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Hydrological Modeling Using SWAT Due to Landslides in the Badeng Watershed

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***Abstract*—Badeng watershed is one of the important watersheds in the Banyuwangi Regency. In the years 2018, Alas Malang Village, there was a flash flood. This flooding occurs because of the high rainfall intensity and causes erosion and landslides in the upstream area of Badeng Watershed, recorded in Badeng Watershed 26.16 m^3/second from the drainage capacity of 3.8 m^3/sec. The condition of land cover changes causes the complexity of hydrological conditions in Badeng Watershed. This causes the need for the use of models in watershed management activities. In hydrological modeling using the help of SWAT software. Soil and Water Assessment Tool (SWAT) is a hydrological model of watershed-scale that is based on a physical, deterministic, and continuous basis. Spatial data in the form of digital maps DEM, land use, soil type, slope, and daily rainfall and climate data. For calibration using river discharge data for 2010-2013 and validation using 2018-2019 data. The results of SWAT hydrological modeling have a total average annual rainfall of 10467.91 mm/yr, total evapotranspiration of 1577.21 mm/yr, total potential evapotranspiration value of 3722.61 mm/yr, total percolation value of 6760.05 mm/yr, total surface runoff value of 2128.41 mm/yr, total sediment discharge value of 29779.44 tons/yr, total sediment yield value of 250.65 tons/ha/yr, and total erosion rate value of 601.92 tons/ha/yr. With the results of the calibration with a determinant coefficient (R^2) of 0.78 and NSE of 0.69, for validation with a determinant coefficient (R^2) of 0.75 and NSE of 0.70.**

Keywords—badeng watershed, discharge, flood, hydrological model, SWAT

I. INTRODUCTION

A. Background

The hydrological model is a simple description of an actual hydrological system. Hydrological models are usually used to study the function and response of a watershed from various watershed inputs. Hydrological events can be studied through the hydrological model, which can be used to predict hydrological events that will occur [1]. Initially, hydrological modeling aims to find the relationship between rain and the response of river discharge to this rain. However, along with the development of technology and science, hydrological modeling has become increasingly complex and sophisticated, including erosion, water availability, sedimentation, and pollutants, like the erosion that occurred in one of the watersheds in Banyuwangi Regency, namely the Badeng Watershed.

Badeng watershed is one of the watersheds in the Banyuwangi district. The Badeng watershed has its upstream in Sempol Village, which is in the Bondowoso Regency area, and through the Banyuwangi Regency area, which turns in the Gintangan Village in Blimbingsari District. Badeng watershed is one of the vital watersheds in the Banyuwangi Regency. On November 25, 2018, Alas Malang Village, Singojuruh Subdistrict, Banyuwangi Regency, a flash flood occurred. This flood was thought to have occurred due to the high intensity of rain around the Badeng river's headwaters. Based on the Center for Volcanology and Geological Disaster Mitigation, which was reported from banyuwangikab.go.id, it was explained that the Badeng river experienced an overflow caused by heavy rains that flushed the Banyuwangi area for days and caused landslides in the upstream area to be precise on the Pendil mountains, causing surface water runoff in the Badeng watershed was recorded of 26.16 m^3/second from a flow capacity of 3.8 m^3/second.

The impact of the landslides and surface water runoff wasthe destruction of forestry areas, tourist attractions, and flooding in Alas Malang Village, Singojuruh District, Banyuwangi Regency. The flood that occurred brought mud and pieces of wood. The floods that occur also cause erosion and small landslides in the Badeng watershed, which causes the land to become increasingly critical. Changes in land conditions in a watershed are natural occurrences that need to be understood to determine the management actions that need to be taken in the future. The complexity of the watershed area still requires an innovative hydrological approach to improve the situation, especially conserving water resources.

Soil and Water Assessment Tools (SWAT) is a watershed-scale hydrological model that is physical, deterministic, and continuous. In its operation, the SWAT model can perform several simulations, including land and river channel practices. The SWAT hydrological model application is considered very suitable for identifying, assessing, evaluating the level of problems of a watershed, and as a tool for managing and controlling problems in the Badeng watershed.

Thus, the researcher will perform hydrological modeling using the SWAT model and perform the calibration and validation of the SWAT model in the Badeng Watershed. The modeling results are expected to become a basis for consideration in determining other management actions in the Badeng watershed and are expected to become the basis for developing the application of the hydrological model, especially for watersheds in the Banyuwangi Regency area.

Previous research related to erosion and watershed hydrological modeling, among others Chrstianto [2]; Erwanto [3-4], Hidayat [5], Junaidi [6], Nugraheni [7], and Ridwansyah [8].

B. Problems

How is hydrological modeling using SWAT in the Badeng Watershed?

C. Research Purpose

The purpose of this research is to determine hydrological modeling using SWAT in the Badeng Watershed.

II. THEORETICAL BASIS

A. Watershed

Watershed is a land area topographically bounded by mountain ridges that collect and store rainwater and channel it to the sea through the main river [9].

