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The Impact of Land-Use and Climate Change on Water and Sediment Yields in Batanghari Watershed, Sumatra, Indonesia

(Kesan Penggunaan Tanah dan Perubahan Iklim terhadap Hasil Air dan Sedimen di Kawasan Tadahan Batanghari, Sumatra, Indonesia)

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ABSTRACT

The Batanghari River flows from the province of West Sumatra into the West Coast of Jambi, with the main river extending up to 870 km. Also, the Batanghari watershed Land use changes have shown a decreasing forest cover and an increasing agricultural area. Therefore, this study aims to calculate the impact of land use and climate change on water and sediment yield using Soil and Water Assessment Tools (SWAT) hydrological modeling. Land-use change analysis was performed with projections in 2040 while, near future and future climate projections under Representative Concentration Pathway (R.C.P.) 4.5 and 8.5 were used for global climate change scenarios. The results show a changing pattern of growing agricultural area and decreasing forest area in 1990, 1997, 2005, 2015, and 2040. SWAT hydrological model used for the simulation was calibrated automatically with SWAT-CUP and the results were validated on good criteria. The sensitivity analysis results showed that effective hydraulic conductivity in main channel alluvium (CH_K2) and Base flow alfa factor (Alfa_BF) formed the most sensitive parameters for discharge. Furthermore, the model simulation showed an increase in surface runoff and a decrease in lateral flow and base flow due to land-use changes, which increased sediment loading over time. The impact of climate change on water and sediment yield increased the average flow discharge ratio, resulting in more frequent droughts and floods events.

Keywords: Future climate; future landuse; sediment yield; SWAT model; water yield

ABSTRAK

Sungai Batanghari mengalir dari wilayah Sumatera Barat ke Pantai Barat Jambi, dengan sungai utama memanjang hingga 870 km. Selain itu, perubahan guna tanah kawasan tadahan Batanghari telah menunjukkan penutupan hutan yang semakin berkurangan dan kawasan pertanian yang semakin meningkat. Oleh itu, kajian ini bertujuan untuk menghitung kesan penggunaan tanah dan perubahan iklim terhadap air dan hasil sedimen menggunakan pemodelan hidrologi Alat Penilaian Tanah dan Air (SWAT). Analisis perubahan guna tanah telah dilakukan dengan unjuran pada tahun 2040 manakala unjuran iklim terdekat dan masa hadapan di bawah *Representative Concentration Pathway* (R.C.P.) 4.5 dan 8.5 digunakan untuk senario perubahan iklim global. Hasil kajian menunjukkan perubahan corak kawasan pertanian yang semakin meningkat dan kawasan hutan yang semakin berkurangan pada tahun 1990, 1997, 2005, 2015 dan 2040. Model hidrologi SWAT yang digunakan untuk simulasi telah ditentukur secara automatik dengan SWAT-CUP dan hasilnya telah disahkan berdasarkan kriteria yang baik. Keputusan analisis kesensitifan menunjukkan bahawa kekonduksian hidraulik yang berkesan dalam aluvium saluran utama (CH_K2) dan faktor alfa aliran asas (Alfa_BF) membentuk parameter yang paling sensitif untuk nyahcas. Tambahan pula, simulasi model menunjukkan peningkatan dalam air larian permukaan dan penurunan dalam aliran sisi dan aliran asas akibat perubahan guna tanah yang meningkatkan beban sedimen dari semasa ke semasa. Kesan perubahan iklim terhadap air dan hasil sedimen meningkatkan nisbah pelepasan aliran purata, mengakibatkan kejadian kemarau dan banjir yang lebih kerap.

Kata kunci: Guna tanah masa hadapan; hasil air; hasil sedimen; iklim masa depan; model SWAT

Introduction

Land use and climate change have been identified as the two factors driving water and sediment yields. Research on the impacts of Land use and climate change on water and sediment yield has provided vital insight and guidance to policymakers, yet most of this research has focused primarily on the effects of existing Land use change or Climate. Land use is related to human activities in specific areas; remote sensing can directly recognize land cover information. However, information about human activities cannot always be interpreted directly from the land cover (Lillesand & Kiefer 1993). Land-use change includes a shift to a different land (conversion), and these changes generally affect: (a) the characteristics of the river flow, (b) the amount of runoff, and (c) the hydrological nature of the area concerned (Feri 2007; Meyer & Turner 1992). Almeida and Gleriani (2005) modeled the dynamics of urban development using the Cellular Automata stochastic model for the City of Bauru, San Paulo, Brazil. The simulation results show that various socio-economic and infrastructure factors can be combined using a weighted approach that predicts the probability of change between land-use types in a raster/grid system map. Moghaddam and Samadzadegan (2009) modelled land-use change in Tehran, Iran using Geo-CA and CA simulation using raster data projected for 40 years. Additionally, a tool in ArcGIS has been developed to define a set of rules and is calibrated according to urban growth patterns. The evaluation shows that the average accuracy for the predictions of settlement growth in 1975 and 2001 was more than 80%.

On the other hand, climate change causes an increase in extreme events, such as rainfall, air temperatures, and changes in the acceleration of the earth's surface hydrological cycle, marked by an elevating disaster frequency. An analysis of climate change impacts requires extensive data to predict future occurrences, which the climate model can achieve. One of the climate prediction models with good resolution is the Regional Climate Model (RCM) (Handoko 2019). The effects of Climate on land-use changes have been widely studied by Bajracharya et al. (2018), Kundu et al. (2017), Leta et al. (2016), Nugroho et al. (2013), and Schilling et al. (2008).

