Geografika Journal (Geografi Lingkungan Lahan Basah)
Vol. 5, No. 2 - December 2024
Geography Study Program, Lambung Mangkurat University

THE SOIL AND WATER ASSESSMENT TOOL (SWAT) MODEL IN THE CONTEXT OF EROSION MONITORING IN THE BATULAYAR SUB-WATERSHED AREA

Ikha Setiawaty Mujiono[1], Sri Rahayu Ayuba[2*], Risman Jaya[3]
[1,3] Geography Study Program, Muhammadiyah University of Gorontalo, Gorontalo, Indonesia
[2] Regional Planning Study Program, Bina Taruna University, Gorontalo, Indonesia

[*]Correspondent Email: srirahayuayuba@gmail.com

Received 2024-10-21 | **Revision** 2024-11-01 | **Accepted** 2024-12-19
Geography Study Program, Lambung Mangkurat University

Abstract: This study was conducted in the Batulayar Sub-Watershed, Distrik Bongomeme, with the aim of assessing the level of erosion and evaluating the SWAT model as a tool for erosion monitoring. A mixed-method approach was employed, with data analyzed using the ArcSWAT software. The results indicated that the Batulayar Sub-Watershed experienced erosion categorized as "very mild" and "mild," ranging from 0-15 tons/ha/year to 15-60 tons/ha/year, according to the classification by the Ministry of Forestry. Very mild erosion occurred in 15 sub-basins, primarily in areas with flat to moderately steep slopes, while mild erosion was observed in 29 sub-basins with steeper slopes. The main factors contributing to erosion were slope gradient, soil type, and land use, particularly agricultural activities on steep slopes. Calibration and validation results showed an NSE value of 0.9, indicating a high level of accuracy in replicating observed discharge. The SWAT model proved effective in mapping the distribution of erosion levels and provided critical insights for sustainable soil and water conservation management.

Keywords: SWAT, Erosion, Batulayar Sub-Watershed

INTRODUCTION

Watershed (DAS) illustrates that 'river' or 'water' is a crucial factor in watershed management (Ruijter and Agus, 2004; Ayuba, 2016). The Minister of Forestry designated the Limboto Bone Bolango Watershed (DAS) as a watershed in critical condition in 2009 and included it in the priority scale of 108 watersheds (Kodoatie, 2010) stated that, the disruption of the hydrological cycle has caused the “3 T” classic water problems of “too much” (which causes flooding), “too little” (which causes drought) and “too dirty” (which causes water pollution). The Batulayar Sub-DAS is situated within the Limboto DAS area. Batulayar Sub-DAS covers 44 subbasins and administratively covers several villages spread across three districts, namely Bongomeme, Dungaliyo, and Biluhu Districts. According to Ayuba (2016), Limboto DAS experienced moderate to very severe erosion of 78.7% of the existing DAS area. This causes Limboto DAS to require special and intensive handling from various parties.

The community around the upstream area of the Batulayar Sub-DAS engages in dry land farming activities, and the topography of the sub-DAS dominated by very steep slopes has contributed to the increasing damage to the upstream area. When it rains, the upstream area of the sub-watershed shows signs of damage; reduced vegetation aids in the infiltration process, and very steep slopes significantly contribute to the erosion process. In order to describe the Erosion Magnitude Level (TBE) accurately, modeling is needed that is most appropriate to the conditions of the

Batulayar Sub-watershed so that the magnitude of the erosion level that occurs can be monitored more accurately. In Junaidi (2011) Pawitan provides an explanation of the SWAT (Soil and Water Assessment Tool), a distributed model that utilizes a Geographic Information System (GIS) to pinpoint and evaluate issues within a watershed area or sub-watershed, including erosion issues.

Figure 1. Research Location Map

Source: Primary Data Processing

LITERATURE REVIEW

1. River Basin Area (DAS)

A river basin area (DAS) is an ecosystem area that is limited by ridges (river divide) and functions as a collector, storage, and distributor of water, sediment, and nutrients in the river system and exits the area through a single point (single outlet). Land or islands are almost entirely divided into river basin units (DAS) (Fitryane Lihawa, 2017a).

Based on data from the Bone Bolango Watershed Management Agency of Provinsi Gorontalo, there are 10 (ten) large watersheds in Provinsi Gorontalo. Limboto Watershed is one large watershed in Provinsi Gorontalo and is the catchment area of Lake Limboto. The catchment area of Lake Limboto is facing several challenges, including a decline in the quality of natural resources such as forests, land, and water; erosion and sedimentation; the recurring flooding in downstream areas such as Tibawa District, West Limboto District, Batudaa District, and Limboto District in the last three years; and the shallowing of Lake Limboto, a vital source of livelihood for the local community (Fitryane Lihawa, 2017b).

2. Erosion

Erosion is the event of moving or transporting soil or parts of soil from one place to another by natural media (Ayuba, 2017). When erosion occurs, it erodes and transports soil or parts of the soil from one place to another, where it subsequently deposits itself (Rantung et al., 2013). The erosion and transportation of soil occurs through natural media, namely water and wind (Rantung et al., 2013).

According to (Bakhtiar et al., 2013) the movement of wind or water on the surface of the soil or channel creates tension that lifts layers of soil or sediment. Furthermore, (Bakhtiar et al., 2013) assert that the velocity of water flow and the nature of the sediment, particularly its grain size, control the rate of erosion in watershed environments. High rainfall and steep watershed slopes are the main factors that generate erosion. The watershed's resistance to erosion depends primarily on land cover.

Engineering efforts can also strengthen defenses against erosion (Bakhtiar et al., 2013). The two main causes of erosion are natural factors and human activities. Natural erosion occurs due to the process of soil formation and in the process of maintaining the balance of the soil naturally. Natural factors generally leave adequate media for the growth of most plants. While erosion due to human activities is caused by the peeling of the top layer of soil due to farming methods that do not respect conservation principles (Nugroho, 2015). Natural factors that greatly influence erosion include high rainfall, length and slope, soil properties that are less sensitive to the threat of rainwater, and inadequate soil cover. Conditions like this greatly influence the occurrence of soil erosion. The size of the erosion is very dependent on the geographical conditions where the natural event occurs (Fadli Kias & Rahmat Zainuddin, 2016).

