THE APPLICATION OF THE SWAT+ MODEL FOR WATERSHED MANAGEMENT SCENARIOS IN LAHAR FLOW AREAS OF MERAPI VOLCANO

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DOI: 10.21163/GT_ 2024.192.17

ABSTRACT

This research aimed to analyze the surface runoff using the SWAT+ model and developed scenarios for watershed management that followed the environmental and community conditions. To achieve this objective, the analysis requires parameters such as land use, soil types, morphology, climatology, and hydrology, which were collected from primary data sources and supplemented by secondary data from relevant stakeholders. The SWAT+ method was employed to delineate watershed boundaries, construct a Hydrologic Response Unit (HRU), edit and input parameters, and perform calibration and validation. The watershed management scenario was developed by altering land use to define conservation areas and buffer zones. The results were then calibrated and validated using multiple tests. Calibration results yielded NSE= 0.52, PBIAS=7.38, and R2= 0.79, while validation showed NSE= 0.50, PBIAS= -5.45, and R2= 0.58. The values of this statistical test were greatly influenced by the quality and length of the data. The analysis also explored how changes in land use affect runoff values, considering factors like Curve Number (CN) values, recharge area classes, and land use patterns (e.g., clustered or dispersed). This analysis takes into account various hydrological parameters, including evapotranspiration and surface runoff, which are influenced by the land's ability to retain water. Additionally, values like lateral flow, return flow, and recharge are affected by the location of land conversion within the watershed (e.g., upstream, midstream, or downstream). The findings from this analysis allow for adjustments in watershed management efforts to align with the desired changes.

Key-words: *Physical Geography, Runoff, Scenario, SWAT+ Model, Curve Number (CN) values, Watershed management.*

1. INTRODUCTION

One of the functions of a watershed is to collect, store, and distribute runoffs from upstream to downstream areas. Unfortunately, this function is often disrupted by various factors, such as anthropogenic activities, erosion, and sedimentation processes, or natural phenomena that can change the characteristics and patterns of the river flow (Jayawardena 2015).

A real example of such disruptions can be seen in the sub-watershed of Blongkeng, located in the vulcanic areas of Mount Merapi. Eruption activities produce pyroclastic materials that can affect the shape and morphology of the river and impact the watershed system in general. These disruptions cause erosion, mass movement, and intense sedimentation in the Blongkeng Sub-Watershed, which in turn increases vulnerability to flood disasters due to the narrowing and sedimentation of the river-cross section (Solikha, Marfai 2012, Zulfahmi et al. 2016).

The variation in slope classes and soil types influences flow velocity. The predominance of steep topography indicates a higher rate of erosion, which is further exacerbated by sand mining and other anthropogenic activities that alter the natural characteristics of the river. The parent rock formations in the area, composed of both young and old volcanic deposits from Mount Merapi, generally exhibit varying porosity and permeability, which affect the capacity for groundwater storage and movement.

Watershed modelling is an effective tool to simulate the impacts of watershed's management and process on land and water resources. In this context, the Soil Water Assessment Tool Plus (SWAT+), an advanced version of the previous SWAT model, was used to analyse water flow and enhance the

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understanding of spatial relationships in watershed analysis (Armoa et al. 2023). Particularly for applications in volcanic areas, physical hydrological modeling, such as SWAT+, is more effective at modeling complex conditions than empirical and conceptual hydrological modeling (Gull & Shah, 2020). The use of the innovative SWAT+ method aims to develop sustainable watershed management strategies and achieve a balance between natural resources and human needs (Wang et al. 2016). By employing SWAT+, this study focuses on analysing runoff and developing watershed management scenarios to address issues identified in the Blongkeng Sub-Watershed, such as erosion, sedimentation, and changes in river morphology.

2. STUDY AREA

The Blongkeng Sub-Watershed (Sub-DAS) has an elevation ranging from 190 to 2,720 meters above sea level. Administratively, this area is located in Magelang Regency, Central Java Province, Indonesia. The Blongkeng Sub-Watershed is part of the Progo River Basin, situated between 110˚15'18" and 110˚26'39" East Longitude, and 7˚32'10" and 7˚38'41" South Latitude. This region falls under the Köppen climate classification Af, indicating a tropical rainforest climate.

