

Research Article

# Analysis of Erosion Rate and Mainstay Discharge Programming in Ake Lamo Basin, North Maluku

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## Abstract

One of the potential sources of water resources that is quite large and strategic is the river. One of these rivers is the Ake Lamo River which is used to support local water needs. To support these needs, there are plans in the construction of reservoirs so that it is necessary to analyze the erosion rate and mainstay discharge using digital elevation model (DEM) data and meteorological data. Based on spatial analysis using digital elevation model (DEM), the catchment value of Ake Lamo watershed is 335.71 km<sup>2</sup>, land slope is 4.54 which can be classified as a rather steep slope level, and land cover includes dry forest with an area of 260.41 km<sup>2</sup>, shrubs with an area of 45.27 km<sup>2</sup>, reeds with an area of 18.00 km<sup>2</sup>, and water bodies with an area of 12.03 km<sup>2</sup>. Based on the spatial analysis, the erosion rate value was 86.64 tons/ha/year with class III classification in the form of moderate erosion hazard level. The mainstay discharge analysis was conducted using the F.J Mock method with the help of MATLAB software to obtain a value of 10.47 m<sup>3</sup>/s

**Keywords:** catchment area, erosion rate, soil physical characteristics

## ARTICLE INFO

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## 1. Introduction

One of the important natural resources for the life of all living things is water. According to UU No. 17 of 2019, water as part of water resources is an important branch of production and controls the livelihood of many people who are controlled by the state to be used for the greatest prosperity of the people. There are various large and strategic potential sources of water resources that can support the needs of living things, including rivers. Ake Lamo River is a water resource that is used to support local water needs. To support these needs, there is a plan to build a reservoir through an analysis of the Ake Lamo River discharge. Analysis of river discharge in the form of water demand is very useful in planning river water utilization projects for raw water supply, irrigation, hydropower generation, and other uses (Sachro et al., 2013). In addition, watershed analysis and management can optimize the benefits of soil, water, and vegetation in alleviating droughts, floods, preventing soil erosion and increasing water availability in a sustainable manner (Rao et al., 2020).

The flow discharge of a river has a fluctuating nature where it will change all the time depending on the natural events that are happening (Mughtar & Abdullah, 2007). When the rainy season occurs, the discharge state will increase. Vice versa, the dry season will cause the discharge to decrease. In a long dry season, some areas will be threatened by drought. To overcome this, sustainable management of water resources is needed. There are various efforts in overcoming the disaster, one of which is the planning of the mainstay discharge to estimate the flow rate that will remain available with certain reliability for a long time and the calculated risk of failure. This calculation is used so that the fulfillment of water needs can be adjusted to the available

potential (Jatiningrum & Amalia, 2021). Based on the existing water potential, it is hoped that it can be used to meet water needs in the region and be utilized sustainably.

The construction of a reservoir on the Ake Lamo River, apart from acting as a water reservoir, is also used to accommodate soil drift due to erosion from the area above it to secure the area below it from flooding and erosion (Asrib, 2012). Soil washed away due to erosion will form sedimentation in the reservoir which will gradually cause a reduction in the volume, area, and depth of the reservoir. Therefore, it is necessary to calculate the erosion rate which can then be used as a consideration in determining the sedimentation control model so that the reservoir capacity can be maintained, and the utilization of the reservoir function can be sustainable while maintaining the surrounding nature.

