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EROSION AND SEDIMENTATION ANALYSIS IN CEMPAKA AND GUNUNG KUPANG RESERVOIRS USING THE USLE METHOD IN CEMPAKA DISTRICT, BANJARBARU CITY

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ABSTRACT

Floods are one of Indonesia's most frequent natural disasters, especially in densely populated cities. Major floods in February 2023 hit Cempaka and Gunung Kupang Districts. To overcome this problem, the government built the Cempaka Embung and the Gunung Kupang Embung to control flooding and increase water infiltration into the ground. Land use changes upstream of the reservoir greatly affect the reservoir, especially land erosion and sedimentation that enter the reservoir body, which will reduce the performance of the reservoir in reducing flooding. Therefore, erosion and sedimentation analysis is needed to support better management in flood control in Cempaka District. The data used in this study are land use data, soil type data, topographic data, conservation data, and location photos are secondary data. In this study, the rate of erosion and sedimentation was calculated using the USLE method. Based on the results of the analysis, it was found that the erosion rate of the USLE method in the Cempaka Reservoir was 131.934 tons/ha/year, and the sediment rate was 38.0765 tons/ha/year. In the Gunung Kupang Reservoir, the USLE method erosion rate was 18,790 tons/ha/year, and the sediment rate was 6,057 tons/ha/year.

Keywords: Watershed Erosion, Reservoir Sediment, USLE, Reservoir

1. INTRODUCTION

Indonesia is in an area that is vulnerable to various types of disasters, including natural disasters. Natural disasters are natural phenomena that can destroy the environment and cause damage, casualties, and damage to existing buildings (Wahyuningsih et al., 2022). In some areas in Indonesia, especially in densely populated areas such as cities, flooding is a common problem. The problem of flooding must receive serious attention because of the potential for great losses, both material and human. If the flood does not interfere with the activities or interests of the community, the flood is not a problem; however, when community activities in floodplains will become a problem (Wahyuningtyas et al., 2017).

Floods are usually caused by several factors, one of which is the erosion of land that enters water bodies into sedimentation, causing a decrease in reservoir capacity. Erosion is an event in which natural media such as water and wind transport soil or parts of land from one place to another. Erosion causes the soil layer to disappear, which reduces the soil's ability to absorb and retain rainwater. One of the efforts that can be made is to ensure

that the erosion that occurs does not exceed the rate of soil formation. Erosion caused by human activities is usually caused by deforestation, mining, and plantations. The deposition of material formed by erosion into river flows and forms alluvial plains is called sedimentation. This process is considered to interfere with the flow of the river because sedimentation in the flow (body) of the river can reduce the volume of water that passes through the river so that the water overflows around the river body (Roy, 2021). According to news published by Banjarmasinpost, in February 2023, Cempaka District experienced a major flood. Almost the entire Area of Cempaka, Mount Kupang, and its surroundings were hit by floods due to high and prolonged rainfall. High rainfall disrupts the flow of water on the surface, inundating the surrounding Area, which is the main cause of flooding in Cempaka and Mount Kupang. To reduce flooding, the Banjarbaru city government built the Cempaka Embung and the Gunung Kupang Embung, which are water storage systems built to reduce or reduce flooding and increase the availability of groundwater. The existence of land erosion and sedimentation upstream of the reservoir can affect its performance, so an Erosion and Sedimentation Analysis in the Cempaka Reservoir and Mount Kupang is needed for flood control in the Cempaka District.

2. THEORETICAL STUDY

Land Erosion

Soil erosion is a process or event of loss of the upper soil surface layer, either caused by the movement of water or wind. This erosion process can cause a decline in soil productivity, soil carrying capacity, and environmental quality (Hariati et al., 2022). Based on the Ministry of Forestry of the Republic of Indonesia (2009), the level of erosion hazard is divided into 5 (five) classes, which are as follows.

Table 1. Erosion Hazard Level Classification

Class	Erosion Rate (tons/ha/year)	Classification
I	0 – 15	Very Low
II	15 – 60	Low
III	60 – 180	Moderate
IV	180 – 480	High
V	> 480	Very High

References: Kementerian Kehutanan Republik Indonesia (2009)

The Universal Soil Loss Equation (USLE) was developed at the National Runoff and Soil Loss Data Center, established in 1954 by the Science and Education Administration of the United States in collaboration with Purdue University (Wischmeier and Smith, 1978).