SWAT modeling is a highly developed model. Diverse types and conditions of watersheds have widely utilized this physical-based modeling. SWAT modeling is capable of predicting the complex relationship between water runoff, sediment, and agricultural land in a watershed, taking into account factors such as soil type, land use, and periodic land condition management. SWAT uses the MUSLE formula for erosion and sedimentation analysis. The use of the SWAT model can identify, assess, and evaluate the level of problems in a watershed and serve as a tool for selecting management actions to control these problems, so that it is hoped that by using the SWAT model, several scenarios can be developed to determine the best watershed management planning conditions (Rahmad et al., 2017).

3. Hulu

As an ecosystem, river basins (DAS) typically divide into three parts: upstream, middle, and downstream (Chai Asdak, 2010). According to (Chai Asdak, 2010), the upstream watershed ecosystem plays a crucial role as it provides a protective function for all parts of the watershed. The watershed can be viewed as a management system, where the watershed receives input, which is then processed in the watershed to produce output (Paimin et al., 2012). According to (Chai Asdak, 2010) states that a river basin is a land area that is topographically bounded by mountain ridges that collect and store rainwater and then channel it to the sea via the main river.

Thus, it can be concluded that a watershed is a natural unit that is bounded by a ridge, functions as a reservoir/storage of water (upstream), and then flows it to a lower place (downstream). In this area, there is interaction between living things and their environments.

4. Soil and Water Assessment Tool (SWAT)

Dr. Jeff Arnold developed the SWAT Model in the early 1990s for the USDA Agricultural Research Service (ARS), as explained by (Febrianti et al., 2018). During the modeling process, SWAT partitions the watershed or sub-watershed into smaller segments, each linked by a network of rivers. Hydrological Response Units (HRU), the smallest parts of the watershed, simulate all hydrological processes.

Two main components divide the simulation of hydrological processes: the land component, which involves the movement of water, nutrients, pesticides, and sediment to the river, and the river component, which involves the movement of water in the channel to the river and then to the watershed outlet. Reported from swat.tamu.edu Among other things, SWAT can forecast erosion by examining the Sediment Yield value (metric tons/ha), also known as SYLD. Each time, the HRU transports a certain amount of sediment to the main channel, which is known as SYLD. The Modified Universal Soil Loss Equation (MUSLE), which simulates erosion and sediment using the amount of surface flow, estimates erosion and sediment for each HRU.

5. Climate Data

The climate variables required by SWAT consist of daily rainfall data, maximum and minimum air temperatures, solar radiation, wind speed, and relative humidity (Alibuyog, 2012). Furthermore, Alibuyog (2012) explains that SWAT employs a Nicks (1974) model to construct simulated daily rainfall data without relying on field measurement data. The generator generates maximum and minimum air temperatures and solar radiation based on a normal distribution. The generator integrates continuous calculations to determine temperature and radiation variations resulting from rainy and dry conditions.

When the simulation runs in rainy conditions, it will produce a low maximum air temperature and solar radiation, and a high one in dry conditions. To generate the daily mean wind speed from the monthly mean, SWAT employs a modified exponential equation for wind speed data. As for the calculation of relative humidity data, SWAT uses a triangular distribution to simulate the daily average and monthly average relative humidity (Alibuyog, 2012).

RESEARCH METHODS

The tools used in the study were the ArcGIS application integrated with SWAT and Microsoft Office. The study used SWAT input data, which included land cover, soil type, slope, climate, and discharge data for calibration and validation.

Table 1. Materials data and data sources

No	Material Name (Data)	Source	Information
1	Water Discharge Data	Field Measurement	Secondary Data
2	Land Cover Data	Directorate General of Environmental Planning and Planning	Secondary Data
3	Soil Type Data	*RePPProt 1987*	Secondary Data
4	Slope Gradient Data	Aster DEM 25 M/ https://earthexplorer.usgs.gov	Secondary Data
5	Climate Data	Global Weather https://www.uoguelph.ca/watershed/w3s/	Secondary Data

1. Research methods

The method used in the Soil and Water Assessment Tool (SWAT) Model Research for erosion monitoring in the Batulayar Sub-DAS Area, Distrik Bongomeme, Kabupaten Gorontalo, Provinsi Gorontalo, is a mixed method consisting of qualitative and quantitative methods (SWAT modeling & survey method). This study integrates the ArcSWAT application with ArcGIS for modeling (Ayuba et al., 2019). Detailed land cover data, including vegetation type data from the Batulayar Sub-DAS area, soil type data, climate data, and slope gradient data, comprise the input data for SWAT.

The Geographic Information System (GIS) connects to the distributed model SWAT (Soil and Water Assessment Tool), which integrates the Spatial DSS (Decision Support System). This model is able to simulate long-term hydrological parameters by considering the physical characteristics of a watershed (Ayuba, 2017).

2. Data collection technique

Data collection in this study as a whole uses secondary data, namely water discharge data (for validation and calibration of the resulting model), land cover data, climate data obtained from Global Weather, soil data from rePPProt 1987, and slope data obtained from the 2017 National DEM data. In addition to SWAT data, supporting data is also used in the form of the RBI map of Gorontalo Province.

3. Data Analysis Techniques

At the data analysis stage, the data that has been obtained will be analyzed using ArcSWAT modeling which consists of several stages.

a. Land Use, Soil Type, and Slope Gradient Data are Overlaid in ArcSWAT. Furthermore, the Overlay results of the three data produce an Output in the form of an HRU (Hydrology Response Unit) map.
b. The resulting HRU map is then re-run with climate data and then produces several outputs including sediment yields, namely the amount of sedimentation produced by the HRU and carried to the main channel (SYLDt) which is used to identify the level of erosion that occurs and output discharge data.
c. The water discharge from the River Basin Office (observation discharge) is then calibrated with the output discharge (model discharge) to obtain the NSE value for validation.
d. After the Erosion Value is obtained, the classification according to the Ministry of Forestry in 2013 is used to determine the amount of erosion that occurs in the Batulayar Sub-DAS Area.