## 2. Methodology

### 2.1 Erosion rate

Modeling erosion rates can use the Universal Soil Loss Equation (USLE) method, the origin of the USLE type model is in the United States to provide a management decision support tool and is based on thousands of controlled studies on field plots and small watersheds since 1930 (Alewell et al., 2019). The USLE method is a commonly used method because it is simple and can be used in areas where the main factors causing erosion in the area are rainfall and surface runoff (Arifandi & Ikhsan, 2019). The following is the formula for calculating the erosion rate:

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

Where

A = erosion rate

R = rain erosivity Index

K = soil erodibility factor

LS = length and slope factor

CP = vegetation and soil management factors

Based on the erosion rate formula, the following is the workflow of the erosion rate:

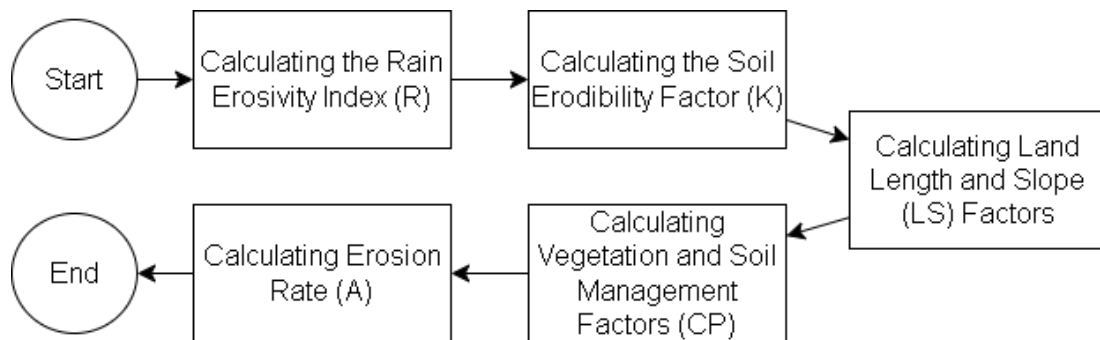


Figure 1. Erosion rate flowchart

Based on the results of the erosion rate calculation, the erosion hazard level can be determined. Based on the Kementerian Kehutanan (2009), the level of erosion hazard can be classified into 5 classes with the following information:

Table 1. Erosion hazard classification

No	Classification	Soil loss (ton/ha/year)	Description
1	I	<15	Very Light
2	II	16 - 60	Light
3	III	60 - 180	Medium
4	IV	180 - 400	Heavy
5	V	>400	Very Heavy

Source: Kementerian Kehutanan, 2009

## 2.2 Calculation of mainstay discharge

The data used in the calculation of the mainstay discharge using the Mock method is secondary data in the form of meteorological data derived from the Sriwijaya Rainfall Station with coordinates 1°34'33" S and 127°26'55" E. The data obtained from the Sriwijaya Rainfall Station are as follows (Departemen PU, 2006).

1. Monthly rainfall from 2007 to 2021.
2. Monthly rainy days (n) from 2007 to 2021.
3. Monthly average temperature (T) in 2007 to 2021.
4. Solar irradiation (S) in 2007 to 2021.
5. Monthly average relative humidity (h) in 2007 to 2021.
6. Monthly average wind speed (w) in 2007 to 2021.

The use of the Mock model is done because river discharge data is not available. Therefore, the calculation of the mainstay discharge is obtained through an approach (empirical) using rain data through the transformation of rain into flow following the principle of water balance to estimate the water availability of a river (Tunas, 2007).

Through the Mock method, rain falling on the watershed will partly be lost as evapotranspiration, partly as runoff, and partly as infiltration into the soil. In the Mock method, soil moisture storage (SMS) will be calculated for each month. If the value of the SMS is greater than the soil moisture capacity (SMC), then a water surplus (WS) will be formed because of water flowing downward due to gravity (percolation) to saturated aquifers in the form of ground water that will exit into the river as base flow and some water that forms direct runoff in the form of storm runoff. The value of groundwater storage is obtained through the calculation of infiltration value through infiltration factor (i), soil flow recession (k), and storm runoff factor (PF). If the value of the SMS is smaller than the SMC, then there is no excess water (WS = 0). Then, these steps are made in a program using MATLAB software to get the value of the discharge on the Ake Lamo River. The following is the flow of the Mock method in the calculation of discharge in this study.