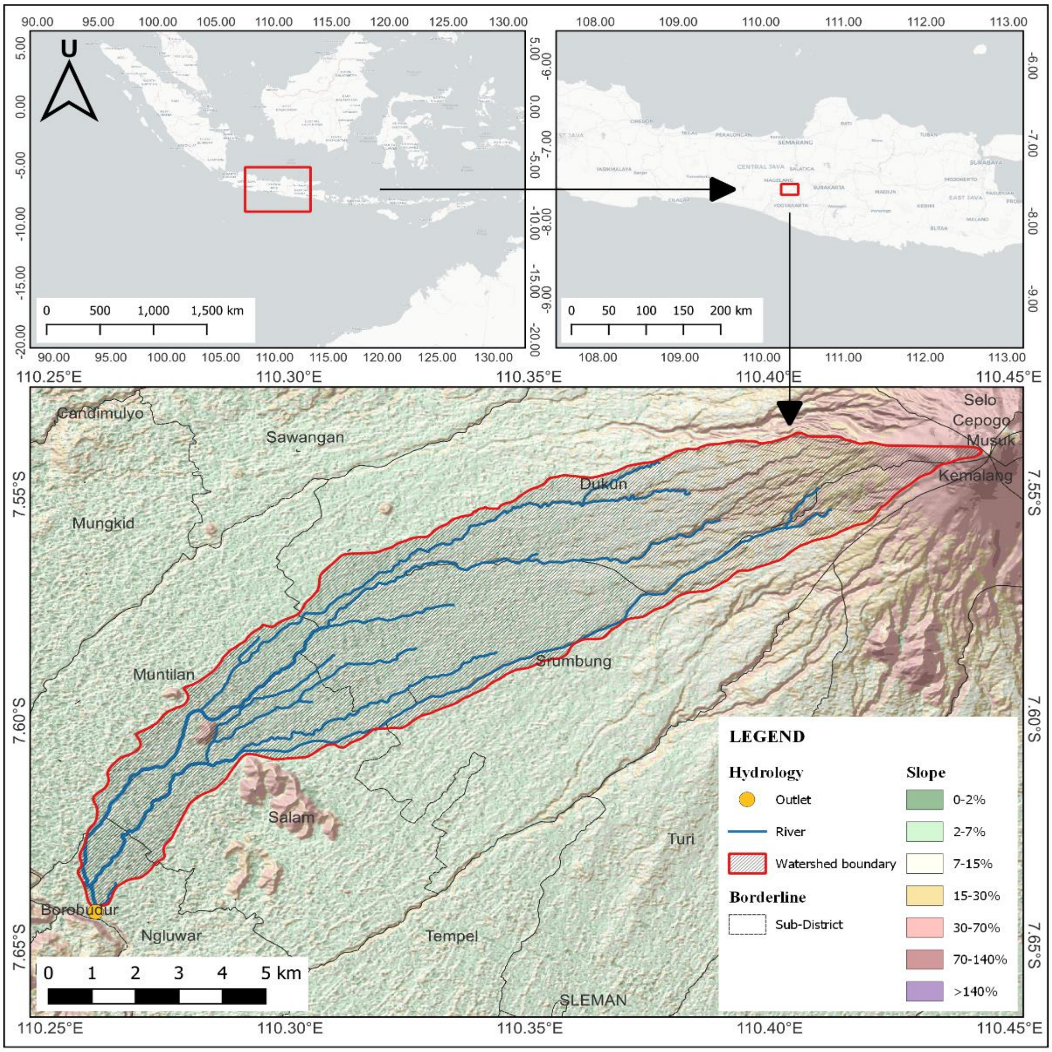

Fig. 1. Location Map of the Blongkeng Sub-Watershed.

As shown in **Fig. 1**, the Blongkeng Sub-Watershed exhibits high-risk factors concerning water resources but lacks sufficient field observation data. Therefore, runoff modeling using SWAT+ is crucial for developing a hydrological system that is suitable for the characteristics of the area and for formulating effective watershed management strategies (Morante-Carballo et al. 2022).

3. DATA AND METHODS

The Soil and Water Assessment Tool (SWAT+) is a physical hydrology model capable of analyzing runoff using complex data. This data includes climatological data (precipitation, humidity, temperature, solar radiation, and wind speed), soil data (texture, permeability, moisture, organic matter, coarse materials, and bulk density), land cover and land use data, and other data such as slope, morphology, and observation flow data.

3.1. Data

To support the analysis using the SWAT+ model, streamflow data were collected using an Automatic Water Level Recorder (AWLR) installed at the watershed outlet for one year. In addition to measurements with the TMA (Stage Height), direct observations of streamflow were recorded to establish a relationship between TMA and flow using a rating curve. This observation method involved the use of a float with the following formula:

-Flow Rate (Q), $Q = A \times V$

-Flow Velocity (V), V = 1/n R^(2/3) S^(1/2)

-Hydraulic Radius (R), $R = A/P$

A = Cross-sectional area
n = Manning's roughness coefficient
S = Slope of the riverbed
P = Wetted perimeter

Furthermore, soil data were obtained by collecting soil samples using a pedo geomorphological approach, with landform unit scale as the classification unit (Christanto et al. 2019). The Blongkeng sub-shedwater has nine types of land such as upper slope, middle slope, lower slope, foot slope, valley, undulating plain, alluvial fan, hillock, and floodplain (BIG 209). The soil sample was gathered by taking into account the accessibility and activity of the volcano because the Merapi Mount is categorized into the Siaga level (watch) (BBD-DIY 2024). Thus, the soil data should be integrated into the global data of the DSOL Map (López-Ballesteros et al. 2023).

Another data required in this analysis was climatological data. These data were obtained from the records of an Automatic Rainfall Recorder (ARR), an Automatic Weather Recorder (AWR), and an ARR Logger installed around the Blongkeng sub-watershed areas. The SWAT+ model analysis utilized regional rainfall data, which was processed using the Thiessen Polygon method. Additionally, climatological data were classified based on elevation to account for orographic factors.

To ensure comprehensive analysis of the SWAT+ model, the study requires a range of data types, including land use data. Accurate and up-to-date land use data are essential for the SWAT+ analysis to reflect the current landscape conditions. In this study, land use data were based on the Indonesian Topographic Map (RBI) in accordance with the Indonesian Geographic Element Catalog (KUGI) (BIG 2019). This data was subsequently updated using Planetscope imagery with a spatial resolution of 5 meters to reflect the land cover conditions during the research year in 2021 (Planet Labs 2023).

3.2. SWAT+ method

With the land use data prepared, the next step in the SWAT+ analysis involved defining the characteristics of the study area and setting up the model for simulation. The SWAT+ model process began with determining the watershed's characteristics by delineating watershed boundaries and establishing HRU. The watershed boundaries, serving as the unit of analysis, were determined based on DEM data and river network data, while the HRUs were defined using land use, soil, and slope data. The simulation process included setting up a warming-up period, followed by calibration and validation, as shown in **Fig. 2**.