Table 2. Erosion Classification

No	Surface Erosion Classification	Magnitude of Surface Erosion (ton/ha/yr)
1	Very Light	<15
2	Light	≥15 – 60
3	Currently	≥60- 180
4	Heavy	≥180- 480
5	Very heavy	>480

Source: Department of Forestry, 2013

RESULTS AND DISCUSSION

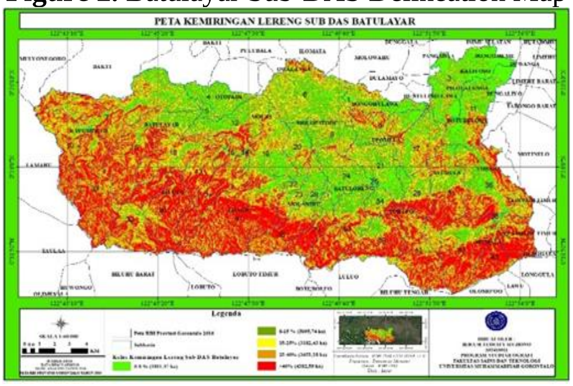
The Limboto River Basin (DAS), administratively located in Gorontalo Province, is geographically situated between (121020'24"–1230 32'09" E) and (000 24'04"–02030" N). Tabba (2013) describes the Limboto DAS as consisting of 12 sub-DAS (1). Biyonga Bulota Sub-DAS, which has an area of 8,915 ha; (2) Alo Sub-DAS, which has an area of 11,270 ha; (3) Batulayar Sub-DAS, which has an area of 17,130.6 ha; (4) Pone Sub-DAS, which has an area of 3,117 ha; (5) Marisa Sub-DAS, which has an area of 7,539 ha; (6) Molamahu Sub-DAS, which has an area of 12,797 ha; (7) Payunga Sub-DAS, which has an area of 4,644 ha; (8) Pilolalenga Sub-DAS, which has an area of 4,537 ha; (9) Pulubala Sub-DAS, with an area of 10,789 ha; (10) Tabongo Sub-DAS, with an area of 2,792 ha; (11) Talumelito Sub-DAS, which has an area of 1,583 ha; and (12) Tuladenggi Sub-DAS, which has an area of 2,832 ha.

The location of this research is in the Batulayar Sub-DAS, which is one of the Sub-DAS included in the Limboto Watershed Area. Based on the delineation results, the Batulayar Sub-DAS is known to consist of 44 sub-basins and 753 Hydrology Response Units (HRU). Administratively, it is located in three sub-districts, namely Bongomeme District, Dungaliyo District, and Biluhu District. Geographically, it is located at coordinates 122050'27.49 E–0034'52.85" N. The high demands for economic needs have resulted in land-clearing activities even in sloped areas; this certainly has an ecological impact and can potentially cause landslides.

1. Delineation of Batulayar Sub-DAS

Watershed delineation is one of the stages in the SWAT preprocess. The delineation results of the Batulayar Sub-DAS, utilizing National DEM data, reveal that the Batulayar Sub-DAS comprises 44 sub-basins, with sub-basin 7 being the largest at 1044.30 ha. This sub-basin accounts for 6.10% of the total area of the Batulayar Sub-DAS, which spans 17,123.31 ha. Based on the delineation results, the yellow line depicts the Batulayar Sub-DAS Area, while the blue and red lines illustrate its flow across three sub-districts in Gorontalo Regency Bongomeme, Dungaliyo and Biluhu Sub-DAS. Figure 2 below presents the results of the delineation of the Batulayar Sub-DAS.

Figure 2. Batulayar Sub-DAS Delineation Map



2. SWAT Input Data Preparation

a. Slope gradient

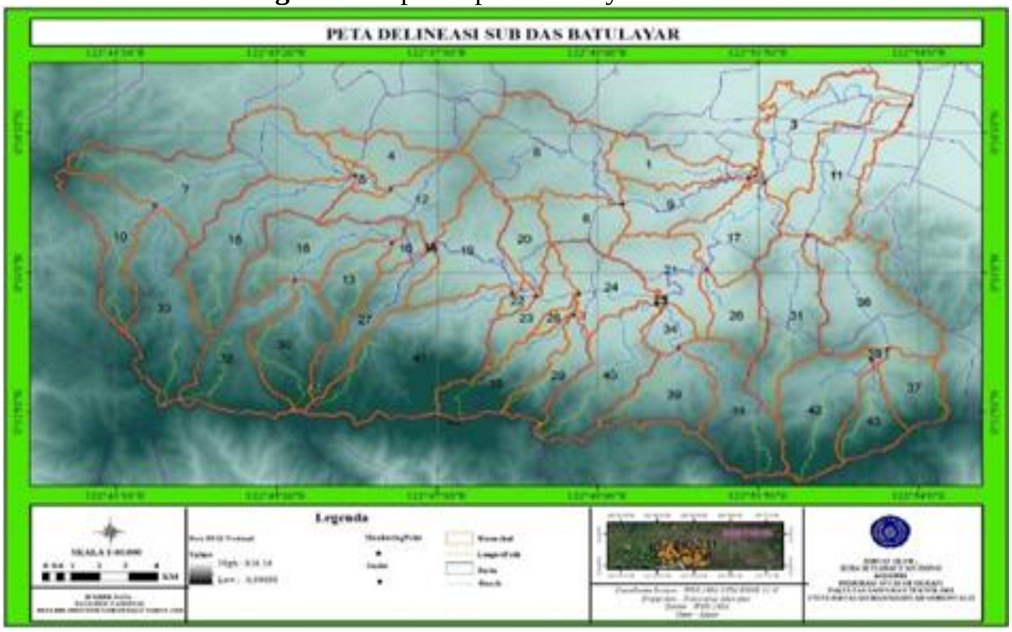
The National DEM data processing results, conducted with the Geographic Information System (GIS) application, reveal that over 25% of the Batulayar Sub-DAS area, or over 40%, features very steep topography. This denotes an expanse of 4382.59 hectares within the overall region of the Batulayar Sub-DAS. The SWAT output indicates a variety of slopes in the Batulayar Sub-DAS, ranging from flat to very steep classifications. The SWAT output indicates minimal erosion in 19 sub-basins, with one sub-basin exhibiting a slope above 40 percent. Minor erosion occurs in 29 sub-basins, with several exhibiting slopes greater than 40 percent. Table 3 and Figure 3 display the slope gradient data.