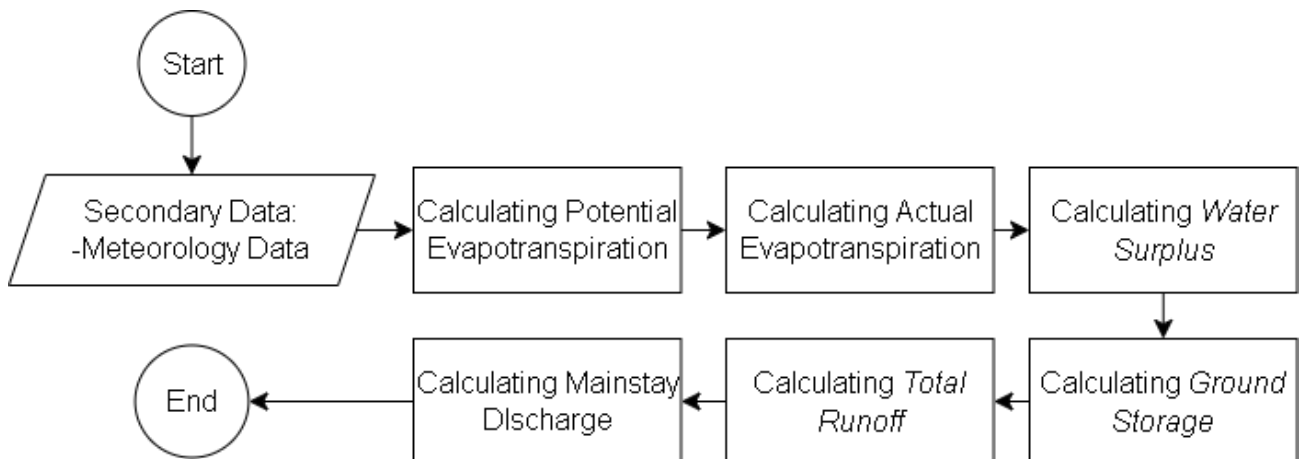


Figure 2. Flowchart mock method

## 3. Result and Discussion

### 3.1 Spatial analysis of the Ake Lamo River watershed

Based on the topography and land use approach using digital elevation model (DEM) data, a spatial analysis using GIS (Geographic Information System) software will be conducted in the Ake Lamo watershed.

Figure 3 shows a map of the Ake Lamo River catchment area. The red line on the map shows the catchment area of the Ake Lamo River with a catchment area of 335.71 km<sup>2</sup>.