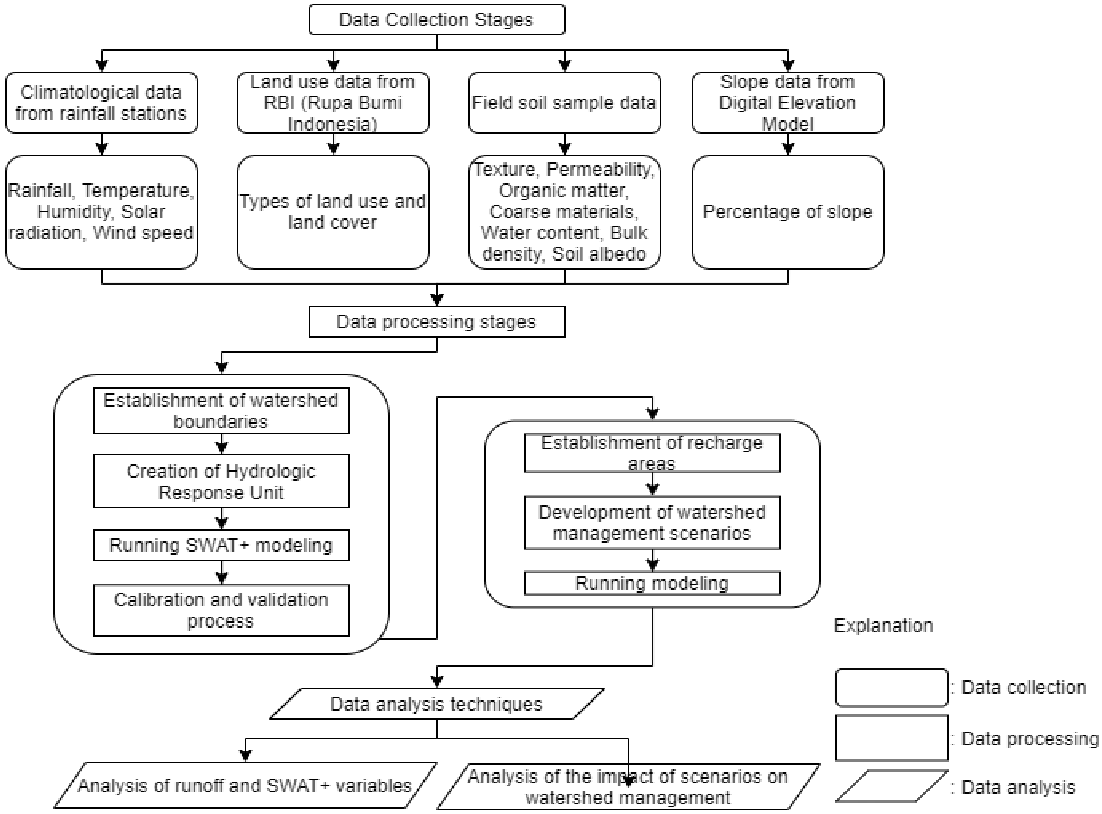

Fig. 2. SWAT+ modeling flowchart.

The calibration and validation steps were used to test the accuracy of the model results against observational data. The steps involved statistical tests over different time periods. Calibration and validation were processed using the SWAT+ Toolbox on 16 parameters. The tool also identified sensitivity parameters that influence the simulation process. The performance levels of the calibration and validation using the NSE, PBIAS, and R2 methods are shown in **Table 1**.

Table 1.

Results of statistical tests on performance levels.

Performance Level	NSE	(PBIAS) %	R^2
Very good	0.75 – 1	≤ 10	0.7 – 1
Good	0.65 – 0.75	10 – 15	0.6 – 0.7
Satisfactory	0.5 – 0.65	15 – 25	0.5 – 0.6
Unsatisfactory	≤ 0.5	> 25	≤ 0.5

Source : de Salis et al. (2019).

Building on the calibration and validation, the runoff analysis was conducted using Curve Number (CN) values, with simulations performed to assess how changes in land use impacted CN values. Many studies around the world have confirmed the efectiveness of integrating the SCS-CN method with hydrological modeling (Melesse et al., 2003; Melesse & Graham, 2004; Satheeshkumar et al., 2017). These impacts were further illustrated in flow hydrographs generated by the SWAT+ model. Land use changes involved altering the percentage of vegetative cover in recharge areas.

Following the runoff analysis and the creation of land use scenarios, the next step involved determining recharge areas. This was achieved using a hydrogeomorphological approach that considers parameters such as morphology, precipitation, geology, soil, and land cover (Suprayogi et al. 2013). These parameters were assessed and weighted, and the identification of recharge areas was carried out using the Weighted Method. The next step in watershed management involved creating scenarios to manage runoff. This stage focused on efforts to reduce runoff by adding vegetation areas designated as conservation zones for water and soil. The scenarios developed considered both environmental conditions and community needs.

4. RESULTS

This section presents the results obtained from the SWAT+ model simulations and the subsequent analysis of the data. We will discuss the key findings regarding streamflow (debit) data, soil data, climatological data, and other relevant parameters, including land use changes and their effects on hydrological processes. The discussion also explores the effectiveness of proposed management scenarios.

4.1. Data processing stage for the Blongkeng sub-watershed

Our first finding focuses on the streamflow data, which was obtained through precise measurements using the Automatic Water Level Recorder (AWLR). The logger requires observational data to calibrate the rating curve, and in this study, five sets of observation data were collected and presented in **Table 2**. The table indicates that the accuracy of the rating curve improves with the number of observations. The process of measuring streamflow began with recording the morphometric characteristics of the river segment: the river width was 16.7 meters, the wetted cross-sectional area was 20.1 meters, the riverbed slope was 0.113, and the Manning's roughness coefficient was 0.161.