The USLE formula is expressed as:

E_A= Rw.K.L.S.C.P.....(1)

Where:

E_A = It is the amount of soil eroded in (tons/ha/year).

Rw = It is the factor of rainfall and surface runoff, namely the amount of rainfall erosion index units, obtained by multiplying the total rainfall energy with the maximum 30-minute rainfall intensity (30 years). There are two commonly used equations to calculate rainfall erosivity (Rw): the Bols equation (1978) and the Lenvain equation (1975).

a) The Bols equation is used when rainfall data such as monthly rainfall, the number of rainy days in a month, and maximum 24-hour rainfall in a complete month are available. The following is the Bols equation (1978).

$EI = 6{,}119\ (Rain)^{1,98}(Day)^{-0,47}(MaxP)^{0,53}$.....(2)

Rain: Average monthly rainfall (cm)

Day : Average monthly number of rainy days

MaxP : Maximum daily rainfall (cm)

b) The Lenvain equation is used when rainfall data such as monthly rainfall, the number of rainy days in a month, and maximum 24-hour rainfall in a month are not available. The following is the Lenvain equation (1975)

$EI_{30} = 2{,}34\ R^{1,98}$.....(3)

R: Monthly Rainfall (cm)

K = Soil erodibility factor, soil erodibility refers to the rate of erosion per rainfall erosion index for a specific type of soil obtained from a standard experimental plot.

LS = The slope length and steepness factor (LS) consists of two components, namely the slope length factor and the slope steepness factor, which can be determined based on the slope map. The slope map of the study location

C = The vegetation cover factor and crop management factor; the vegetation factor is obtained from the amount of erosion in an area with specific vegetation cover and crop management practices (Jasmadi, 2022).

Table 2. The C Factor Value in Crop Management

No	Land used	Value Factor C
1.	Open ground without plants	1,0
2.	Forests and Shrubs	0,001

No	Land used	Value Factor C
3.	Savannah and Prairie are in good shape	0,01
4.	Broken savannah and prairie for shepherding	0,1
5.	Paddy	0,01
6.	Tegalan is not specified	0,7
7.	Cassava	0,8
8.	Corn	0,7
9.	Soybean	0,399
10.	Potato	0,4
11.	Peanut	0,2

Sumber: Sarief (1985), Suripin (2002), dan Arsyad (2010) dalam (Naharuddin, 2020)

P = The average eroded soil from land that received certain conservation treatment compared to the average eroded soil from land that was cultivated without conservation measures, with the note that other erosion-causing factors were assumed to remain unchanged (Nugraheni et al., 2013)

Table 3. The P Factor Value for Various Soil Conservation Practices

No	Soil Conservation Actions	P Factor Value
1.	Without erosion control action	1,00
2.	Bench terrace	
	Good construction	0,04
	Medium construction	0,15
	Poor Construction	0,35
	Traditional terrace	0,40
3.	Plant strips	
	Bahia grass	0,40
	Clotararia	0,64
	With contours	0,20
4.	Tillage and planting according to contour lines	
	Slope 0 – 8%	0,50
	Slope 8 – 20%	0,75
	Slope > 20%	0,90

References: Seta (1987), Suripin (2002), Arsyad (2010) dalam (Naharuddin, 2020)

Sedimentation Rate

The sedimentation rate is the amount of sediment from the river that flows into the reservoir located downstream of the river in a certain period of time. Before calculating the sedimentation rate, the SDR is first calculated, which is the ratio between the amount of sediment measured at the outlet and erosion in the land. To calculate SDR, you can use the equation of the DPU of the Director General of Irrigation (1999):

$$SDR = S\frac{(1-0{,}8683(A^{-0{,}2018}))}{2(S+50.n)} + 0{,}8683(A^{-0{,}2018}) \quad \text{.....(4)}$$

With:

SDR = *Sediment Delivery Ratio*, nilainya 0 < SDR < 1

A = Area DAS (ha)

S = Average slope slope of the surface DAS (%)

n = coef Manning

So, the rate of sedimentation.