B. Hydrological Model

The hydrological model is a simple description of an actual hydrological system [10]. The notion of a system as a structure, tool, scheme, or procedure, both real and abstract, are linked in a particular time reference input or cause, energy, or information with the overall output of influence or response. The purpose of using models in hydrology includes forecasting, predicting, as a detection tool in problems, as an identification tool in planning problems, exploring data/information, and environmental estimates due to changing human behavior that increasing, basic research in hydrological processes [5].

C. SWAT Hydrological Model

Soil and Water Assessment Tools (SWAT) is a physical, deterministic, and continuous watershed-scale hydrological model developed by the USDA Agricultural Research Service, a development of the SWRRB model (Simulator for Water Recruitment in Rural Basins) in 1980, until the release of the SWAT model in 2005. SWAT is designed to predict the impact of management on water, sediment, and agrochemicals in watersheds. The SWAT model is physically based, efficient in performing calculations, and capable of simulating long-term simulations [11].

D. ArcSWAT

ArcSWAT is hydrological modeling software widely used today to study the impact of agricultural activities and land use management on the overall watershed, including flow and water quality. ArcSWAT is an extension of the ArcGIS-ArcView application for the SWAT hydrological model. ArcSWAT ArcGIS application or software develops from AVSWAT2000 and ArcView. This application can be used to simulate or simulate a single watershed or a system of multiple watershed hydrologist. Each watershed is first divided into sub-basins or sub-watersheds and then into Hydrologic Response Units (HRUs) based on land distribution and land use [1].

E. Calibration and Validation

Modeling performance using SWAT is assessed using validation methods, namely calibration and verification using statistical criteria R2 (Coefficient of Determination), and Nash-Sutcliffe Model Efficiency (NSE).

Validation is the process of evaluating a model to get an idea of the uncertainty a model has in predicting the hydrological process. In general, validation is carried out using data outside the data period used for calibration [12].

The validation test model is by calibrating using rainfall and climate data, which are scattered in the Badeng watershed area. For the efficiency model criterion [13], the R^2 value ranges from 0 - 1. If the R^2 value gets closer to 1, it means that there is a close relationship between the simulation data and the observed data. The NSE value ranges from 0 to 1. The NSE value is close to 1, indicating that the performance of a model is excellent. To find out the R^2 and NSE values, the following formula is used:

R^2 value correlation formula:

$$R^2 = \left(\frac{\sum_{i=1}^{n}(Q_{0,i} - \bar{Q}_0)(Q_{s,i} - \bar{Q}_s)}{\sqrt{\sum_{i=1}^{n}(Q_{0,i} - \bar{Q}_0)^2 \sum_{i=1}^{n}(Q_{s,i} - \bar{Q}_s)^2}}\right)^2 \quad (1)$$

NSE value calculation formula:

$$NSE = 1 - \left(\frac{\sum_{i=1}^{n}(Q_{0,i} - \bar{Q}_s)^2}{\sum_{i=1}^{n}(Q_{0,i} - \bar{Q}_0)^2}\right) \quad (2)$$

with:

Q0,i = Measurement discharge in the field (m3/second)

Qs,i = Simulation discharge (m3/second)

$\bar{Q}_0$ = Average measurement discharge (m3/second)

$\bar{Q}_s$ = Average simulation discharge (m3/second)

The criteria for the determinant coefficient value R2 and the efficiency model (NSE) can be seen in Tables 1 and 2.

TABLE I. DETERMINANT COEFFICIENT CRITERIA [11]

Criteria	Determinant Coefficient (R^2)
Uncorrelated	0
Very Weak Correlation	0 - 0.25
Sufficient Correlation	0.25 – 0.5
Strong Correlation	0.5 – 0.75
Very Strong Correlation	0.75 – 0.99
Perfect Correlation	1

TABLE II. VALUE CRITERIA OF THE EFFICIENCY MODEL WITH NSE [11]

Criteria	NSE
Well	NSE ≥ 0,75
Satisfactory	0,36 < NSE < 0,75
Not Satisfactory	NSE ≤ 0,36

III. METHODOLOGY

A. *Location of Study*

The research location was in the Badeng Watershed, Banyuwangi Regency which has an area of 52.40 km2 and located at geographic coordinates 8° 6’ 12.367" S to 8° 20’ 19.109" S, and 114° 6’ 34.242" E to 114° 19’ 15.679" E, with projection UTM WGS 1984 Zone 50 S.

B. *Data Collection*

Secondary data was obtained by researchers from the Banyuwangi Irrigation Service, the Banyuwangi Regional Development Planning Agency, and the Climatology Station of the Banyuwangi Regency. The following is secondary data used in the study, namely:

- Data from the Banyuwangi Irrigation Service is ten years of rainfall data from 2010 - 2019, and river discharge data.
- Climate data from the Climatology Station of the Banyuwangi Regency.
- DEM data obtained from download at USGS.

Data from the Banyuwangi Regional Development Planning Agency, namely:

- Digital map of topographic / contour.
- Digital map of land use.
- Digital map of soil types.
- Digital map of slopes.
- Digital map of the Badeng river basin network.
- Digital map of the boundaries of the Badeng watershed and sub-watershed.

