rate of 2,954 tons/ha/year.

Keywords: Erosion, Sedimentation, USLE, Reservoir

1. INTRODUCTION

The Kebun Raya Banua Reservoir and the Kampung Banjar Reservoir function as water storage systems designed to address the disruption of the catchment areas caused by large-scale land clearing in the new government center region. In addition to serving as water storage and fulfilling water supply needs, these reservoirs also function as tourist destinations for the local community. As both reservoirs continue to operate over time, issues arising from natural influences or other factors, such as sedimentation, are unavoidable. The deposition of incoming materials results in sedimentation, which negatively impacts the reservoirs and the surrounding areas. Therefore, analyzing the erosion and sedimentation rates at the Kebun Raya Banua and Kampung Banjar Reservoirs is crucial to determine the extent of sedimentation occurring in both reservoirs.

2. THEORETICAL STUDY

Erosion Rate using the USLE (Universal Soil Loss Equation) Method

The analysis of the erosion equation is shown as the product of the rainfall erosivity (EI) and environmental resistance factors, which include K (soil erodibility), LS

(topographic factor), C (crop management), and P (soil conservation practices), as designed by Wischmeier & Smith (1978) as follows:

$$E_A = EI \times K \times LS \times C \times P \quad \text{.....} \quad (1)$$

Description:

E_A = estimated average annual soil loss (tons/ha/year)

EI = rainfall erosivity factor

K = soil erodibility factor

LS = slope length and steepness factor (topography)

C = crop management factor (cover crops)

P = soil conservation practices factor

1. Rainfall Erosivity (EI)

   The rainfall erosivity factor (EI) represents the erosive power of rainfall in a given area, calculated using the equation from Bols (1978) in Samudera et al. (2021) as follows:

   $$EI = 6{,}119(rain)^{1{,}21}(days)^{0{,}47}(maxP)^{0{,}53} \quad \text{.....} \quad (2)$$

   Description:

   EI = average monthly rainfall erosivity factor (KJ/ha)

   Rain = average monthly rainfall (cm)

   Days = average number of rainy days per month

   MaxP = maximum daily rainfall (cm)

2. Soil Erodibility Factor (K)

   Soil erodibility is the susceptibility of soil to erosion, and its value is obtained based on Puslitbang Pengairan Bogor (1985).

3. Slope Length and Steepness Factor (LS)

   Erosion increases with the slope's steepness and length Asdak (2002). The LS value is obtained based on Kementerian Kehutanan Republik Indonesia (2009).

4. Crop Management Factor (C)

   The C factor integrates the effects of soil cover and plant coverage. The value of the crop management factor (C) is obtained based on studies by Sarief (1985), Suripin (2002), and Arsyad (2010) in Naharuddin (2020).

5. Soil Conservation Practices Factor (P)

The P value is the ratio between the erosion occurring under a specific soil conservation practice and the erosion in cultivated land. The value of the soil conservation factor is based on the work of Seta (1987), Suripin (2002), and Arsyad (2010) in Naharuddin (2020).

Sedimentation Rate using the USLE (Universal Soil Loss Equation) Method

The sedimentation rate refers to the amount of sediment from a river flowing into a reservoir located downstream over a certain period of time. Before calculating the sedimentation rate, the SDR (Sediment Delivery Ratio) is first determined using the USDA (United States Department of Agriculture) equation from 1979, as presented by Cahyono et al. (2017) below.

$$SDR = 0{,}5656 \times A^{-0{,}11} \quad \text{(3)}$$

Description:

SDR = Sediment Delivery Ratio, with values 0 < SDR < 1

A = catchment area (ha)

Once the SDR value is obtained, the sedimentation rate for the USLE method is calculated using the following equation:

$$Sy = SDR \times E_A \quad \text{(4)}$$

Sy = sedimentation rate (tons/ha/year)

SDR = Sediment Delivery Ratio

E_A = erosion (tons/year)

3. METHOD

Research Location

The research was conducted in the Watershed of the Kebun Raya Banua Reservoir and Kampung Banjar Reservoir, located in Cempaka District, South Kalimantan Province, as shown in Figure 1 below.