Table 2.

Observational streamflow measurements.

Date	Water Flow	Q
8 December 2020	11 cm	0.022
15 January 2021	42 cm	2.344
19 May 2021	5 cm	0.886
11 October 2021	14 cm	1.656
23 November 2022	33 cm	1.772

The rating curve was derived from comparing the observational streamflow measurements with the water level data, resulting in the equation y = e1.7103x and an R^2 value of 0.7952, as shown in **Fig. 3**. This equation was used to convert the water level data from the logger into streamflow data. **Fig. 4** shows the resulting streamflow data in 7 months (June 2021 - January 2022). However, it is important to note that this data includes only one rainy season and one dry season, which should be considered when utilizing and analyzing the data. The limited data period is due to constraints in field data recording. Collecting discharge and rainfall data poses challenges in extreme conditions like lahar flows. Therefore, this research requires the installation of measuring instruments. Issues of missing or unreadable data also affect the length of the dataset.

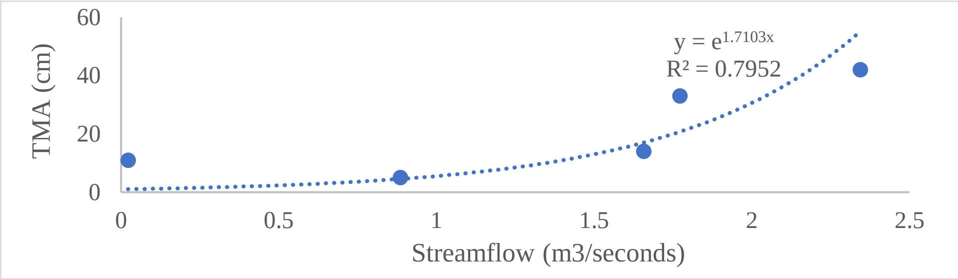

Fig. 3. Rating curve of water level and measured streamflow.

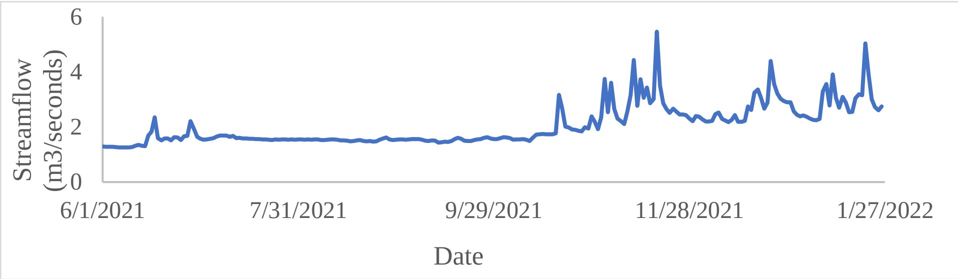

Fig. 4. Observed streamflow recorded by the logger.

The second finding relates to the soil conditions in the Blongkeng Sub-Watershed, which were distinguished based on landform analysis units. Soil data were obtained through field sampling at each landform type using a pedo geomorphological analysis. The sampling locations are shown in **Fig. 5a**, and the data represent the uppermost soil layer or the first layer. The sequence of soil samples is as follows: sample 1 = Floodplain, sample 2 = slope, sample 3 = alluvial fan, sample 4 = undulating plain, sample 5 = valley, sample 6 = foot slope, and sample 7 = lower slope. The soil characteristics are detailed in **Table 3**.

Table 3.

Soil data.

Sample	Permeabilitas (cm/jam)	Soil textures (%)			Water content (%)	Coarse materials (%)	Bulk density (gr/cm3)	Organic materials (%)
		Sand	Clay	Silt				
1	23.78	71%	19%	10%	1.00	0.10	1.17	0.34
2	26.33	54%	25%	21%	7.71	3.87	0.96	0.39
3	50.11	60%	24%	16%	1.83	8.58	1.34	2.14
4	22.51	57%	15%	27%	2.45	3.28	1.30	2.53
5	6.37	62%	17%	21%	0.80	11.43	1.87	2.61
6	22.51	64%	26%	10%	1.00	2.97	1.88	2.02
7	31.00	55%	41%	3%	1.00	7.63	1.67	2.69

The calculation of regional rainfall in the SWAT+ model is based on the Thiessen Polygon method, as illustrated in **Fig. 5b**. Climatological data were generated according to elevation to account for orographic factors. Although there were limitations in the availability of field data, the climatological data used in this study were still sufficiently representative.

Subsequently, **Fig. 5c** indicates that the types of land use significantly affect the amount of surface runoff. Specifically, vegetative land use types play a crucial role in retaining and storing rainfall as groundwater reserves through the process of infiltration. In contrast, built-up land use types result in high surface runoff because water cannot infiltrate the soil.

The next findings focus on the recharge area analysis. The analysis is identified in three classes: very low, low, and moderate (see **Fig. 5d**). The most influential parameters affecting the changes in recharge area classes in the Blongkeng Sub-Watershed are vegetation cover and slope gradient. Areas with vegetative cover tend to have higher recharge values, while flatter slope conditions also result in higher recharge values. These recharge area classes serve as indicators for evaluating the effectiveness of watershed management efforts, particularly through land use changes. The role of vegetation in conservation efforts is crucial as it helps retain rainfall, reduce immediate runoff, and allow water to be absorbed into the ground, thereby increasing groundwater reserves.