Table 3. Slope Gradient Class

No	Slope Class	Category	Area (ha)	Percentage (%)
1	0-8 %	Flat	2811.37	16.42
2	8-15 %	Sloping	3095.74	18.08
3	15-25%	A bit steep	3182.43	18.59
4	25-40%	Steep	3651.18	21.32
5	>40%	Very Steep	4382.59	25.59
	Total		**17,123.31**	**100**

Source: Analysis Results

Figure 3. Slope Map of Batulayar Sub-DAS



b. Land Use

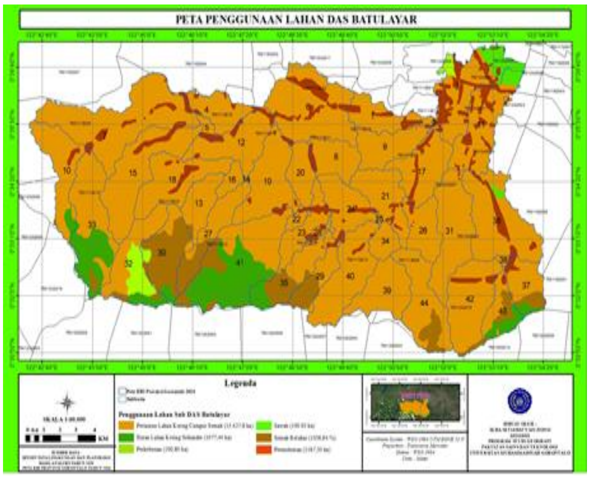
The interpretation of data processing results indicates that mixed dryland agriculture with shrubs (AGRL) dominates the land cover around the Batulayar Sub-DAS area, covering an area of approximately 13,427.8 ha (78.89%). The SWAT output results reveal that 44 subbasins have dryland agricultural land use activities mixed with shrubs, while only two subbasins, namely subbasin 3 and subbasin 11, have rice fields. Subbasins 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, and 17 have land use for settlements. The brown color on the map indicates land use for mixed dryland agriculture with shrubs, green for primary secondary forest land use, yellowish green for plantations, red for residential land use, brownish green for shrubs, and Stabilo green for wetland or rice field use. Table 4 and figure 4 below display the land cover data.

Table 4. Land Use in Batulayar Sub-DAS Area

No	Land use	Code SWAT	Area (Ha)	Percentage (%)
1.	Mixed Shrub Dry Land Farming	AGRL	13,427.8	78.89
2.	Settlement	URBN	1187.50	6.58
3.	Plantation	ORCD	200.80	1.11
4.	Ricefield	RICE	190.93	1.06
5.	Secondary Dryland Forest	FRST	1077.44	5.97
6.	Shrubs	RNGB	1038.84	6.38
	Total		17,123.31	100

Source: Research Results.

Figure 4. Land use map of batulayar sub watershed



c. Soil Type

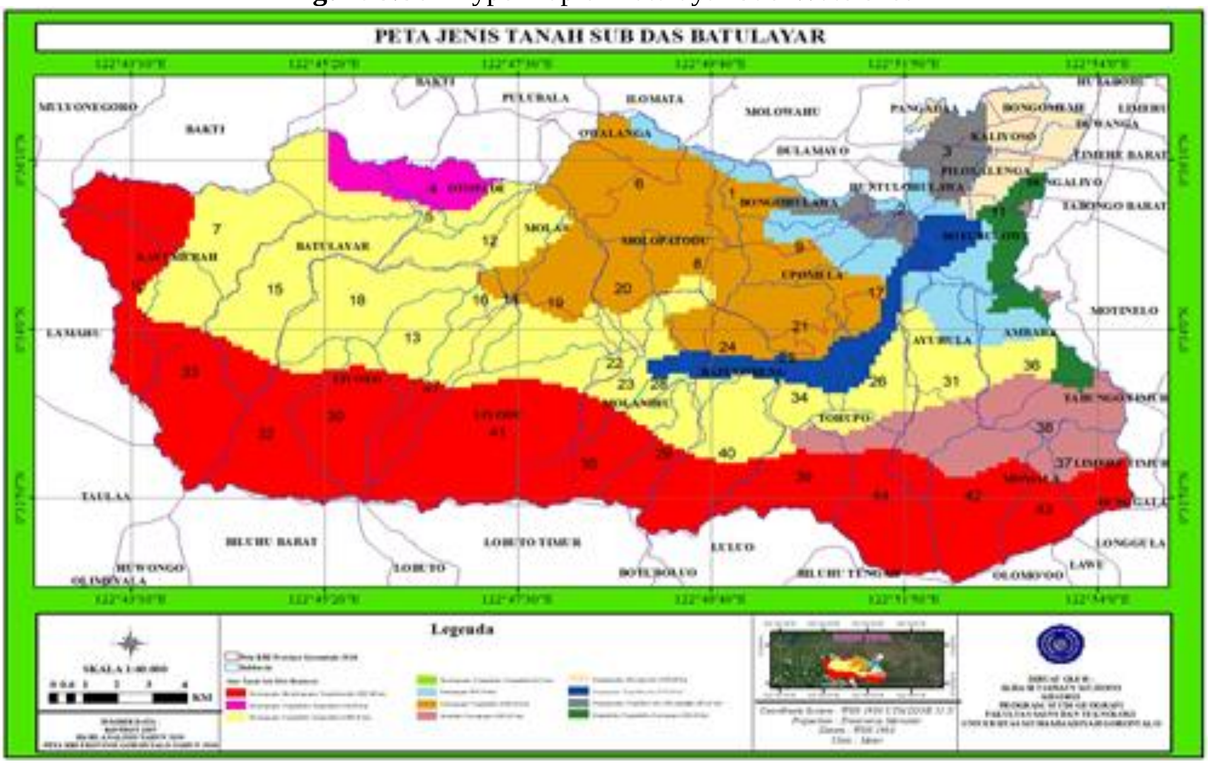
The Batulayar Sub-DAS area is known to contain a variety of soil types, as indicated by the data processing results. The Batulayar Sub-DAS area is covered by the varieties of soil Dystropepts, Humitropepts, and Tropohumults (Soil 06). They comprise 32.63% of the area and are distributed across 19 subbasins, including Subbasins 7, 10, 13, 15, 23, 27, 29, 30, 31, 32, 33, 35, 37, 39, 40, 41, 42, 43, and 44. Among other soil types, Dystropepts, Tropudalfs, and Tropdults (Soil 10) are found in Subbasins 4, 5, and 7. The soil type data is presented in Table 5 and Figure 5