Figure 1. Research Location

Research Procedure

This research was conducted by collecting the necessary data, including rainfall data, soil type data, topographic data, crop management data, and soil conservation data. Rainfall data was obtained from the BMKG Online website of the Class I Climatology Station in South Kalimantan for a period of 20 years, from 2004 to 2023. Soil type and topographic data were obtained from the official websites of BAPPEDA Banjarbaru City and Geoportal Indonesia and were subsequently analyzed using ArcGIS software. Crop management and soil conservation data were obtained through land cover analysis using Google Earth. These data were then analyzed using the USLE method to determine the erosion rate and sedimentation rate.

4. RESULT AND DISCUSSION

Analysis of Rainfall Erosivity Factor (EI)

The rainfall erosivity factor at the research location was calculated based on equation (2) using maximum daily rainfall data, average monthly rainfall data, and the number of rainy days per month. These values were then averaged to obtain the annual average rainfall erosivity factor, as shown in Table 1 below.

Table 1. Annual Rainfall Erosivity Factor (EI) Values

Year	EI	Year	EI
2004	744,955	2014	589,230
2005	487,621	2015	623,627
2006	592,239	2016	845,116
2007	740,608	2017	969,030
2008	890,064	2018	771,193
2009	735,213	2019	445,604
2010	971,253	2020	933,466
2011	807,459	2021	1240,660
2012	494,478	2022	787,731
2013	640,974	2023	734,121

The value of the average annual rainfall erosivity, EI = 752.232 KJ/ha.

Analysis of Soil Erodibility Factor (K)

The soil erodibility factor (K) for the soil type map of the Kebun Raya Banua Reservoir watershed and the Kampung Banjar Reservoir watershed can be seen in Figure 2 below.

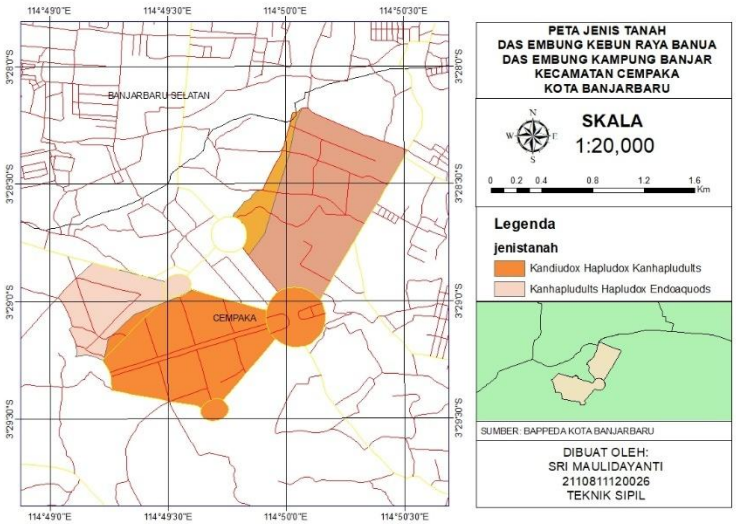

Figure 2. Soil Type Map of the Kebun Raya Banua Reservoir Watershed and the Kampung Banjar Reservoir Watershed

The value of the K factor refers to the Puslitbang Pengairan Bogor (1985). Based on these sources, the Kandiudox soil classification is categorized as yellowish-red latosol with a K value of 0.054, and the Kanhapludults classification is categorized as yellowish-red podzol with a K value of 0.166. These K values were averaged considering the land area, resulting in the K value shown in Table 2 below.