$Sy = SDR\ x\ A$.....(5)

dengan:

Sy = Sedimentation rate (ton/ha/tahun)

SDR = *Sediment Delivery Ratio*

E_A = Erosion (tons/Year)

(Putri dkk., 2023)

3. METHOD

Research Location

The location of this research is in Cempaka District, Banjarbaru City, South Kalimantan Province. Geographically, Cempaka District is located at 233º 27' LS and 114º 45' E; the map of the research location can be seen in the figure below.

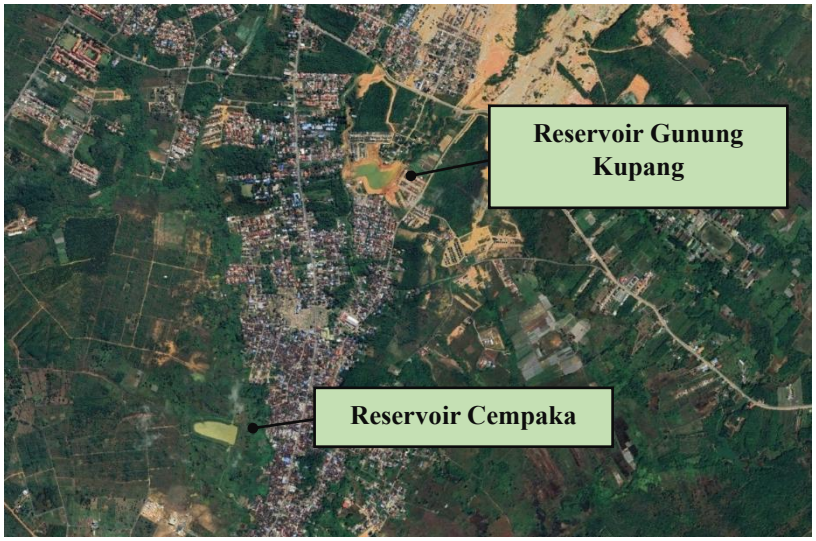

Figure 1. Research Location

Research Procedure

The first stage is to prepare and collect secondary data, namely rainfall data for 20 years, soil type, land cover, and slope or DEM (*Digital Elevation Model*) found in the embung sub-watershed. After all the data is obtained, it is then processed by analyzing it on ArcGIS and through the calculation of rain erosivity analysis for the calculation of rain

data. The processed data is then included in the calculation of erosion rate and sedimentation rate.

4. RESULT AND DISCUSSION

Digitization of Land Use

Land use in this study takes the Area of the Watershed (DAS - Daerah Aliran Sungai) of Cempaka Reservoir and Gunung Kupang Reservoir in Banjarbaru City. The data used in this study were sourced from manual digitization through Google Earth, and as a reference for the Watershed, river distribution data was used. After digitizing, the watershed Area was obtained, which was then divided and shaded according to different land use areas. The Area of each land use type is shown below.

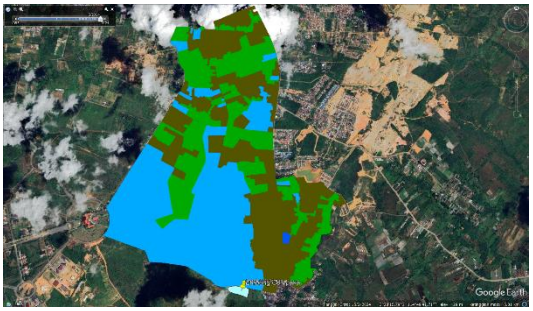

Figure 2. Watershed Area Digitization of Cempaka Reservoir

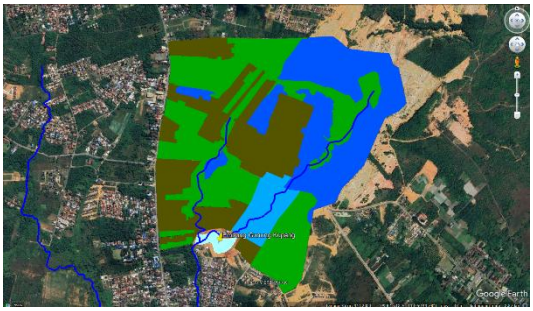

Figure 3. Watershed Area Digitization of Gunung Kupang Reservoir

Rainfall Erosivity Factor (EI)

The value of the rainfall erosivity factor (EI) is obtained from the average monthly rainfall data, maximum monthly rainfall data, and the number of rainy days per month. The monthly rainfall erosivity factor value is then averaged to obtain the annual rainfall erosivity factor using equation (2).