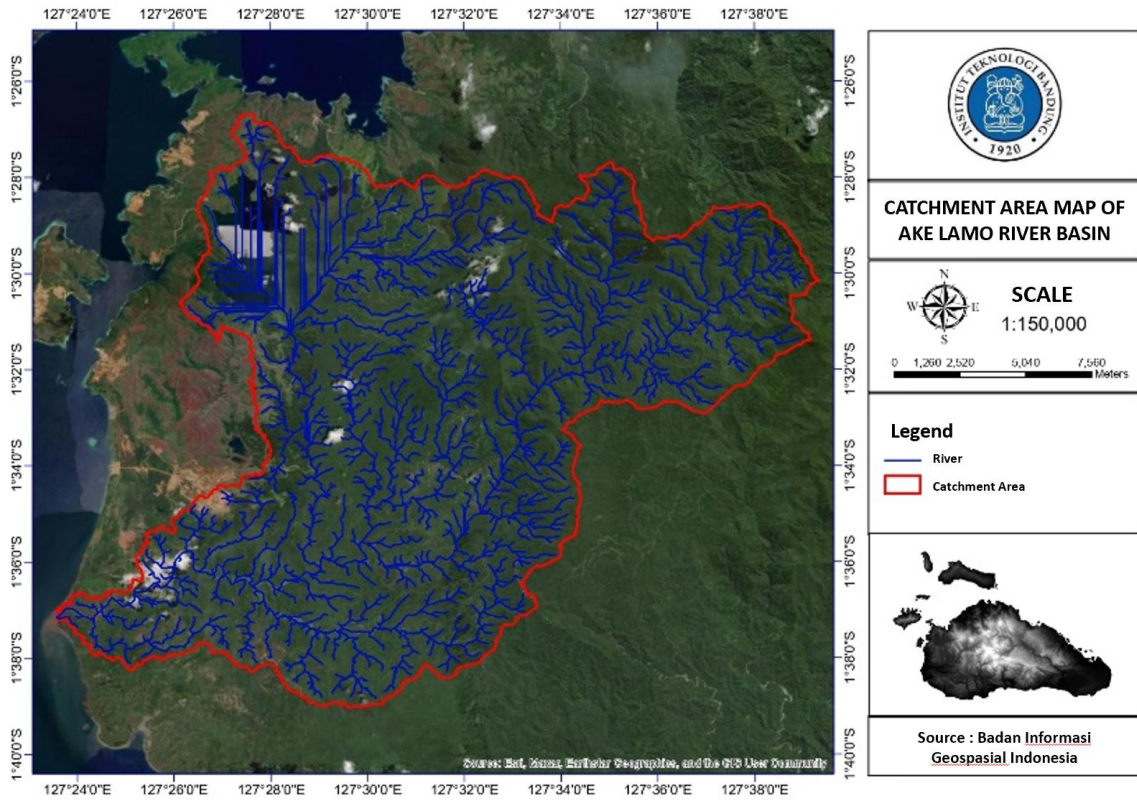


Figure 3. Ake lamo watershed catchment area map

Land slope analysis is obtained through the level of land slope in the Ake Lamo watershed. The following is a map of land slope in the Ake Lamo watershed using a geographic information system (GIS).