Table 5. Soil Types in the Batulayar Sub-DAS Area

No	Soil Great	ID Soil	Area (ha)	Percentage (%)
1.	Dystropepts; Humitropepts; Tropohumults	SOIL 06	5587.55	32.63
2.	Dystropepts; Tropudalfs; Tropdults	SOIL 10	316.62	1.85
3.	Dystropepts; Tropdults; Troperthents	SOIL 14	5100.19	29.79
4.	Dystropepts; Tropdults; Tropudalfs	SOIL 15	0.11	0.00
5.	Eutropepts	SOIL 18	875.15	5.11
6.	Eutropepts; Tropudalfs	SOIL 21	2501.01	14.61
7.	Rendolls; Eutropepts	SOIL 32	1011.23	5.91
8.	Tropaquepts; Fluvaquents	SOIL 36	446.40	2.61
9.	Tropaquepts; Tropofluvents	SOIL 39	550.34	3.21
10.	Tropaquepts; Tropofluvents; Fluvaquents	SOIL 40	433.21	2.52
11.	Tropdults; Tropudalfs; Eutropepts	SOIL 59	302.18	1.76
	Total		**17,123.31**	**100%**

Source: Analysis Results

Figure 5. Soil Type Map of Batulayar Sub-Watershed



d. Formation of Hydrologic Response Units (HRU)

The results of data processing using HRU Analysis through Geographic Information System (GIS) software reveal 753 Hydrologic Response Units, or hydrological units, in the Batulayar Sub-DAS Area. These units are derived from overlay data on slope gradient, soil type, and land use, all of which influence the hydrological conditions in the area. In the Batulayar Sub-DAS Area, with 44 sub-basins, the total area of the Batulayar Sub-DAS area is 17,123.31 ha. The report on the results of the HRU formation analysis is presented in Figure 6 below.

Figure 6. Hydrological Response Unit Map of Batulayar Sub-DAS

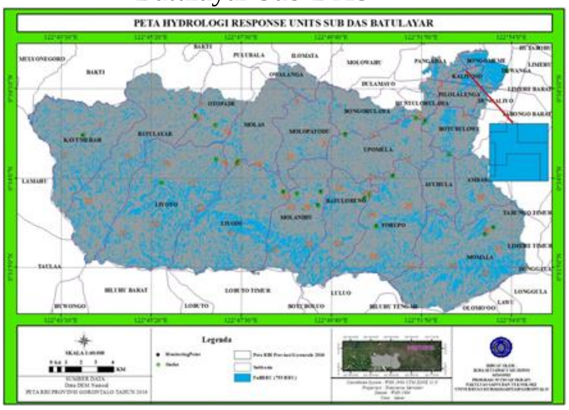


Figure 7. Report on the results of the formation of HRU in the Batulayar Sub-DAS


HRULandUseSoilsReport.txt - Notepad
File Edit Format View Help

SWAT model simulation Date: 08/07/2020 00:00:00 Time: 00:00:00
MULTIPLE HRUs LandUse/Soil/Slope OPTION THRESHOLDS : 0 / 0 / 0 [%]
Number of HRUs: 753
Number of Subbasins: 44

The Batulayar Sub-DAS consists of 44 Subbasins and 753 Hydrological Response Units (HRU), the HRU value is obtained from overlaying slope gradient data, soil type, and land use.

e. Climate Data Input Process and Running SWAT

The SWAT running process is carried out to obtain monthly simulation data. The SWAT simulation uses climate data consisting of rainfall and temperature data representing the Sub-DAS area, as well as weather generator data obtained from global weather data consisting of wind speed, solar radiation, humidity, temperature, and rainfall in the Batulayar Sub-DAS area. The appendix contains the SWAT Simulation Data.

f. Calibration and Validation

SWAT model calibration is carried out to carefully find the input parameter values of the model and compare the predicted output data of the model on a set of conditions that are the same as the observation data (Munggaran et al., 2017). Meanwhile, according to (Suhartanto et al., 2019), validation is the process of evaluating a model to get an idea of the level of uncertainty that it has in predicting hydrological processes. Generally, (Suhartanto et al., 2019) carry out validation using data outside the calibration period.