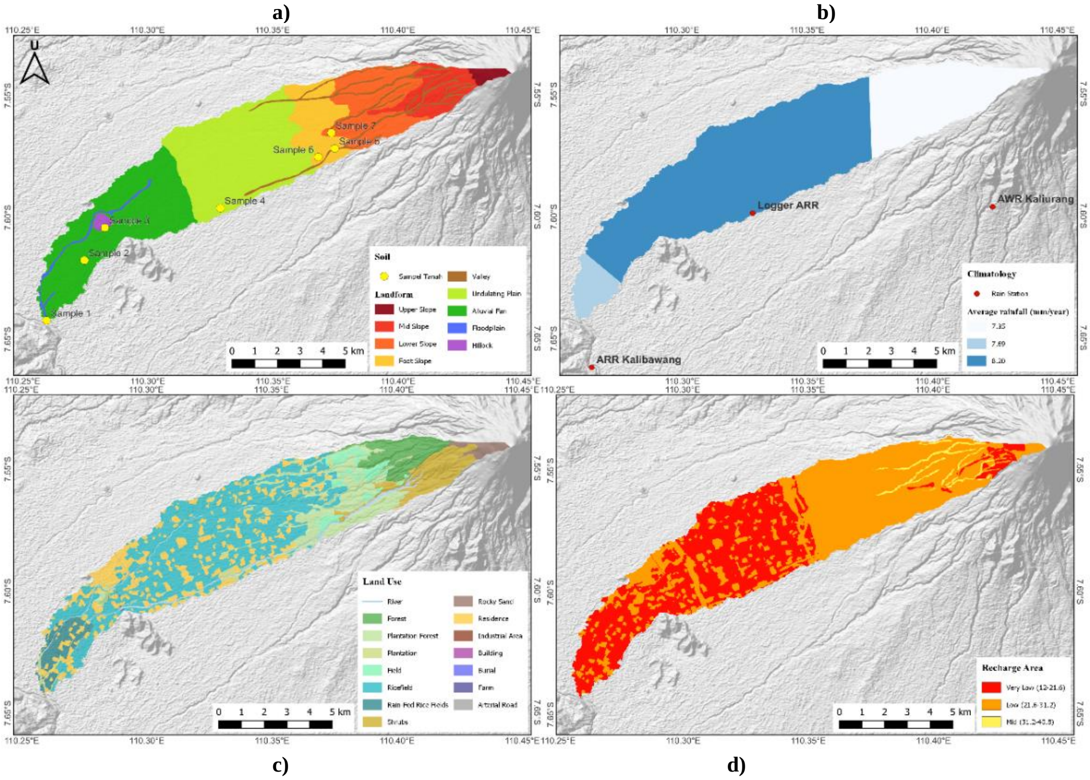

Fig. 5. (a) Pedo geomorphological map; (b) Regional rainfall map; (c) Land use map; (d) Recharge area map.

4.2. SWAT+ modeling based on Curve Number

Following the detailed analysis of various data types, including land use, soil characteristics, climatological data, and recharge areas, the next step was to run the SWAT+ model (Easton et al., 2008). The delineation of the watershed boundaries resulted in the Blongkeng Sub-Watershed covering 6,890.10 ha, divided into three subbasins and 25 channels. Additionally, the creation of Hydrologic Response Units (HRUs) produced a total of 1,147 HRUs. Each HRU represents the smallest unit of analysis in hydrology and is characterized by homogenous hydrological properties.

The use of Curve Number (CN) in hydrology, which relates surface runoff to land use and soil hydrological groups, is a critical component in this analysis (Chow 1988). The CN index which is the main parameter used for runoff estimation in ungauged basins is based on the physical characteristics of watersheds that influence the runoff, namely the land use, soil type, texture and the antecedent moisture conditions (Crăciun et al., 2009; Haidu and Ivan (2016a); Haidu and Ivan (2016b); Strapazan and Petruț, 2017). A high CN value indicates greater runoff and lower soil infiltration. Hydrological soil groups are classified as A, B, C, and D, with CN values increasing from lower to higher values for the same land use type, reflecting the soil's runoff potential.

4.2.1. Sensitivity Analysis and calibration

The next finding revolves around the sensitivity analysis. This analysis plays a crucial role in refining the SWAT+ model. By identifying which parameters have the greatest impact on model outcomes, this analysis helps prioritize which factors to focus on when adjusting scenarios and improving model accuracy. As detailed in **Table 4**, the results reveal that the parameter CN2 shows the highest sensitivity, indicating its significant role in modeling land use changes. Following CN2, parameters such as CN3_SWF (soil water adjustment factor) and AWC (available water capacity), related to soil properties, also show substantial influence, further guiding adjustments in model scenarios.

Table 5 shows the calibration period conducted from October to November 2021. In this study, CN values were obtained from the SWAT+ database, as detailed in **Table 6**. Although the dataset was relatively short due to the limited availability of observed streamflow data, the calibration yielded satisfactory results. The test produced an NSE value of 0.53, a PBIAS of 7.38, and an R^2 of 0.79 (**Fig. 6**). These values indicate a reasonable fit and meet the minimum required thresholds. The parameter values used during calibration were subsequently applied in the validation period.

Table 4.

Results of sensitivity analysis.

No	Group	Name	Change Type	Sensitivity
1	hru	cn2	Percent	0.506
2	hru	cn3_swf	Percent	0.470
3	hru	awc	Relative	0.120
4	aqu	epco	Percent	0.002
5	rte	revap_co	Replace	0.001

Table 5.

Calibration results.