Table 2. Soil Erodibility Factor (K) Value

Reservoir	Classification	Area (ha)	Area Percentage (%)	K Value	Average K
Kebun Raya Banua Reservoir	Kandiudox Hapludox Kanhapludults	107,025	73%	0,054	0,084
	Kanhapludults Hapludox Endoaquods	39,210	27%	0,166	
Kampung Banjar Reservoir	Kandiudox Hapludox Kanhapludults	98,801	88%	0,054	0,067
	Kanhapludults Hapludox Endoaquods	13,426	12%	0,166	

The K value used for the Kebun Raya Banua Reservoir watershed is 0,084, and for the Kampung Banjar Reservoir watershed, it is 0,067.

Analysis of Slope Length and Steepness Factor (LS)

The slope length and steepness factor (LS) for the topographic map of the Kebun Raya Banua Reservoir watershed and the Kampung Banjar Reservoir watershed can be seen in Figure 3 below.

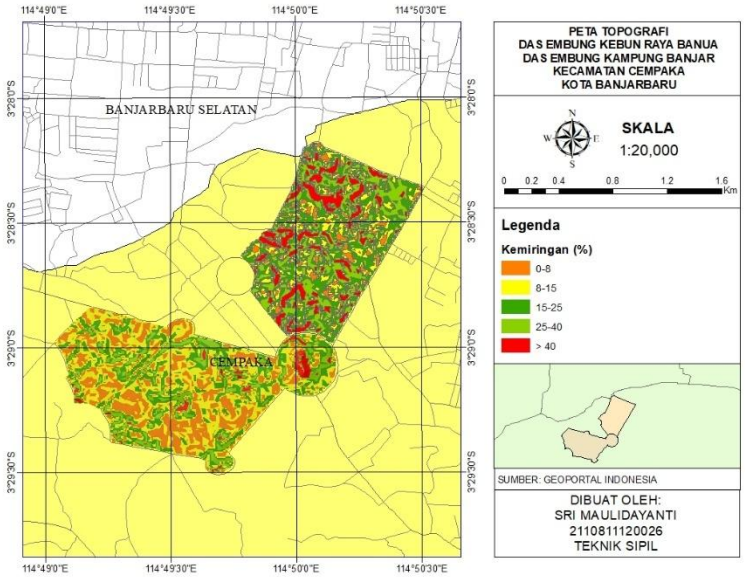

Figure 3. Topographic Map of the Kebun Raya Banua Reservoir Watershed and the Kampung Banjar Reservoir Watershed

The LS factor values refer to Kementerian Kehutanan Republik Indonesia (2009). Based on these sources, the LS value for a slope of 0 – 8% with a flat classification is 0,4, a

slope of 8 – 15% with a slope classification of 1,4, a slope of 15 – 25% with a rather steep classification is 3,1, a slope of 25 – 40% with a steep classification is 6,8, and a slope of > 40% with a very steep classification is 9,5. The value is leveled by paying attention to the area of land so that the LS value can be seen in Table 3 below.

Table 3. Slope Length and Steepness (LS) Values

Reservoir	Class	Slope (%)	Classification	Area (ha)	Area Percentage (%)	LS Value	Average LS
Kebun Raya Banua Reservoir	I	0 – 8%	Flat	41,409	28,32%	0,4	2,301
	II	8 – 15%	Slope	50,942	34,84%	1,4	
	III	15 – 25%	Rather Steep	34,727	23,75%	3,1	
	IV	25 – 40%	Steep	15,202	10,40%	6,8	
	V	> 40%	Very Steep	3,954	2,70%	9,5	
Kampung Banjar Reservoir	I	0 – 8%	Flat	8,641	7,70%	0,4	4,641
	II	8 – 15%	Slope	19,978	17,80%	1,4	
	III	15 – 25%	Rather Steep	33,547	29,89%	3,1	
	IV	25 – 40%	Steep	33,410	29,77%	6,8	
	V	> 40%	Very Steep	16,651	14,84%	9,5	

The LS value used for the Kebun Raya Banua Reservoir watershed is 2,301 and for the Kampung Banjar Reservoir watershed, it is 4,641.

Analysis of Crop Management Factor (C)

The crop management factor (C) for the crop management map of the Kebun Raya Banua Reservoir watershed and the Kampung Banjar Reservoir watershed can be seen in Figure 4 below.