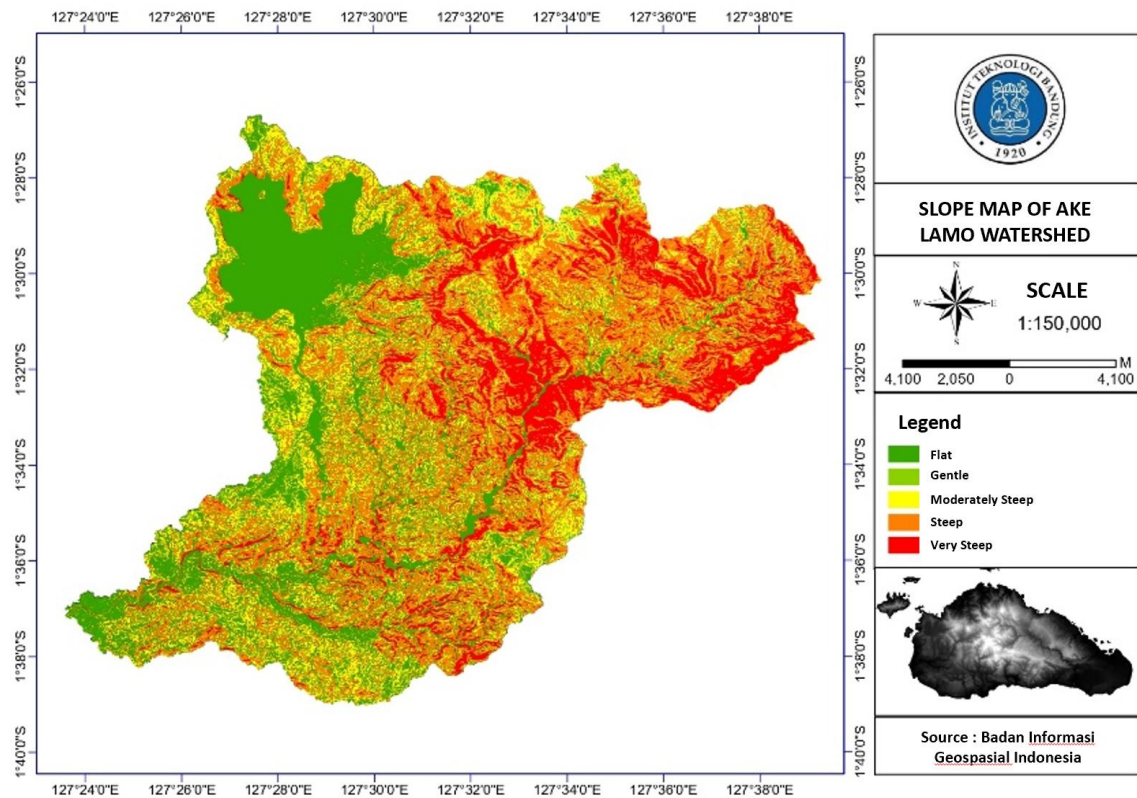


Figure 4. Slope map of Ake Lamo watershed

Based on the results of the analysis in Figure 4, the value of the slope area in each land slope class is obtained as follows.

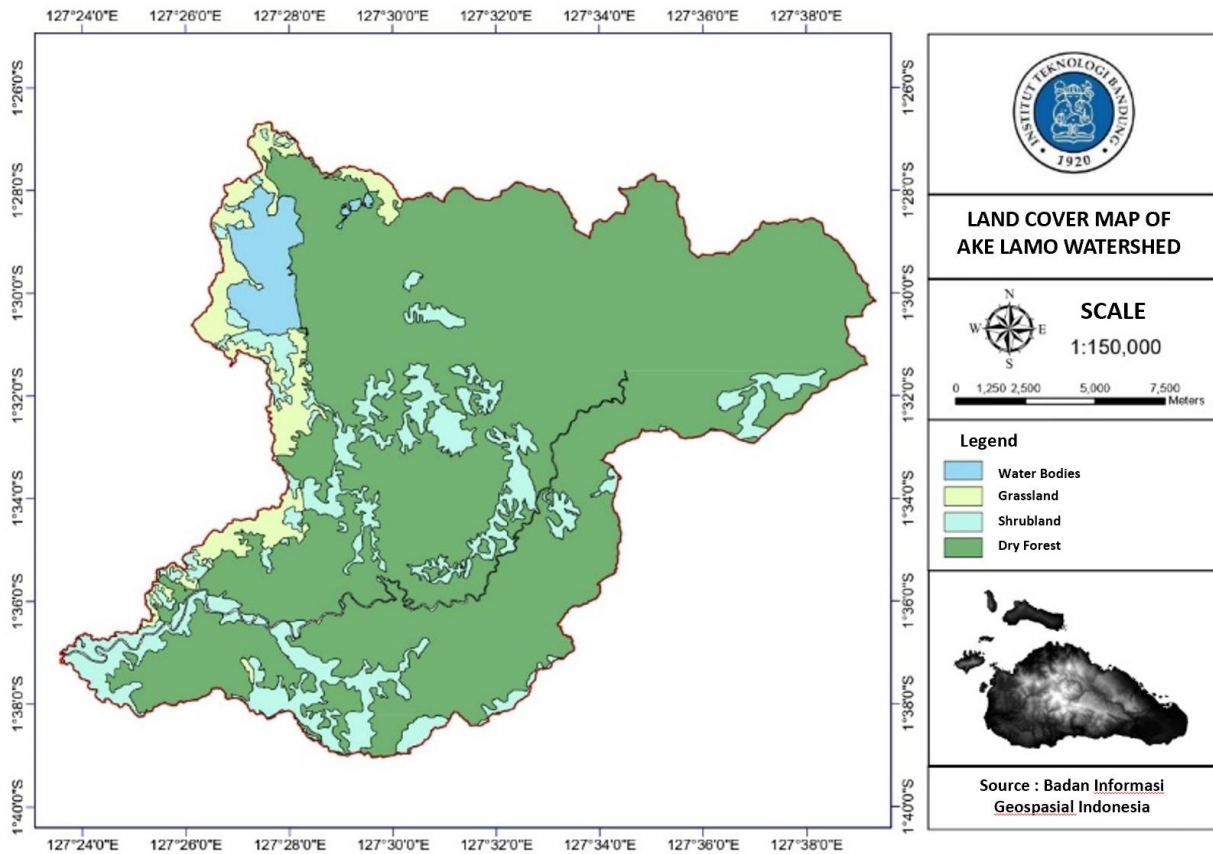
**Table 2.** Land slope area of ake lamo watershed