C. *Step Work*

1) *Watershed delineation:* This process forms boundaries or defines the watershed being modeled. The process includes the DEM setup.

2) *HRU analysis:* A processing activity that overlaps land use maps, soil, and slopes to form or define a hydrologic response unit (HRU's) in the modeled watershed area.

3) *Write input tables:* And this process contains input values for model input, including weather definition. This process determines the next process if this process is successful, it will be able to continue to the next stage.

4) *SWAT Simulation:* Was in this process that the running model was run so that the modeling output in the Badeng Watershed can be seen.

5) *Calibration and validation data:* the process of comparing the simulation results of the SWAT model with the observation data using trial and error methods and additional software, namely SWAT- CUP.

The research flowchart starts with a literature study and secondary data collection. Furthermore, the data would be processed to be used for modeling in the SWAT software. After the modeling was complete, the calibration and validation process was carried out to adjust the parameters so that the model could be used.

IV. RESULTS AND DISCUSSION

A. *Rain Data Processing*

The average annual rainfall in the Badeng watershed is measured from 3 rain stations, namely the Songgon, Gambor, and Alas Malang rain stations. The rainfall data used are data from 2010-2019. Rainfall data used for further calculations were tested first to see its consistency. This consistency test was carried out using the multiple mass curve technique, which compares the annual cumulative data from the observed rain stations with the annual cumulative data of the surrounding stations. The recapitulation results of the consistency test of rain data are shown in Table 3.

TABLE III. RECAPITULATION OF RAINFALL DATA CONSISTENCY

No	Rainfall Station	Equations	R^2	Information
1	Songgon	y = 1.0767x + 157.71	0.8831	Consistent
2	Alas Malang	y = 1.166x - 115.53	0.9592	Consistent
3	Gambor	y = 0.7242x - 7.1984	0.9637	Consistent

Based on Table 3, it can be seen that the three-rainfall data from 3 rain stations in the Badeng watershed are stated to be consistent because they have an R2 value with a very high correlation.

B. *Establishment of Sub-Watershed*

The SWAT model for delineation of the Badeng watershed would automatically obtain complete topographic calculations, river network maps, watershed boundary maps, sub-watershed, and outlet maps. In the delineation process, apart from a DEM (Digital Elevation Model) map, the location of the watershed area, a map of the river basin network, and the determination of the required watershed / sub-watershed outlet points were also required.

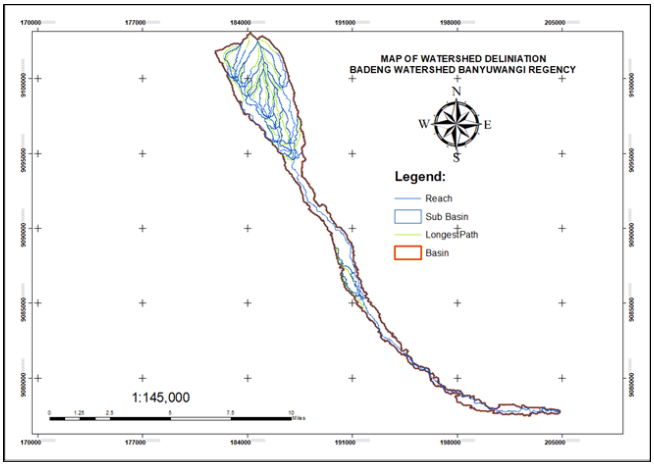

Fig. 1. Map of Badeng watershed delineation results.

In Figure 1, it can be seen that the results of the delineation of the Badeng watershed model are divided into 27 sub-watersheds, which are shown by the total area of the Badeng watershed formed by the model delineation of 42.2977 ha.

C. *Establishing Land Units or HRUs Analysis*

This stage is a land grouping with the same land and landuse characteristics, so the map used is a land map and a land- use map. Then input data to the slope. The following are theresults of the HRUs Map like Figure 2.

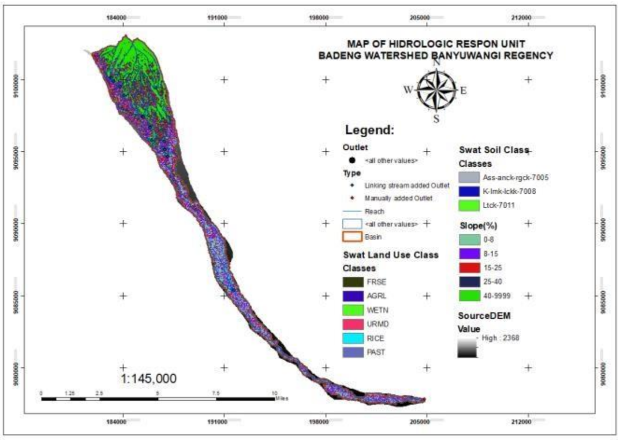

Fig. 2. Map of HRU analysis results.

HRU Analysis made 27 Badeng sub-watersheds into 41 types of land units or HRU. The results of HRU processing produce three types of land cover, namely forest (FRSE), pasture (PAST), and rice fields (RICE). It can happen because when inputting the HRU, the definition was determined to be less than 30%, so that the area of less than 30% was ignored by SWAT.