The goal of calibration and validation is to ensure that a model's output closely matches the observed output. Calibration is generally performed on model inputs, both parameters, structures, and variables. NSE values approaching 1 indicate a close relationship between model results and observation results. The NSE value for the discharge data model can be determined through the following equation (Ayuba et al., 2018).

$$NSE = 1 - \left(\frac{\sum_{i=1}^{n}(Q_{Obs,i} - Q_{Mod,i})^2}{\sum_{i=1}^{n}(Q_{Obs,i} - \overline{Q}_{Mod,i})^2}\right)$$

$$NSE = 1 - \left(\frac{(3393691.016)^2}{(173817.3694)^2}\right)$$

$$NSE = 1 - (0.000112327)$$

$$NSE = 0{,}99$$

The NSE (Nash Sutcliffe Coefficient of Efficiency) model is categorized into 3, namely "good" if NSE ≥ 0.75, satisfactory if 0.75 > NSE ≥ 0.36, and less satisfactory if NSE < 0.36 (Ayuba et al., 2018). This means that the NSE value obtained is included in the "good" class or there is a similarity between the model discharge and the observation discharge. From the results above, it is known that the NSE value obtained is included in the good class category, or there is a similarity between the model discharge and the observation discharge.

g. SWAT Output Analysis

The determination of the classification of the erosion levels in the Batulayar Sub-DAS was obtained by using the SYLDt value, which is one of the outputs of the SWAT model, and processed using an equation in Microsoft Excel software to obtain the average value of the amount of erosion per ton per year per sub-basin in the Batulayar Sub-DAS Area over a period of 10 years.

From the results of the study, it is known that several sub-basins have an erosion rate of more than 15 tons/ha/year; however, the erosion that continues to occur can have fatal consequences for agricultural productivity and sedimentation in the upstream of the Limboto DAS and is potentially prone to disasters. The classification used is the 2013 Forestry Department Classification. Table 2 presents the classification of erosion data, while table 6 and figure 8 below present the erosion distribution per village.

Table 6. Distribution of erosion levels per subbasin

Sub-watershed name	TBE	Total Area (ha) / %	Subbasin / Village
Batulayar Sub-watershed	0-15 tons/ha/year **(Very Light)**	4384.07 ha / 25.60%	**Subbasins** 1, 4, 5, 6, 8, 9, 12, 14, 19, 20, 21, 22, 35, 37, 38 / Villages Bongohulawa, Otopade, Molopatodu, Upomela, Molas, Liyodu, Tohupo, Molanihu, Momala.
	15-60 tons/ha/year **(Light)**	12739.25 ha / 74.60%	**Subbasins** 2, 3, 7, 10, 11, 13, 15, 16, 17, 18, 23, 24, 25, 26, 27, 28, 28, 29, 30, 31, 32, 33, 34, 36, 39, 40, 41, 42, 43, 44. Huntulohulawa, Botubulowe, Kayumerah, Liyoto, Batulayar, Tohupo, Molanihu, Batuloreng, Ayuhula, Ambara, Momala.
Total		17,123.31	

Source: Analysis Results

Figure 8. Erosion Distribution Map of Batulayar Sub-DAS

Batulayar Sub-DAS consists of 44 Sub-basins and 753 HRU based on SWAT output. It is known that Batulayar Sub-DAS experiences erosion ranging from 0 to 15 tons/ha/year and 15 to 60 tons/ha/year. The Ministry of Forestry classified the erosion in Batulayar Sub-DAS in 2013 into two categories **very light** and **light**. Sub-basins 1, 4, 5, 6, 8, 9, 12, 14, 19, 20, 21, 22, 35, 37, and 38 experience very light erosion. The slope classes range from 0 to 8 percent, 8 to 15 percent, 15 to 25 percent, 25 to 40 percent, and more than 40 percent. This indicates that the steeper the slope, the greater the level of soil sensitivity to erosion, as quoted from Yulina et al (2015). The slope itself has a great influence in increasing the rate of erosion that occurs in the Batulayar Sub-DAS.

There is also very little erosion in 19 subbasins that have different types of land uses, such as mixed dryland agriculture with shrubs (AGRL), settlements (URBN), secondary dryland forests (FRST), and shrubs (RNGB). Field observations reveal that mixed dryland agriculture with shrubs, primarily in the form of corn commodities, occupies the majority of land in the Batulayar sub-watershed. The results of the SWAT output also reveal that dryland agriculture persists on progressively steeper slopes, even exceeding 40 percent. Vegetation itself has an important role in inhibiting the rate of erosion; strong vegetation roots can minimize the rate of erosion that occurs. According to (Tarigan Elementary School & Junaidi, 2010), the root system and litter have the ability to anchor soil particles, thereby preserving the soil's ability to absorb water. Denser plantings intercept more rain, thereby reducing erosion. Additionally, a wide and dense root system can effectively reduce erosion. Corn plant commodities themselves are known to have roots that are susceptible to erosion.

The subbasin with very light erosion comprises the following types of soil: Dystropepts; Humitropepts; Tropohumults (Soil 06); Dystropepts; Tropudalfs; Tropdults (Soil 10); Dystropepts; Tropdults; Troperthents (Soil 14); Dystropepts; Tropdults; Tropudalfs (Soil 15); Eutropepts (Soil 18); Eutropepts (Soil 21); Rendolls; Eutropepts (Soil 32); Tropaquepts; Tropofluvents (39); and Fluvaquents (Soil 40). Based on the Landuse Soils Report, it is known that the most abundant soil types in the 15 subbasins that experienced very light erosion were Soil 06, 14, and 21. Referring to the Soil Taxonomy carried out by *(Staff Survey, 2022)*, Dystropepts, Humitropepts, Eutropepts soil types are soil types included in the Inceptisol order. The Ultisol order includes Tropohumults and Tropudults soil types, the Alfisols order includes Tropudalfs soil types, and the Entisols order includes Tropethens soil types. Rendolls is a type of Renzina soil. The permeability is low, so its ability to hold and bind water is high. The Ultisol order has a very low erodibility value; the Inceptisol and Entisol orders have low erodibility values, while the Alfisol order has a moderate erodibility value (Dangler & El-Swaify, 1976). This demonstrates that the type of soil with low sensitivity to erosion also influenced the extremely light erosion that occurred in 15 subbasins.