Class	Slope (%)	Area (km <sup>2</sup> )
Flat	0 – 8	60.95
Ramps	8 – 15	33.14
Slightly Steep	15 – 25	87.12
Steep	25 – 45	107.37
Very Steep	>45	46.13

Source: Sinaga, J., 2014

In Table 2, the level of slope varies from flat (0 - 8%), ramps (8% - 15%), slightly steep (15% - 25%), steep (25% - 45%), and very steep (>45%). With a land area in a flat area of 60.95 km<sup>2</sup>, in a sloping area of 33.14 km<sup>2</sup>, in a rather steep area of 87.21 km<sup>2</sup>, in a steep area of 107.37 km<sup>2</sup>, and in a very steep area of 46.13 km<sup>2</sup>. Based on the level of slope in the Ake Lamo watershed, the calculation of the average between the value of the slope coefficient with the total so that the LS value of 4.54 is obtained so that it can be said that the level of slope on the Ake Lamo River is at a rather steep level.

Using spatial analysis, the following is the land cover condition in the Ake Lamo watershed catchment area.



**Figure 5.** Land cover map of ake lamo watershed

Based on the spatial analysis, the type and extent of land cover is obtained with information in the following table.

**Table 3.** Land cover area of ake lamo watershed

Land Cover	Area (km <sup>2</sup> )	Area (%)
Dry Forest	260.41	77.5
Shrubs	45.27	13.5
Reeds	18.00	5.4
Water Body	12.03	3.6

Based on Table 3, it is found that the land cover area is dry forest with an area of 260.41 km<sup>2</sup>, shrubs with an area of 45.27 km<sup>2</sup>, reeds with an area of 18.00 km<sup>2</sup>, and water bodies with an area of 12.03 km<sup>2</sup>. Based on these data, the land cover in the Ake Lamo watershed catchment area is a non-agricultural area with the most extensive type of land cover is dry forest with an area of 260.41 km<sup>2</sup> or about 77.5% of the total catchment area of the Ake Lamo watershed

3.1 Analysis of erosion potential in the Ake Lamo watershed

The calculation of erosion rates in the Ake Lamo watershed will use the Universal Soil Loss Equation (USLE) method.

**Rain Erosivity Index (R)**

The monthly erosivity index (R) can be determined based on empirical studies of the annual average rainfall (P) in mm (Teh et al., 2011).

$$R = \frac{2,5P^2}{100(0,073P+0,73)} \quad (2)$$

The calculation of the rainfall erosivity factor will be carried out for each year with the calculation results shown in the following table:

**Table 4.** Rain erosivity index (R)

Year	R (mm/year)	Year	R (mm/year)	Year	R (mm/year)
2007	1094	2012	1377	2017	913
2008	1308	2013	1289	2018	808
2009	787	2014	747	2019	678
2010	1309	2015	626	2020	987
2011	1185	2016	875	2021	926
Average R(mm/year)					994

**Soil Erodibility Factor (K)**

Based on the field observations of the Ake Lamo River RALC research team, it is known that the soil type in the Ake Lamo watershed is yellow, red podzolic. Yellow, red podzolic is a type of soil with low productivity due to intensive leaching and advanced weathering (Utomo et al., 2016). Based on Sutapa (2010), the erodibility value of yellow, red podzolic soil is 0.32.