No	Name	Change Type	Min	Best Value	Max	
1	cn2	Percent	-20.00	-39.000	20.00	
2	cn3_swf	Percent	-20.00	18.442	20.00	
3	epco	Relative	-500.00	4.025	1000	
4	revap_co	Percent	-20.00	12.596	20.00	
5	chn	Replace	0.50	1.475	2.00	
6	latq_co	Percent	-20.00	11.379	20.00	
7	esco	Replace	0.02	0.197	0.20	
8	lat_ttime	Replace	1.00	176.152	180.00	days
9	alpha	Replace	0.01	0.011	0.30	days
10	perco	Replace	0.30	0.994	1.00	fraction
11	flo_min	Replace	0.00	0.004	1.00	m
12	revap_min	Replace	0.60	0.616	1.00	m
13	bd	Percent	-20.00	-19.964	20.00	mg/m^3
14	canmx	Relative	-0.05	-0.050	0.05	mm/H2O
15	k	Replace	0.00	0.851	1.00	mm/hr
16	awc	Relative	-500.00	182.338	500.00	mm_H2O/mm

Table 6.

Land use areas.

No	SWAT+ Code	Land use	CN	Area (ha)	(%)
1	rice120	Paddy fields	78	3000.13	43.54
2	urml	Residential areas	98	1109.66	16.11
3	frst	Plantation forest	70	827.92	12.02
4	shrb	Shrubs	69	486.87	7.07
5	frse	Forest	52	442.59	6.42
6	rice180	Rain-fed paddy fields	65	268.15	3.89
7	agrl	Field/farm	71	245.94	3.57
8	orcd	Plantation	86	224.24	3.25
9	watr	River	98	172.04	2.50
10	bsvg	Rocky sand	61	103.21	1.50
11	Utrn	Arterial road	98	5.51	0.08
12	Urbn	Building	98	2.38	0.04
13	Uidu	Industrial area	98	0.83	0.01

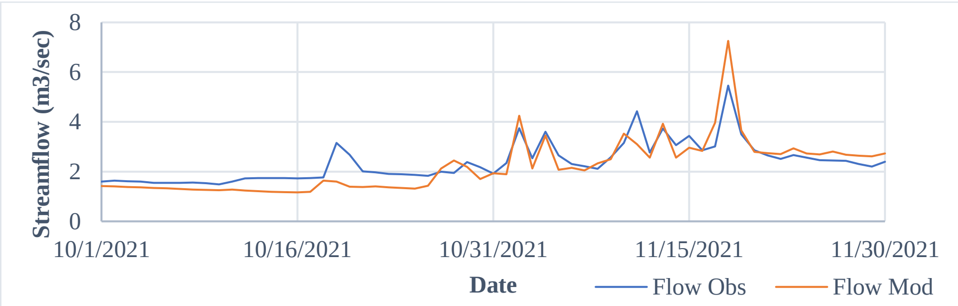

Fig. 6. Comparison chart of observed and calibrated streamflow.

4.2.2. Validation

Following the calibration process, which was conducted from October to November 2021, the validation was carried out during December 2021 and January 2022. The validation results produced statistical test values of NSE = 0.50, PBIAS = -5.45, and R^2 = 0.58, as provided in **Fig. 7**. These results indicate that the simulation is fairly consistent when applied across different time periods. However, it is important to note that the consistency of the data during the dry season was not tested, meaning that the simulation results are more suitable for runoff analysis during the rainy season.

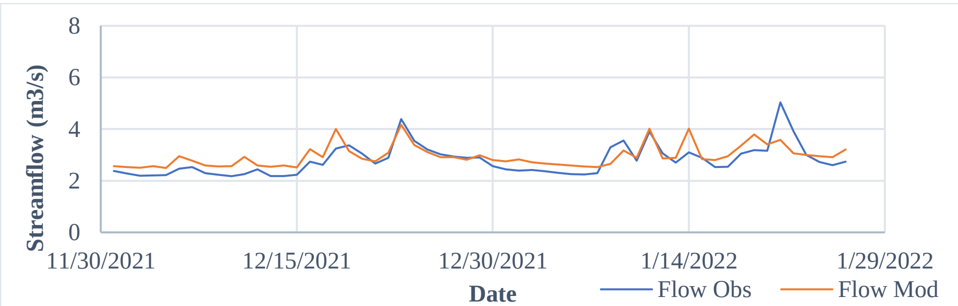

Fig. 7. Comparison graph of observed and validated streamflow.

5. DISCUSSION

5.1. Runoff Analysis

The statistical test values for NSE, PBIAS, and R^2 illustrate the reliability of the simulation results compared to field conditions. In this study, the statistical test results are deemed satisfactory, indicating that the simulation can effectively represent the actual conditions (Almeida et al. 2018).

Building upon this, the simulated streamflow in the Blongkeng Sub-Watershed shows significant fluctuations between the rainy and dry seasons, with a peak flow of up to 13.53 m^3/day in May 2021. These simulations can be seen in **Fig. 8**. These runoff conditions are influenced by environmental factors and rainfall amounts. As a dynamic parameter, land use can change and produce varying runoff conditions. While land use affects evapotranspiration, infiltration, and runoff, soil type and morphology remain constant.

5.2. Watershed Management

This study will examine the impact of land use changes, particularly the conversion of areas into vegetation for conservation and buffer zones. **Table 6** presents the percentage of land use in the Blongkeng Sub-Watershed for 2021. With these land use proportions, it is necessary to create land use change scenarios to assess the extent of their influence. Land use changes are made by altering the types of land use that allow for transformations, such as rice fields, shrubs, fields, rocky sand, and settlements. The area of land use change is standardized to 50 hectares to facilitate comparisons between different types of land use. The locations for the changes in land use are selected based on visual interpretation adjusted to conservation objectives.