Light erosion with the smallest value is 4,561 tons / ha / year, located in Subbasin 6. The slope in Subbasin 6 is dominated by a slope of 8 to 15 percent (gentle) with a percentage of 32.69 percent or 275.50 ha. Land use in Subbasin 6 consists of land use for Dry Land Agriculture Mixed with Shrubs (AGRL) 813.22 ha (96.50 percent) and Settlement (URBN) 28.72 ha (3.41%). The soil type in Subbasin 6 is Eutropepts (Soil 18), a member of the Inceptisol order, and Eutropepts (Soil 21), a member of the Inceptisol and Alfisol orders. The Inceptisol order itself has a low erodibility value, while the Alfisol order has a high erodibility value. The topography of Subbasin 5, characterized by a gentle slope category, supports the low average erosion per year in Subbasin 6.

There was light erosion (15–60 tons / ha /year) in 29 subbasins, specifically subbasins 2, 3, 7, 10, 11, 13, 15, 17, 18, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 36, 39, 40, 41, 42, 43, and 44, with varying slope gradients. All subbasins in the Batulayar Sub-DAS, with the exception of Subbasin 25, exhibit severe erosion, primarily due to the slope factor's steep category. Rain intensity and slope gradient can increase surface flow. High rainfall intensity will have a significant impact on the destruction of soil aggregates. As the slope increases, the flow rate will rise, and the destroyed soil particles' transport capacity will increase, intensifying the erosion process (L.A. Tarigan, 2017).

Meanwhile, settlements (URBN), plantations (ORCD), and secondary dryland forests (FRST) dominate land use in 29 subbasins experiencing mild erosion. One of the factors contributing to mild erosion is the presence of land use activities such as dryland agriculture mixed with shrubs, which is carried out up to a slope of more than 40 percent. Moreover, the existence of secondary dryland forests suggests that primary forests have suffered damage, leading to an average erosion rate of 15-60 tons / ha / year.

The subbasin contains a variety of lightly worn soil types. These are Dystropepts (Soil 06), Humitropepts, Tropohumults, Dystropepts, Tropudalfs, Tropdults, Troperthents, Eutropepts (Soil 18), Eutropepts; Tropudalfs (Soil 21), Rendolls, Eutropepts (Soil 32), Tropaquepts; Fluvaquents (Soil 36), Tropaquepts; Tropofluvents (Soil 39), Tropaquepts; Tropofluvents; Fluvaquents (Soil 40), Tropdults; Tropudalfs; Eutropepts (soil 59). Tropaquepts, Dsystropepts, and Humitropepts are the types of soil included in the Inseptisols order. The Entisols order includes the soil types Tropofluvents, Fluvaquents, and Troperthents. The Tropudalfs type of soil falls under the Alfisols order, while the Tropudults type of soil falls under the Ultisols order (Staff Survey, 2022).

(Dangler & El-Swaify, 1976) Classify the soil erodibility value with categories from very low to high. The Inceptisols and Entisols orders have low soil erodibility values, the Alfisols order has a soil erodibility value with a moderate classification, and the Ultisols order has a low erodibility value.

This indicates that soil types with higher erodibility influence light erosion in 29 subbasins, while 15 subbasins experience very light erosion. Of the 29 subbasins that experienced light erosion, the most severe erosion was experienced by subbasin 17, which was dominated by steep slopes (15–25 percent) at 27.43 percent, or 119.01 ha. Subbasin 17 is home to the following types of soil: Dystropepts, Tropdults, and Troperthents (Soil 14); Eutropepts (Soil 18), type of soil Eutropepts; Tropudalfs (Soil 21), soil type Tropaquepts; Tropofluvents (Soil 39), soil type Tropaquepts; Tropofluvents; Fluvaquents (Soil 40), the type of soil in Subbasin 17 is included in the Inseptiso, Ultisol, Entisol, and Alfisol orders. The Inceptisol, Entisol, and Alfisol orders have low erodibility values, while the Ultisol order has moderate erodibility values.

The land use in Subbasin 17 is primarily composed of mixed dry agricultural land and shrubs (AGRL), which covers an area of approximately 416.32 ha, or 95.95 percent, and settlements, which cover approximately 18.84 ha, or 4.34 percent. The main factor causing light erosion is the slope gradient. Table 7 below presents erosion data for the subbasins experiencing the most severe and lightest erosion.

Table 7. Erosion distribution table per HRU

No Sub Basin	No HRU	Slope Gradient	Land Use	Soil Type	Average Erosion	Classification
Sub-basin 6	000060001 000060002 000060003 000060004 000060005 000060006 000060007 000060008 000060009 000060010 000060011 000060012 000060013 000060014 000060015	0-8% / 197.72 ha (23.46%) 8-15% / 275.50 ha (32.69%) 15-25% / 236.01 ha (28.01%) 25-40% / 106.59 ha (12.65%) >40% / 26.10 ha (3.10%)	Mixed Shrub Dry Land Agriculture (AGRL)/ 813.22 ha (96.50%) Settlement (URBN) / 28.72 ha (3.41%)	Eutropepts (Soil 18) /75.96 ha (9.01%) Eutropepts; Tropudalfs (Soil 21) /765.97 ha (90.90%)	4,561 tons /ha/year	Very Light
Sub-basin 17	000170001 000170002 000170003 000170004 000170005 000170006	0-8% / 90.37 ha (20.83%) 8-15% / 114.65 ha (26.42%)	Mixed Shrub Dry Land Farming (AGRL) / 416, 32 ha (95.95 %)	Dystropepts; Tropdults; Troperthents (Soil 14) / 6.14 ha (1.42 %)	40,182 tons /ha/year	Light

No Sub Basin	No HRU	Slope Gradient	Land Use	Soil Type	Average Erosion	Classification
	000170007 000170008 000170009 000170010 000170011 000170012 000170013 000170014 000170015 000170016 000170017 000170018 000170019 000170020 000170021 000170022 000170023 000170024 000170025 000170026 000170027 000170028 000170029 000170030 000170031 000170032 000170033 000170034 000170035	15-25 % / 119.01 ha (27.43 %) 25-40% / 82.66 ha (19.05%) >40% / 28.45 ha (6.56%)	Settlement (URBN) / 18.84 ha (4.34 %)	Eutropepts (Soil 18) / 113.32 ha (26.12 %) Eutropepts; Tropudalfs (Soil 21) / 161.18 ha (37.15 %) Tropaquepts; Tropofluvents (Soil 39) / 122.71 ha (28.28 %) Tropaquepts; Tropofluvents; Fluvaquents (Soil 40) / 31.80 ha (7.33 %)		