**Land Length and Slope Factors (LS)**

The length and slope factor (LS) can be determined through the results of the spatial analysis of land slope in Figure 4. Through the table, the following results were obtained:

**Table 5.** LS factor value

Class	LS	Area (km <sup>2</sup> )	Total (LS x Area) (km <sup>2</sup> )
Flat	0.40	60.95	24.38
Ramps	1.40	33.14	46.396
Slightly Steep	3.10	87.21	270.351
Steep	6.80	107.37	739.116
Very Steep	9.50	46.13	438.235
Average LS Score			4.54

Based on Table 5, the average LS value is obtained with the following calculation:

$$\overline{LS} = \frac{\sum(LS_i \times luas_i)}{\sum luas_i} \quad (3)$$

$$\overline{LS} = \frac{(0,40 \times 60,95) + (1,40 \times 33,14) + \dots + (9,50 \times 46,13)}{(60,95 + 33,14 + \dots + 46,13)}$$

$$\overline{LS} = 4,54$$

Based on these calculations, an average LS value of 4.54 was obtained, which can be said to be a rather steep slope level.

**Calculating Vegetation and Soil Management Factors (CP)**

The CP factor value was obtained based on the type of land use and land management in the Ake Lamo watershed. In this study, the value of the CP factor refers to the value of the ground cover vegetation factor and soil conservation (CP) contained in the book Hydrology and Watershed Management (Asdak, 2023).

**Table 6.** CP factor value

Land cover	CP	Area (km <sup>2</sup> )
Secondary Forest	0.005	260.41
Shrubs	0.3	45.27
Reeds	0.3	18.00
Water Body	-	12.03
Average CP		0.06

Source: Ambarwati, 2018

Based on Table 6, the CP factor value in Ake Lamo River is 0.06.

**Erosion Rate Prediction**

The erosion rate is obtained using the USLE method found in Equation (1). With the values of the factors that have been obtained above, the value of the erosion rate in the Ake Lamo watershed can be determined as follows:

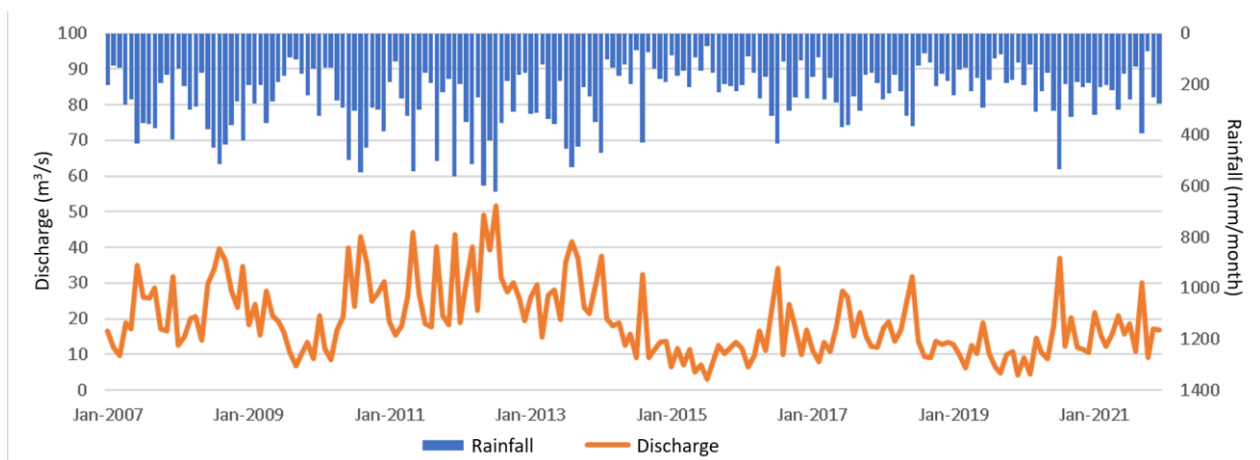
$$A = (994 \times 0.32 \times 4.54 \times 0.06)$$

$$A = 86.64 \text{ ton/ha/year}$$

Based on this, an erosion rate value of 86.64 tons/ha/year was obtained for the entire Ake Lamo river catchment area. Then, following the classification of erosion hazard levels in Table 1, the value of the erosion rate in the Ake Lamo watershed is in class III in the form of a moderate erosion hazard level. Based on the erosion hazard level, conservation measures are needed to maintain the existing vegetation to maintain and reduce the value of the existing erosion rate.