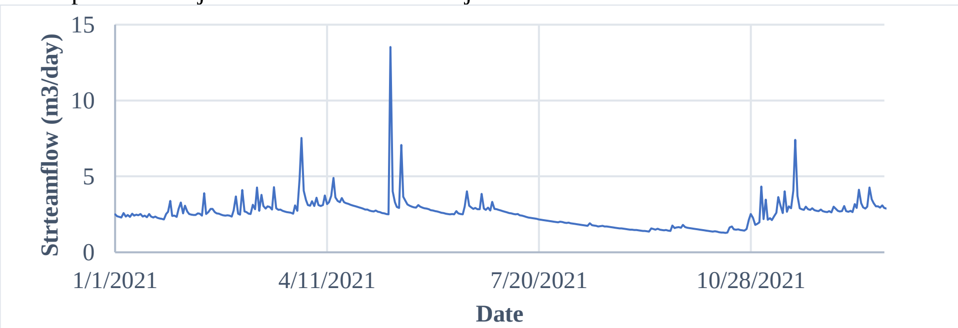

Fig. 8. Blongkeng sub-watershed streamflow.

5.3. Scenarios

Scenario 1. The first scenario involved changing land use by simulating the conversion of paddy fields along riverbanks into buffer zones. This land use change was primarily applied to the downstream area with a very low recharge area class, as shown in **Fig. 9a**. The results generally showed a decrease in maximum, minimum, and average runoff. Specifically, the Curve Number (CN) changed from 48 for paddy fields and 40 for rain-fed paddy fields to 43 for plantation forest areas. This scenario demonstrates how converting paddy fields to forested buffer zones impacts runoff characteristics.

Scenario 2. In the second scenario, the dominant change involved converting shrubland into very low and low recharge area classes (see **Fig. 9b**). This simulation resulted in a significant reduction in peak runoff, decreasing from 13.53 m^3/day to 13.21 m^3/day. Meanwhile, average and minimum runoff values remained relatively unchanged, and only minor adjustments were experienced. The reduction in peak runoff indicates that the conversion of scrubland to forested areas effectively enhances the retention of rainwater and reduces surface runoff. The Curve Number (CN) decreased from 42 for scrubland to 32 for forested areas (frse), reflecting this effective change.

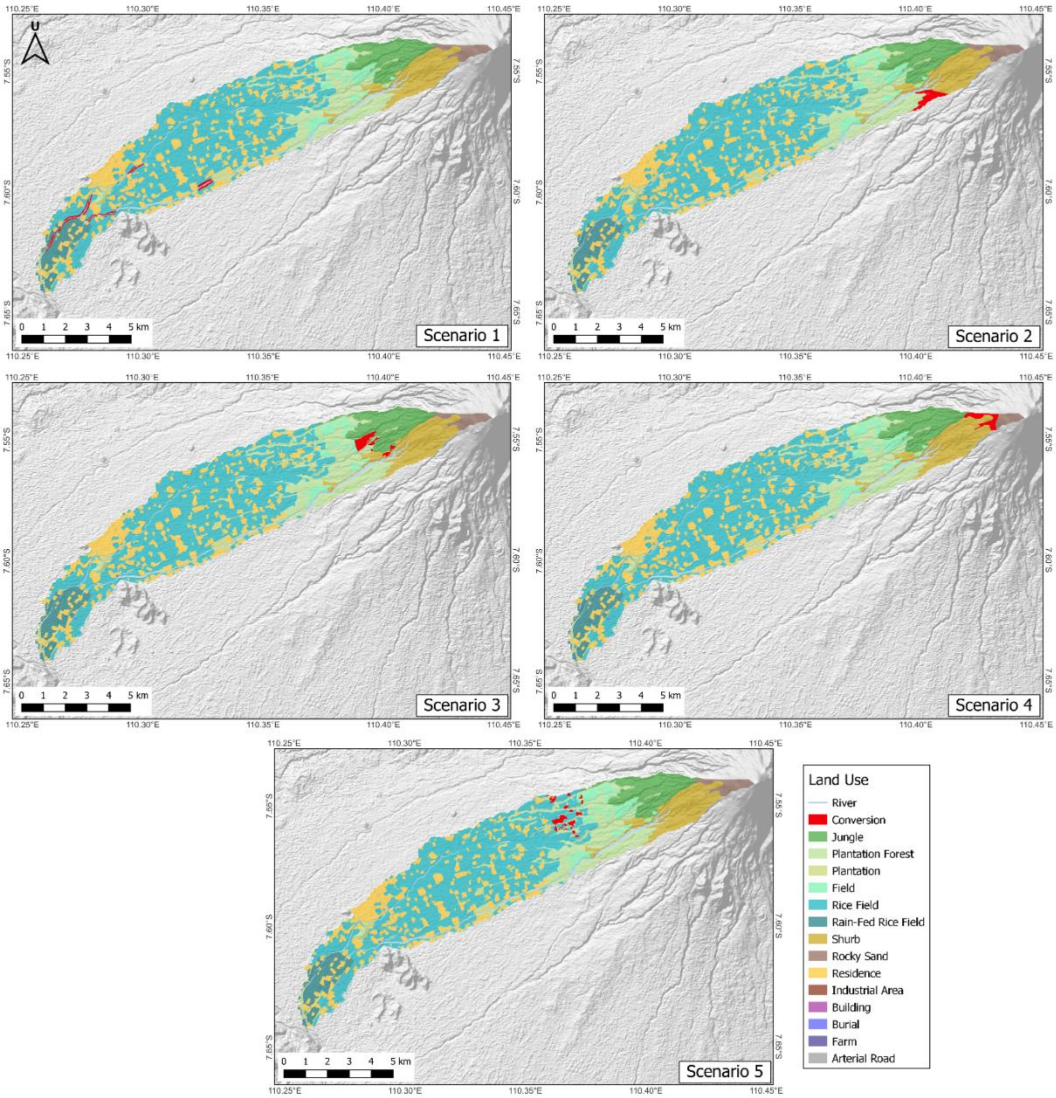

Fig. 9. (a) Scenario 1: Conversion of rice fields; (b) Scenario 2: Conversion of shrubs; (c) Scenario 3: Conversion of fields/farm; (d) Scenario 4: Conversion of rocky soil; (e) Scenario 5: Conversion of residential areas.