Figure 4. Crop Management Map of the Kebun Raya Banua Reservoir Watershed and the Kampung Banjar Reservoir Watershed

The crop processing map refers to Sarief (1985), Suripin (2002), and Arsyad (2010) in Naharuddin (2020). Based on these sources, it was obtained that the C value for asphalt, buildings, and vacant land was 1.0; for parks, it was 0.7; and for forests, it was 0.001. The C value is calculated based on land use for the purpose of erosion and sedimentation rate analysis. The results of the analysis of the C factor value can be seen in Table 4 below.

Table 4. Crop Management Factor (C) Values

Embung	Land Type	Area (ha)	Area percentage (%)	Koefisien C
Kebun Raya Banua Reservoir	Asphalt	20,094	13,74%	1,00
	Parks	32,974	22,55%	0,70
	Buildings	26,817	18,34%	1,00
	Vacant Land	9,869	6,75%	1,00
	Forest	56,481	38,62%	0,001
Kampung Banjar Reservoir	Parks	5,830	5,20%	0,70
	Forest	106,397	94,80%	0,001

Analysis of Soil Conservation Factor (P)

The value of the soil conservation factor (P) refers to Seta (1987), Suripin (2002), and Arsyad (2010) in Naharuddin (2020). Based on the results of land digitization data processing using Google Earth software for the Kebun Raya Banua Reservoir watershed and the Kampung Banjar Reservoir watershed, as shown in Figure 4, there are no soil conservation measures in place, the value of P = 1.

Analysis of Erosion Rate

The erosion rate analysis refers to equation (1), which can be seen in Table 5 below.

Table 5. Erosion Rate Value

Reservoir	Land Type	EI (KJ/ha)	K	LS	C	P	A (Ha)	E_A (tons/year)
Kebun Raya Banua Reservoir	Asphalt	752,232	0,084	2,301	1	1	20,094	2922,499
	Parks	752,232	0,084	2,301	0,7	1	32,974	3357,126
	Buildings	752,232	0,084	2,301	1	1	26,817	3900,422
	Vacant Land	752,232	0,084	2,301	1	1	9,869	1435,360
	Forest	752,232	0,084	2,301	0,001	1	56,481	8,215
Kampung Banjar Reservoir	Parks	752,232	0,067	4,641	0,7	1	5,830	960,195
	Forest	752,232	0,067	4,641	0,001	1	106,397	25,032

Based on the values in Table 5 above, the total erosion rate in the Kebun Raya Banua Reservoir watershed is 11.623,622 tons/year, and in the Kampung Banjar Reservoir watershed, it is 985,228 tons/year. To determine the erosion rate per hectare, the erosion rate is divided by the total land area, resulting in an erosion rate of 79,486 tons/ha/year for the Kebun Raya Banua Reservoir watershed and 8,779 tons/ha/year for the Kampung Banjar Reservoir watershed.

Analysis of Sedimentation Rate

Before analyzing the sedimentation rate, the SDR is first calculated using equation (3). Once the SDR value is obtained, the sedimentation rate is calculated using equation (4). The results of the sedimentation rate analysis can be seen in Table 6 below.

Table 6. Sedimentation Rate Value

Reservoir	SDR	Sy (tons/ha/year)
Kebun Raya Banua Reservoir	0,327	25,980
Kampung Banjar Reservoir	0,337	2,954

Based on the values in Table 6 above, the erosion rate for the Kebun Raya Banua Reservoir watershed is 25,980 tons/ha/year, and for the Kampung Banjar Reservoir watershed, it is 2,954 tons/ha/year.

5. CONCLUSION

Based on the analysis results, the erosion rate in the Kebun Raya Banua Reservoir watershed is 79,486 tons/ha/year, and the sedimentation rate is 25,980 tons/ha/year. Meanwhile, in the Kampung Banjar Reservoir watershed, the erosion rate is 8,779 tons/ha/year, and the sedimentation rate is 2,954 tons/ha/year.

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