**3.3 Mainstay discharge**

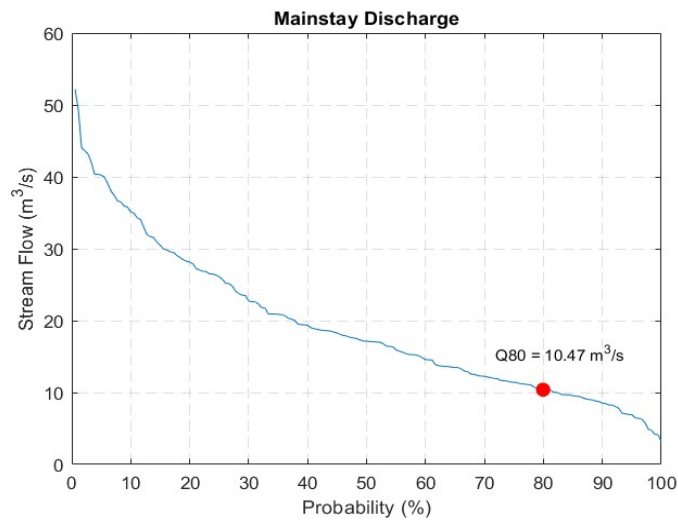
The following is the discharge data obtained from the calculation of the mainstay discharge in the Ake Lamo watershed using the Mock method.



**Figure 6.** Discharge calculation result

The calculation of the mainstay discharge uses the F.J Mock method where the principle of the F.J Mock method is that the rain that falls on the catchment area will be lost due to evapotranspiration, direct runoff, and into the soil or infiltration. Ake Lamo River has a catchment area of 335.71 km<sup>2</sup>, where the size of the river catchment area will affect the fluctuation of Ake Lamo River discharge. The mainstay discharge will be

determined using a probability of 80% for irrigation water needs. The following is a graph of the mainstay discharge of the Ake Lamo River with a probability of 80%.



**Figure 7.** Mainstay discharge of ake lamo watershed

Figure 7 is a graph of the mainstay discharge for each probability. With a probability of 80%, the mainstay discharge value is 10.47 m<sup>3</sup> /second.

#### 4. Conclusion

Based on the results of this research, it can be concluded that the Ake Lamo River Basin has a catchment area of approximately 335.71 km<sup>2</sup>, as determined through spatial analysis. The land slope of the basin, with a value of 4.54, indicates that it is classified as moderately steep. The land cover within the catchment area consists predominantly of dry forest (260.41 km<sup>2</sup>), followed by shrubs (45.27 km<sup>2</sup>), reeds (18.00 km<sup>2</sup>), and water bodies (12.03 km<sup>2</sup>). The calculated erosion rate in the Ake Lamo River catchment area is 86.64 tons/ha/year, suggesting that conservation efforts are required to preserve existing vegetation and reduce erosion. Computational modeling using the F.J. Mock method with MATLAB software was carried out to simulate the hydrological conditions of the basin. Furthermore, the Ake Lamo River has a dependable (mainstay) discharge value of 10.47 m<sup>3</sup>/s at an 80% probability level, which can serve as an important consideration for the design and development of reservoirs to meet the raw water demands of surrounding areas.

In light of these findings, several suggestions can be made. Further studies are recommended to calculate dependable discharge values that differentiate between the rainy and dry seasons, allowing for a more accurate representation of river flow conditions. In addition, future research should include more comprehensive data collection and analysis of land use changes over time to improve the accuracy of erosion rate estimation and to support sustainable watershed management in the Ake Lamo River Basin.

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