CONCLUSION

This study shows that the Batulayar Sub-watershed experienced erosion with the classification of **very light** (0-15 tons / ha /year) and **light** (15-60 tons / ha / year) according to the 2013 Ministry of Forestry classification. Very light erosion occurred in 15 Sub-basins, one of which was Sub-basin 6 with the smallest value of 4,561 tons/ha/year, which was influenced by gentle slopes (8-15%) and the dominance of low-erodibility soil.

Meanwhile, light erosion occurred in 29 subbasins, with subbasin 17 recording the largest value due to steep slopes (15–25%) and the dominance of dryland agricultural land use mixed with shrubs. The main things that affect the amount of erosion are slope, soil type, and land use. The SWAT model calibration and validation results show that the model and observations agree well, with an NSE value of 0.9.

THANK-YOU NOTE

Thank you to the Gorontalo River Region II Office and to the supervisors and examiners for being willing to assist in this research.

REFERENCE

Ayuba, SR (2017). Classification of Erosion Levels in the Bone River Watershed. Bindhe: Scientific Journal of Agribusiness Study Program, 2(1).

Ayuba, SR, Nursaputra, M., & Manyoe, IN (2019). Simulation of Land Use Direction in Limboto Watershed in the Framework of Drought Control. Indonesian Geography Magazine, 33(2), 87–94. https://doi.org/10.22146/mgi.37460

Ayuba, SR, Nursaputra, M., & Tisen, T. (2018). Classification of Drought Levels in the Limboto River Basin (DAS). Journal of Geographic Information Science, 1(2), 12. https://doi.org/10.31314/jsig.v1i2.174

Bakhtiar, Hadihardaja, J., & Hadihardaja, IK (2013). The Effect of Average Annual Rainfall on Erosion Index and Reservoir Age in the Upper Citarum Watershed. Journal of Civil Engineering Communication Media, 19(1), 41–54.

Chai Asdak. (2010). Hydrology and Watershed Management. Gajah Mada University Press.

Dangler, E. W., & El-Swaify, S. A. (1976). Erosion of Selected Hawaiian Soils by Simulated Rainfall. Soil Sci. Soc. A.M. J, 40. https://doi.org/https://doi.org/10.2136/sssaj1976.03615995004000050040x

Fadli Kias, M., & Rahmat Zainuddin, et al. (2016). Prediction of Soil Erosion in Paneki Watershed Biromaru District Sigi Regency. In Agrotekbis (Vol. 4, Issue 6).

Febrianti, I., Ridwan, I., & Nurlina. (2018). SWAT (Soil and Water Assessment Toll) Model for Erosion and Sedimentation Analysis in Large River Catchment Area. FLUX Journal of Physics, 15(1), 20. https://doi.org/10.20527/flux.v15i1.4506

Fitryane Lihawa. (2017a). Alo River Basin Erosion, Sedimentation and Landslides (1st ed.).

Fitryane Lihawa. (2017b). Alo River Basin Erosion, Sedimentation and Landslides (1st ed.). CV. Budi Utama Yogyakarta.

Junaidi, E., & Tarigan, S. D. (2011). The Influence of Forests in Water Management and Sedimentation Processes in Watersheds (DAS): Case Study in Cisadane Watershed. Journal of Forest Research and Nature Conservation, 8, 155–176.

Ministry of Forestry of the Republic of Indonesia. (2009). Regulation of the Minister of Forestry of the Republic of Indonesia Number: P.1/Menhut-II/2009 Concerning the Implementation of Forest Plant Seeds.

Kodoatie, RJ and RS (2010). Water Spatial Planning. ANDI.

Munggaran, A., Mukaram, & Sarah, IS (2017). The Effect of Earning Per Share (EPS) on Stock Prices. Journal of Business & Investment Research, 3(2).

Nugroho, P. (2015). Soil Water Assessment Tool (SWAT) Model for Predicting Erosion and Sedimentation Rates in Keduang Sub-DAS, Wonogiri Regency.

Paimin, Pramono, IB, Purwanto, & Idrawati, DR (2012). Watershed Management Planning System. http://www.p3kr.org

Rahmad, R., Nurman, A., & Wirda, MA (2017). Integration of SWAT and GIS Models in Efforts to Suppress the Rate of Erosion of the Deli DAD, North Sumatra. Indonesian Geography Magazine, 31(1). https://jurnal.ugm.ac.id/mgi

Rantung, MM, Binilang, A., Wuisan, EM, & Halim, F. (2013). Analysis of Land Erosion and Sedimentation in the Panasen Sub-watershed, Minahasa Regency. Journal of Civil Statics, 1(5), 309–317.

Robert J Kodoatie. (2010). Water Spatial Planning. Andi.

Suhartanto, E., Cahya, EN, & Maknun, L. (2019). Runoff Analysis Based on Rainfall Using Artificial Neural Network (ANN) Model in Upper Brantas Sub-watershed. Journal of Irrigation Engineering, 10, 134–144.

Survey Staff, S. (2022). Keys to Soil Taxonomy Thirteenth Edition. United States Department of Agriculture Natural Resources Conservation Service.

Tarigan, LA (2017). Soil Erodibility Values in Various Land Uses (Rainfall Simulator and Wischmeier Equation) in Ngabab Village, Pujon District, Malang Regency.

Tarigan, S. D., & Junaidi, E. (2010). Accuracy of Mapwindow and Swat Watershed Model in Simulating Hydrologic Characteristics of Cisadane Watershed, West Java Indonesia. Jurnal Hidrolitan, 1, 10–17.