D. *Calibration and Validation*

The calibration process uses annual average discharge data from 2010 to 2013 using the approach discharge data from the Bomo watershed by comparing the area of the Badeng watershed divided by the area of the Bomo watershed and multiplied by the Bomo river discharge data. This was done because there was no discharge measurement tool in the Badeng watershed. The hydrograph of the monthly discharge before being calibrated can be seen in Figure 3. While the graph of the correlation between the observation discharge and simulation discharge before being calibrated can be seen in Figure 3.

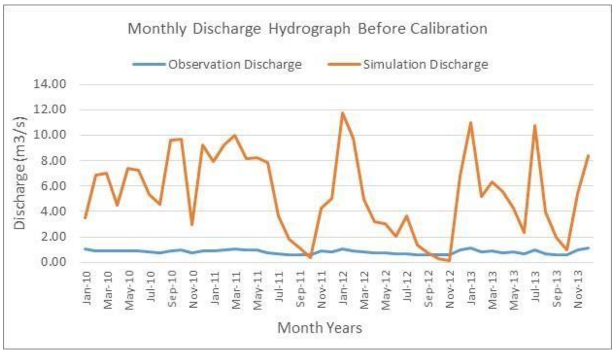

Fig. 3. Monthly discharge Hydrograph before calibration.

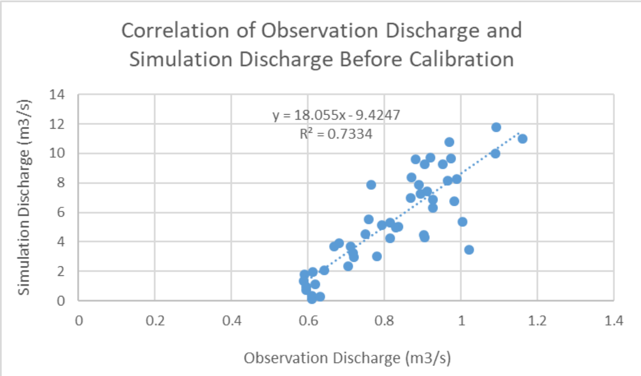

Fig. 4. Correlation of observation discharge and simulation discharge before calibration.

Based on Figure 3 and Figure 4, it can be seen that the correlation value R^2 is 0.73. Furthermore, having an NSE value of -0.48, it can be seen that the modeling results are still far from the conditions in the field, and the observation data is still underestimated, which means the observation data is still below the average simulation data. So that the model needs a calibration process.

Based on the above problems, it is necessary to calibrate the data by changing, reducing, or adding several parameters that influence the model based on references to previous studies. Table 4 shows the parameters for the calibration process.

TABLE IV. CALIBRATION PARAMETERS

Parameter	Value	Min value	Max value
R_CN2.mgt	3	-3	3
V_ALPHA_BF.gw	0.48	0	0.8
V_GW_DELAY.gw	1	0	50
R_GW_REVAP.gw	0.8	0.5	1
V_CH_K2.rte	250	50	500

Based on Table 4, it has been explained that five parameters have been adjusted for calibration at the study location. The CN2 value describes the ability of the soil to absorb and store water. Alfa_BF shows the response of the base flow to the infiltration. A response that ranges from 0.1–0.3 indicates a slow response to recharging times. Meanwhile, fast values ranged from 0.9 – 1 [1]. The value of Alfa_BF in the Badeng watershed shows a value of 0.48, which means that it has a slow base flow response. GW_Delay or groundwater lag time is a parameter that shows the length of time water flows in the soil profile and the aquifer zone before finally coming out again.

The parameter GW_REVAP is the groundwater evaporation coefficient. When the water is dry, it can diffuse into the root area, and the GW_Revap value shows the ability of water to move towards the root area in that state. A value close to 0 indicates a more limited water movement, while a value closer to 1 indicates a movement closer to the potential evapotranspiration value. The calibration results show a GW_Revap value of 0.8, which indicates a limited water movement towards the root zone.

Calibration was also performed using other parameters such as CH_K2. CH_K2 is hydraulic conductivity in the mainline. The value of CH_K2 is 250. After these parameters are changed or calibrated, the observation discharge and SWAT simulation discharge show that the deviation is small, as shown in Figure 5.

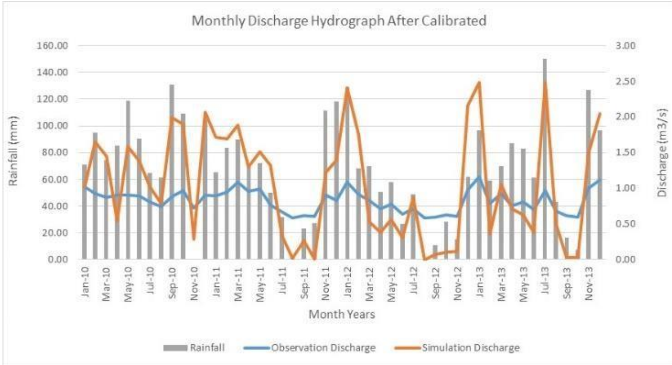

Fig. 5. Monthly discharge Hydrograph after calibrated.