Soil Erodibility Factor (K)

Soil type data for the Cempaka Reservoir and Gunung Kupang Reservoir watersheds are processed using ArcGIS software, with the soil data sourced from the Badan Perencanaan, Penelitian, dan Pengembangan Daerah (BAPPEDA) of Banjarbaru City.

Slope Length and Steepness Factor (LS)

Topographic maps and analysis results for the Cempaka Reservoir and Gunung Kupang Reservoir watersheds are created using ArcGIS software with DEMNAS (National Digital Elevation Model) data from the Ina-Geoportal website of the Geospatial Information Agency (Spatial Information Agency), and world imagery base map data in ArcGIS.

Erosion Rate Using the USLE Method

The erosion rate is calculated based on each type of land use, with the aim of determining the erosion rate for each land use type. To determine the average annual erosion rate for the Cempaka Reservoir and Gunung Kupang Reservoir watersheds, the erosion rates for each land use type are summed up

Table 4. The Factor Value for Each Land Use Type

Land Use	K	LS	C	P
Settlement	752,232	0,102	5,752	0,4
Meadows/shrubs	752,232	0,102	5,752	0,1
Forests/plantations	752,232	0,102	5,752	0,45
Empty (open ground without plants)	752,232	0,102	5,752	0,2

Total Erosion in the Cempaka Reservoir Watershed = 19512,141 tons/year

Total Area of the Watershed = 453,382 ha

Erosion Rate of the Cempaka Watershed = Total Erosion / total erosion

$$= \frac{19512,141}{453,382} = 131,934 \text{ tons/ha/year}$$

Total Erosion in the Gunung Kupang Reservoir Watershed = 3116,029 tons/year

Total Area of the Watershed = 165,531 ha

Erosion Rate of the Gunung Kupang Watershed = Total Erosion / total erosion

$$= \frac{3116,029}{165,531} = 18,790 \text{ tons/ha/year}$$

The results of the Erosion Rate analysis with equation (1) for the Usle method in the Cempaka Embung and the Gunung Kupang Embung it is obtained for each class in Table 5 as follows.

Table 5. Class Recap of Erosion Rate Classification USLE Method

Location	Erosion Rate (E_A) (Tons/ha/Year)	Class	Classification
Cempaka	131,934	III	Moderate
Gunung Kupang	18,790	II	Low

Based on the analysis in Table 5, it is known that the value of the erosion rate in the Cempaka Reservoir is dominated by the moderate classification, and for the Mount Kupang Reservoir, the light classification is obtained. (E_A)

Sedimentation Rate Using the USLE Method

Based on the results of the calculation with equation (5), the sediment rate values in the Cempaka Reservoir and Guung Kupang Reservoir are obtained in Table 6 as follows.

Table 6. Recap of Erosion Rate and Sediment Rate

Location	Erosion Value ($tons/ha/year$)	SDR Value	Sy ($ton/year$)
Cempaka Reservoir	131,934	0,288	38,076
Gunuung Kupang Reservoir	18,790	0,322	6,057

Based on the analysis in Table 6, it was found that the value of the erosion rate and sedimentation rate in the Cempaka Reservoir was 38.076 tons/ha/year and for the Mount Kupang Reservoir was 6.057 tons/ha/year.

5. CONCLUSION

From the results of the analysis and discussion that has been carried out, it can be concluded as follows.

1. Based on the results of the analysis of the erosion rate in the Watershed in the Cempaka Reservoir and Mount Kupang areas, it was concluded that the erosion rate in the Cempaka Reservoir watershed before the reservoir was built was 131.934 tons/ha/year (moderate erosion hazard level). As for the Gunung Kupang Reservoir watershed, it is 18,790 tons/ha/year (light erosion hazard level) after the reservoir is built.

1. Based on the results of the calculation analysis on the Cempaka Reservoir, the sediment rate value was 38,076 tons/ha/year, while in the Gunung Kupang Reservoir, the sediment rate was 6,057 tons/ha/year after the reservoir was built.

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