Scenario 3. In the third scenario, land use changes involved converting dryland farming areas to forested regions, with adjustments based on elevation factors (see **Fig. 9c**). This simulation resulted in a notable decrease in peak runoff, from 13.53 m³/day to 13.20 m³/day. The Curve Number (CN) also changed significantly, from an average of 43 for dryland farming to 32 for forested areas. The primary influence on this reduction was the dominant recharge area class, which was classified as medium in this scenario. This allows for greater groundwater storage, even though the CN value and the extent of land use change are similar to the previous scenarios.

Scenario 4. In the fourth scenario, land use changes were done by converting rocky sand areas (see **Fig. 9d**). This change was primarily applied to areas with very low and low recharge classes. The results of Scenario 4 showed a decrease in peak runoff that was relatively similar to Scenarios 2 and 3 but with a smaller reduction in peak flow. Meanwhile, the values for minimum and average runoff remained relatively consistent. The Curve Number (CN) changed from 37 for rocky sand to 32 for forested areas. The differences in runoff values between Scenarios 2, 3, and 4 were influenced by the extent of the recharge area classes.

Scenario 5. In this final scenario, the focus was on transforming residential areas into tree plantations (see **Fig. 9e**). The results of this land use change are detailed in **Table 7**, which shows a decrease in peak runoff that was not as significant but still lower compared to Scenario 1. These changes are influenced by factors such as changes in CN values, differences in recharge area classes, and patterns of land use change. Each scenario has its own characteristics; for example, in Scenario 1, the conversion of rice fields resulted in a decrease in maximum, minimum, and average discharge, although the values were not very significant. Meanwhile, in Scenario 3, the conversion of fields led to a significant decrease in maximum discharge, but the minimum and average discharge values remained the same. An important point to consider in land conversion for conservation purposes is to pay attention to recharge area classes, changes in CN values, and the patterns of land use change (clustered/scattered).

Table 7.

Comparison of scenarios

Streamflow (m^3/day)	Blongkeng	Conversion				
		Paddy fields	Shrubs	Field/farm	Rocky sands	Residential areas
max	13.53	13.50	13.21	13.20	13.24	13.50
min	1.28	1.27	1.29	1.29	1.29	1.28
average	2.58	2.57	2.58	2.58	2.58	2.58

5.4. Water Balance

The water balance conditions for the land use change scenarios are presented in **Table 8**. Building on the previous analysis of land use impacts, evapotranspiration values depend on land use types; converting to plantation forest increases evapotranspiration values while converting to dense forest results in lower values. Lateral flow, return flow, and recharge values decreased in Scenario 1, located in the downstream area, whereas conversions in the midstream and upstream areas tended to increase. Thus, the water balance in this study was also influenced by the location within the watershed. Meanwhile, surface runoff values decreased in Scenarios 2, 3, 4, and 5 but increased in Scenario 1. Rice paddies have the property of retaining water in irrigation, so when converted, the released water becomes a larger runoff. The most significant change in surface runoff occurred in Scenario 5 because the land was converted to conservation zones. An important note in this scenario change is that the land use changes were made over an area of 50 hectares. Although the changes that occurred are relatively small, the patterns of change between the scenarios can still be studied and analyzed.

Table 8.

Comparison of water balance.

Parameter (mm/year)	Blongkeng	1	2	3	4	5
Evapotranspiration	112.58	112.68	112.44	112.40	112.32	112.68
Lateral flow	3.23	3.17	3.23	3.23	3.23	3.23
Return flow	882.17	872.63	881.22	881.31	881.19	881.03
Recharge	1068.55	1058.69	1068.81	1068.91	1068.77	1068.56
Surface RO	143.48	146.59	143.27	143.18	143.11	140.89

6. CONCLUSIONS

The streamflow of runoff on the Blongkeng sub-watershed has test values as follows: NSE = 0.53, PBIAS = 7.38, and R2 = 0.79 during the calibration period, and NSE = 0.50, PBIAS = -5.45, dan R2 = 0.58 in the validation period. These results are deemed satisfactory, indicating the model performed adequately. The length of the data period and the quality of the observed streamflow data are crucial factors influencing the accuracy of the simulation results.

In exploring watershed management scenarios to improve runoff conditions, several strategies were evaluated, including the creation of conservation areas and buffer zones. For example, the conversion of rice field land showed a slight decrease in maximum, minimum, and average streamflow values, suggesting that rice fields, with their strong water retention capabilities, play a valuable role in reducing runoff. However, the impact on streamflow was not highly significant. On the other hand, the conversion of shrubland, fields, and rocky sand areas led to a decrease in maximum streamflow and an increase in minimum streamflow. Additionally, there was an increase in lateral flow, return flow, and recharge values while surface runoff decreased. These variations can be attributed to differences in Curve Number (CN) values and the classification of recharge areas between these land uses. Finally, the conversion of residential land to conservation areas resulted in a significant reduction in surface runoff. This emphasizes the potential benefits of such land conversions in managing runoff, particularly in reducing the impact of built-up areas.

ACKNOWLEDGMENT

The author would like to extend Universitas Gadjah Mada for funding this research through the Final Project Recognition Grant (Grant Number 4971/UN1.P1/PT.01.01/2024) and the RTA Program Universitas Gadjah Mada (Grant Number 5286/UN1.P1/PT.01.03/2024).

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