The calibration results show that the amount of rainfall value affects the increase in river discharge in the simulationand observation results, as well as the observation results used, which were the approach discharge data from the Bomo watershed. The highest rainfall results from 2010 to 2013 occurred in July 2013 with a value of 150 mm and a simulation discharge with a value of 2.48 m^3/s, for the observation discharge it has a value of 0.59 m^3/s.

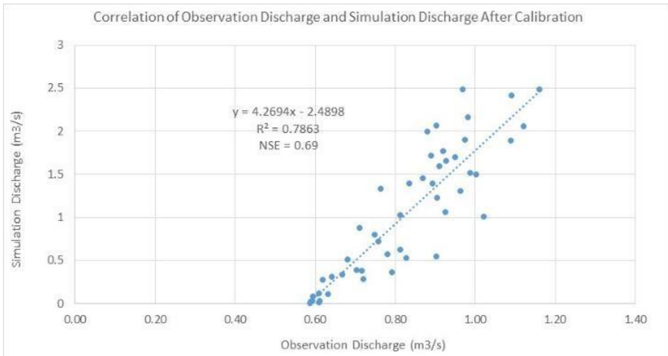

Fig. 6. Correlation of observation discharge and simulation discharge after calibration.

Based on Figure 6, it is obtained that the equation y = 4.2694x + 2.4898 and shows the correlation value R2 of 0.78. The model can be accepted if the value of R2 > 0.5 or getting closer to one. So this calibration gets a good value or meets the requirements [14]. The correlation results fall into the very strong correlation category, namely between 0.75 - 0.99. The NSE value obtained a value of 0.69, which means that results are classified as satisfactory so that the model can be used. From the calculation results, the RMSE value is 0.3, and this value shows the error rate or the deviation of the flow rate model is small. The NRMSE value is 0.49.

Validation in the Badeng watershed uses data from 2018 to 2019. The validation process is the same as the calibration process, and only the data used are data from the last two years. Observation data for the last two years in the Badeng watershed is the result of observations on the conditions in which the Badeng watershed experienced flash floods due to landslides on Mount Pendil of Raung hills. The results of modeling before being validated from the SWAT analysisare shown in Figure 7.

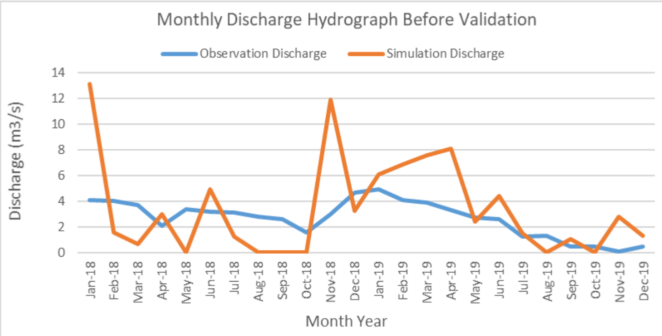

Fig. 7. Monthly discharge hydrograph before validation.

In Figure 7, it is known that the simulation discharge is higher than the observed discharge. It happened because, in 2018, the observation discharge used was the discharge data when the Badeng watershed was flooded. Meanwhile, in 2019, the Badeng watershed was damaged due to landslides.

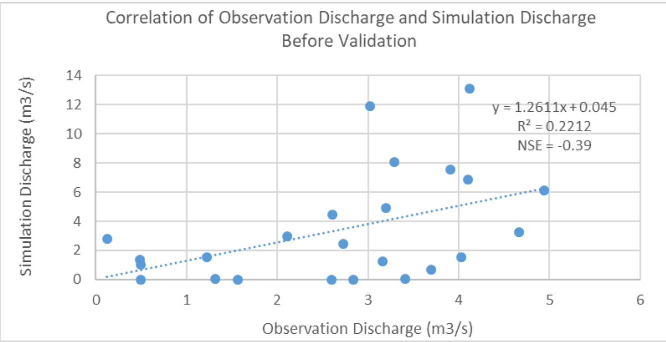

Fig. 8. Correlation of observation discharge and simulation discharge before validation.

Based on Figure 8 shows that the graph of the correlation between the observed discharge and the simulation discharge before being validated gets an equation of y = 1.2611x + 0.045 with an R^2 value of 0.22, which shows a very weak correlation. Before being validated, the NSEvalue was -0.39, which means that the data had a very high deviation (underestimate). Based on the results of the R^2 calculation analysis and the NSE criteria, it can be concluded that these results cannot be used, so it is necessary to adjust the parameters again to get a value that meets the criteria anda satisfactory result. The parameters used can be seen in Table 5.

TABLE V. 12 VALIDATION PARAMETERS

Parameter	Value	Min value	Max value
R__CN2.mgt	0.69	-0.80	1.00
V__ALPHA_BF.gw	0.18	-0.20	0.32
V__GW_DELAY.gw	10.70	2.50	49.35
V__GWQMN.gw	2220.50	1500.85	2871.61
V__CH_K2.rte	430.18	25.46	488.00
V__CH_N2.rte	0.09	-0.20	0.30
V__EPCO.hru	-0.11	-0.12	0.50
V__ESCO.hru	0.12	-0.20	0.35
V__REVAPMN.gw	192.02	173.60	419.25
V__SURLAG.bsn	17.19	12.86	23.04
R__GW_REVAP.gw	0.10	0.05	0.17
V__RCHRG_DP.gw	0.29	0.01	0.50
V__SLSUBBSN.hru	143.62	42.90	146.20

After adjusting these parameters, the results are as shownin Figure 9.

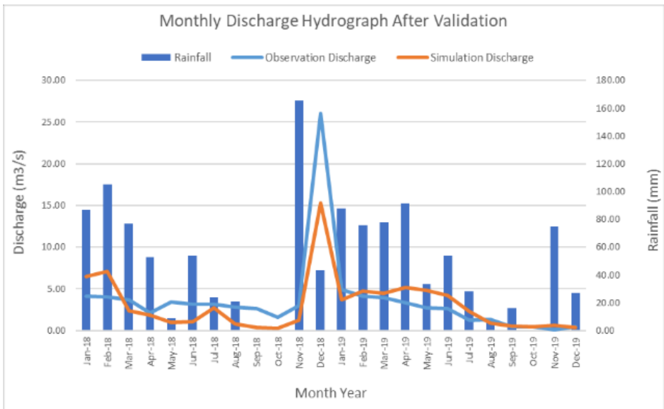

Fig. 9. Monthly discharge hydrograph after validation.

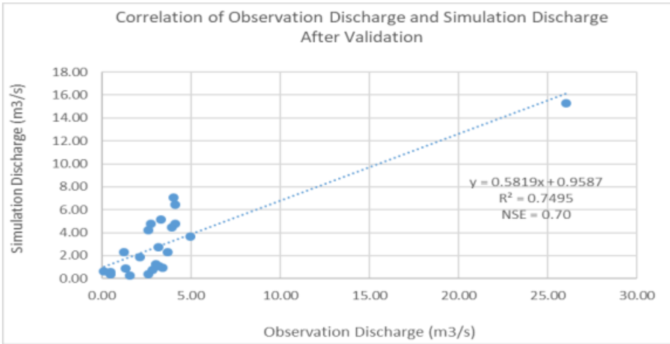

Fig. 10. Correlation of observation discharge and simulation discharge after validation.

Based on the correlation in Figure 10, the equation y = 0.5819x + 0.9587 and the R^2 value is 0.75. From the validation results, it can be seen that R^2 has decreased in value from the calibration results, but the value is still good.However, the NSE value has increased from the calibration results from 0.69 to 0.70. The NSE score is still in the satisfactory category, which is between 0.36 and 0.75.

TABLE VI. CALCULATION OF NSE VALIDATIONS

Month-Years	Total Discharge (m^3/s)		NASH - Sutcliffe Criterion			
	Qo	*Qm*	*[Qo-Qm]*	*[Qo-Qm]^2*	*[Qo-'Qo]*	*[Qo-'Qo]^2*
Jan-18	4.12	6.436	2.31	5.35	0.56	0.31
Feb-18	4.03	7.057	3.03	9.16	0.47	0.22
Mar-18	3.69	2.333	1.36	1.85	0.13	0.02
Apr-18	2.11	1.84	0.27	0.07	1.45	2.11
May-18	3.41	0.966	2.44	5.95	0.16	0.02
Jun-18	3.20	1.095	2.10	4.41	0.37	0.13
Jul-18	3.16	2.745	0.41	0.17	0.40	0.16
Aug-18	2.84	0.7662	2.07	4.30	0.72	0.52
Sep-18	2.60	0.3945	2.21	4.87	0.96	0.93
Oct-18	1.57	0.2904	1.27	1.62	2.00	3.99
Nov-18	3.03	1.253	1.77	3.14	0.54	0.29
Dec-18	26.03	15.31	10.72	114.96	22.47	504.86
Jan-19	4.94	3.645	1.30	1.68	1.38	1.90
Feb-19	4.10	4.765	0.66	0.44	0.54	0.29
Mar-19	3.91	4.489	0.58	0.33	0.35	0.12
Apr-19	3.29	5.161	1.87	3.49	0.27	0.07
May-19	2.73	4.792	2.06	4.26	0.83	0.70
Jun-19	2.61	4.236	1.63	2.65	0.95	0.91
Jul-19	1.23	2.306	1.08	1.17	2.34	5.46
Aug-19	1.32	0.8734	0.44	0.20	2.24	5.04
Sep-19	0.49	0.5585	0.06	0.00	3.07	9.42
Oct-19	0.49	0.4149	0.08	0.01	3.07	9.42
Nov-19	0.12	0.6423	0.52	0.27	3.44	11.83
Dec-19	0.49	0.3998	0.09	0.01	3.07	9.44
AVERAGE	3.56	3.03	1.68	7.10	2.16	23.67
SUM	85.51	72.77	40.35	170.37	51.79	568.18
STDEV	4.97					
RMSE	1.01					
NRMSE	0.26					
NSE	0.70					
CORREL	0.87					
R^2	0.75					

E. Simulation Results of Rainfall

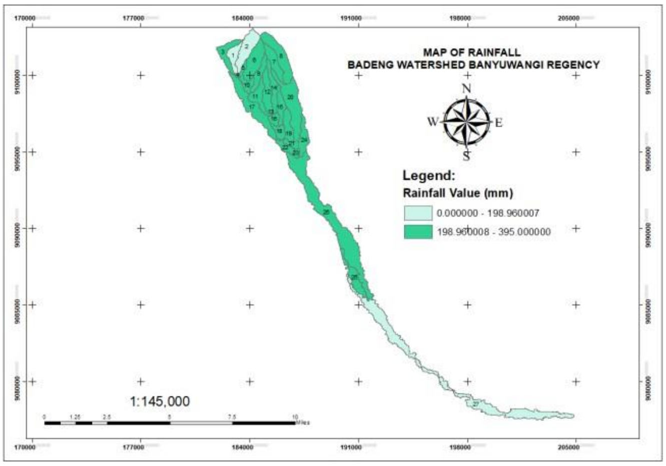

Fig. 11. Map of Annual Average Rainfall in the Badeng Watershed.

Figure 11 explained that the distribution of the annual average rainfall from 2010 to 2019 was 10467.91 mm/year, with an average of 387.70 mm/year. The lowest rainfall value is in sub-watershed 27. Sub-watershed 27 has an average rainfall value of 198.26 mm/year, sub-watershed 27 is an area with rice and residential land cover.

F. Simulation Results of Surface Runoff

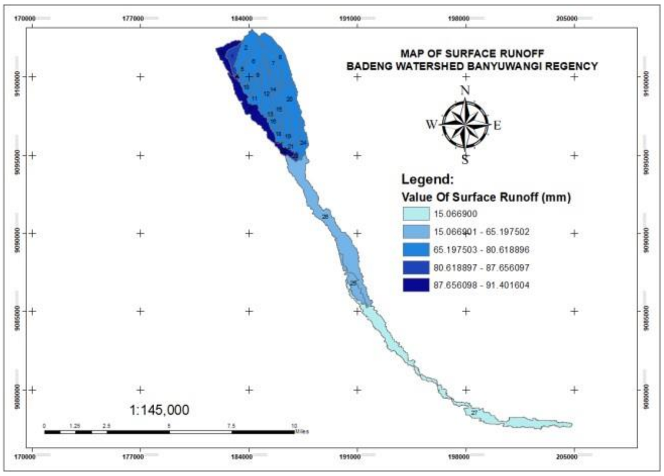

Fig. 12. Map of Annual Average Surface Runoff in The Badeng Watershed.

Based on Figure 12, it is explained that the distribution of the annual average surface runoff from 2010 to 2019 is 2128.41 mm/year, with an average of 78.83 mm/year. The highest surface runoff value is found in sub-watershed number 22, with an average value of 91.4 mm/year.

G. Simulation Results of Evapotranspiration

The map in Figure 13 explains that the distribution of the annual average evapotranspiration value in the Badeng watershed in 2010 to 2019 has a total of 1577.21 mm/year, with an average of 58.42 mm/year. The highest evapotranspiration value was in sub-watershed 26, with an average value of 63 mm. sub-watershed 26 is a rice field area, so in this area, it is necessary to take conservation measures or the application of mulch to prevent excess water loss due to evapotranspiration.

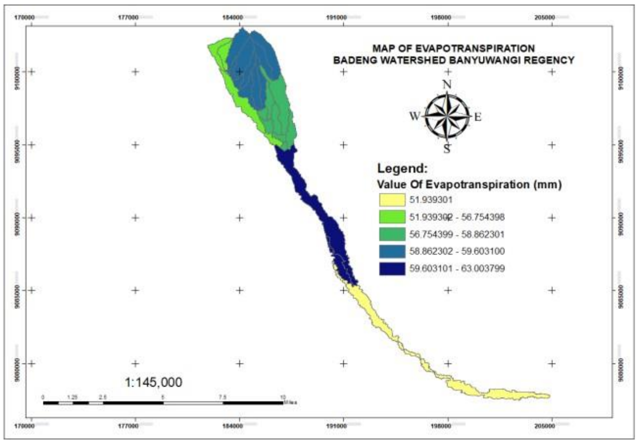

Fig. 13. Map of Annual Average Evapotranspiration in The Badeng Watershed.

H. Simulation Results of Potential Evapotranspiration

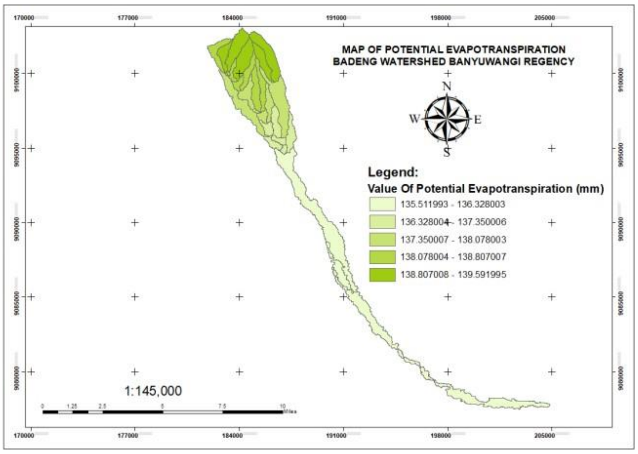

Fig. 14. Map of Annual Average Potential Evapotranspiration in the Badeng Watershed.

Based on Figure 14, it is explained that the distribution of the annual average potential evapotranspiration value in the Badeng watershed in 2010 to 2019 has a total value of 3722.61 mm/year, with an average of 137.87 mm/year.

I. Simulation Results of Sediment Discharge

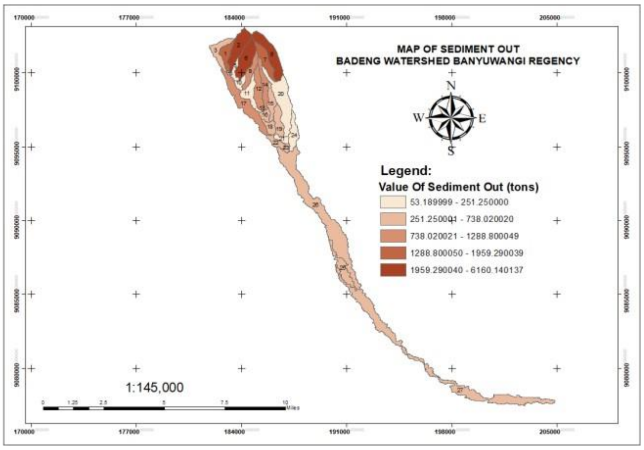

Fig. 15. Map of Annual Average Sediment Discharge in The Badeng Watershed.

The SWAT simulation results in the form of sediment discharge have a total annual average value in the Badeng watershed in 2010 to 2019 of 28779.44 tons/year, with and average value of 1102.94 tons/year. The high sediment discharge values were found in sub-watersheds 2, 6, and 8, with respective values of 5901.73 tons/year, 4059.36 tons/year, and 6160.14 tons/year. The three sub-watersheds are areas with forest land cover, so it is necessary to take conservation actions to reduce the value of wasted sediment. The sediment discharge zoning map can be seen in Figure 15.

J. Simulation Results of Erosion Rate

Hydrological modeling also produces erosion values from the Badeng Watershed, where the erosion values are directly processed or analyzed by SWAT software using the USLE method. For a zoning map, the annual average erosion rate in the Badeng Watershed can be seen in Figure 16.

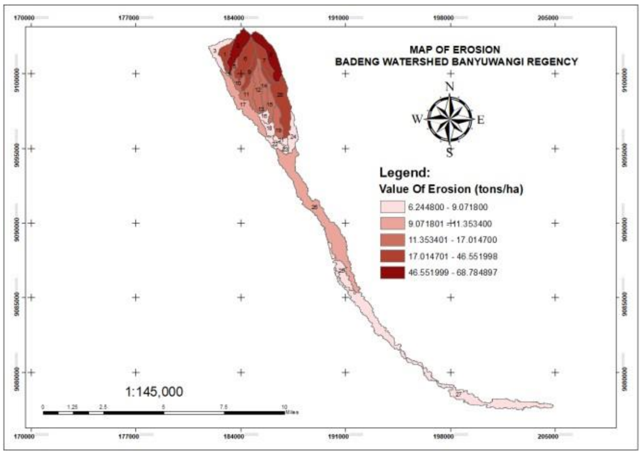

Fig. 16. Map of Annual Average Erosion Rate in The Badeng Watershed.

Based on the erosion rate zoning map in Figure 16, it is explained that the annual average erosion rate in the Badeng watershed in 2010 to 2019 has a total value of 601.92 tons/ha/year, with an average of 22.29 tons/ha/year. The highest erosion values occurred in sub-watersheds number 2 and number 8, with values of 68.78 tons/ha/year and 61.98 tons/ha/year. The area is an area with forest land cover, so it is necessary to take land conservation measures in the Badeng watershed, especially in sub-watersheds 2 and 8, so that the erosion that occurs does not get bigger.

V. Conclusions

Based on the analysis and discussion of hydrological modeling using SWAT in the Badeng watershed, it can be concluded that the total annual average rainfall was 10467.91 mm/year, total evapotranspiration of 1577.21 mm/year, the total potential evapotranspiration value of 3722.61 mm/year, total the percolation value of 6760.05 mm/year, the total surface runoff value of 2128.41 mm/year, the total sediment discharge value of 29779.44 tons/year, the total sediment yield value of 250.65 tons/ha/year, and the total erosion rate value of the USLE method was 601.92 tons/ha/years. The calibration results with a determinant coefficient (R^2) of 0.78 and NSE of 0.69. Then, for the validation result with the determinant coefficient (R^2) of 0.75, and NSE of 0.70.

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