The River Batanghari is the longest river on Sumatra Island, extending up to 870 kilometers. The river's depth ranges from six to seven m, and the width range from 300 to 500 m (Water Resources Management Office Batanghari 2012). This river originates from West Sumatra Province and the Kerinci Seblat National Park area, flowing to Muaro Jambi and the Karikata Strait. Land-use Changes in the River Batanghari watershed are essential issues in regional planning, especially in implementing policies that affect residential (urban growth) and agricultural land development patterns. As the condition of the Batanghari River watershed has been degraded by mismanagement, particularly in the Lower Sub-watershed, where 54,225 ha of forest area was converted to oil palm plantations between 1990 and 2010 (Marhendi, Rasyid & Kresnanto 2014; Ramdhan et al. 2017; Tambun & Yulianus 2016). Oil palm planted on land with wavy and undulating topography without soil and water conservation techniques will cause erosion and sedimentation. The erosion rate of the River Batanghari watershed attained about 5,891,000 million tons/year, while the amount of sediment in the Batanghari River estuary was about 521.86 million tons/year (BPDAS Batanghari 2011).

Accordingly, this study quantifies the impact of Land-use and climate change on water and sediment yields in the Batanghari watershed using the SWAT hydrological model. This study provides preliminary information on the estimation and distribution of sedimentation in the estuary area which is a shipping route, especially in planning for the construction of international harbor, including as a basis for managing the upstream area to reduce sediment flowing into the river estuary. For the SWAT hydrological model input, the dynamic parameters were; (1) a time series of existing Land-use (1990, 1997, 2005, 2015) and projected Land-use (2040) paired with (2) observed precipitation and projected precipitation from the Global Climate Model (GCM).

Material and Methods

This study uses a combination of models that have been carried out or currently designed. The models used consist of hydrological models, climate projection models, and landuse projection models. Only the SWAT hydrological model was designed from the start of dividing sub-watersheds through to the calibration and validation processes. The research process flowchart is shown in Figure 1, which also shows land use and climate input data from previous research, conducted by Utami, Sapei and Apip (2017) and climate projections by Handoko et al. (2018).

Study Area

Batanghari watershed is located in Jambi Province and West Sumatra Province, Indonesia (between 100° 43' 9.7'' E - 104° 8' 23.0'' E and 0° 43' 35.8'' S - 2° 46' 52.0'' S. The catchment area and the length of the main river were about 44,028 km^2 and 870 km, respectively. The river's water originates from a part of the Bukit Barisan area, with the highest peak at Mount Kerinci, 3,805 m above sea level.

The topography varies from upstream to downstream; mountainous areas in the west and floodplains stretch to the east. Around 60% of the watershed is hilly, with

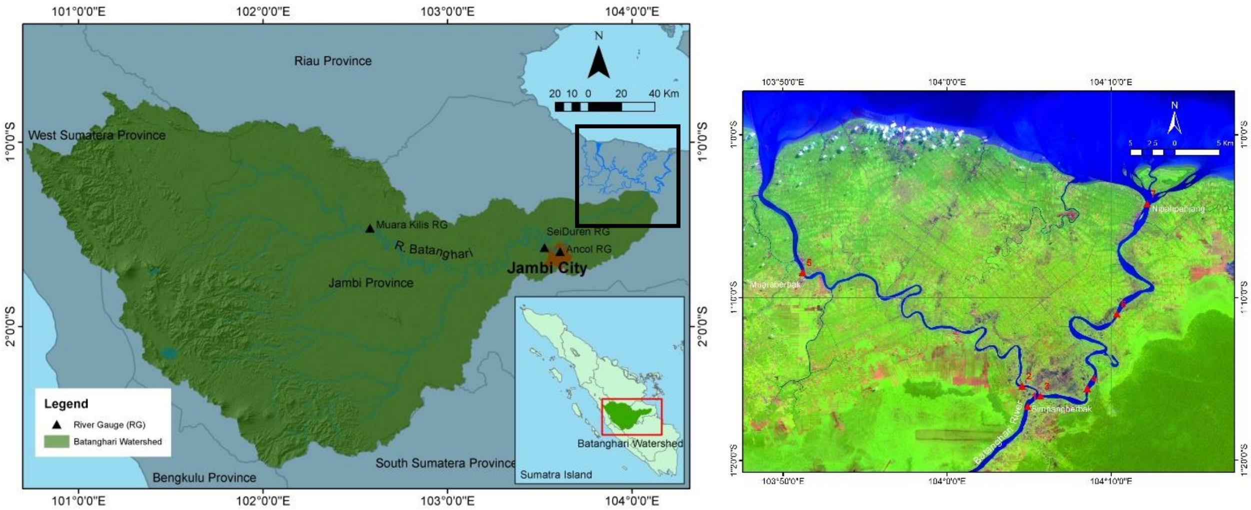


FIGURE 1. The study location in the Batanghari watershed

an elevation between 10-100 m above sea level. The population in the River Batanghari watershed reached 3.5 million people in 2007 and increased by 12% in 2017 (Ministry of Public Works 2012).

Batanghari watershed climate is a humid tropical watershed with variations according to geographical conditions. The Batanghari watershed is dominated by agricultural land (12,805 km^2), but the irrigated rice fields in only 460 km^2, while the forest area reaches 12,805 km^2 (Utami, Sapei & Apip 2017; Yamamoto et al. 2020). Figure 2 shows the study location in the Batanghari watershed. The figure shows the location of the model

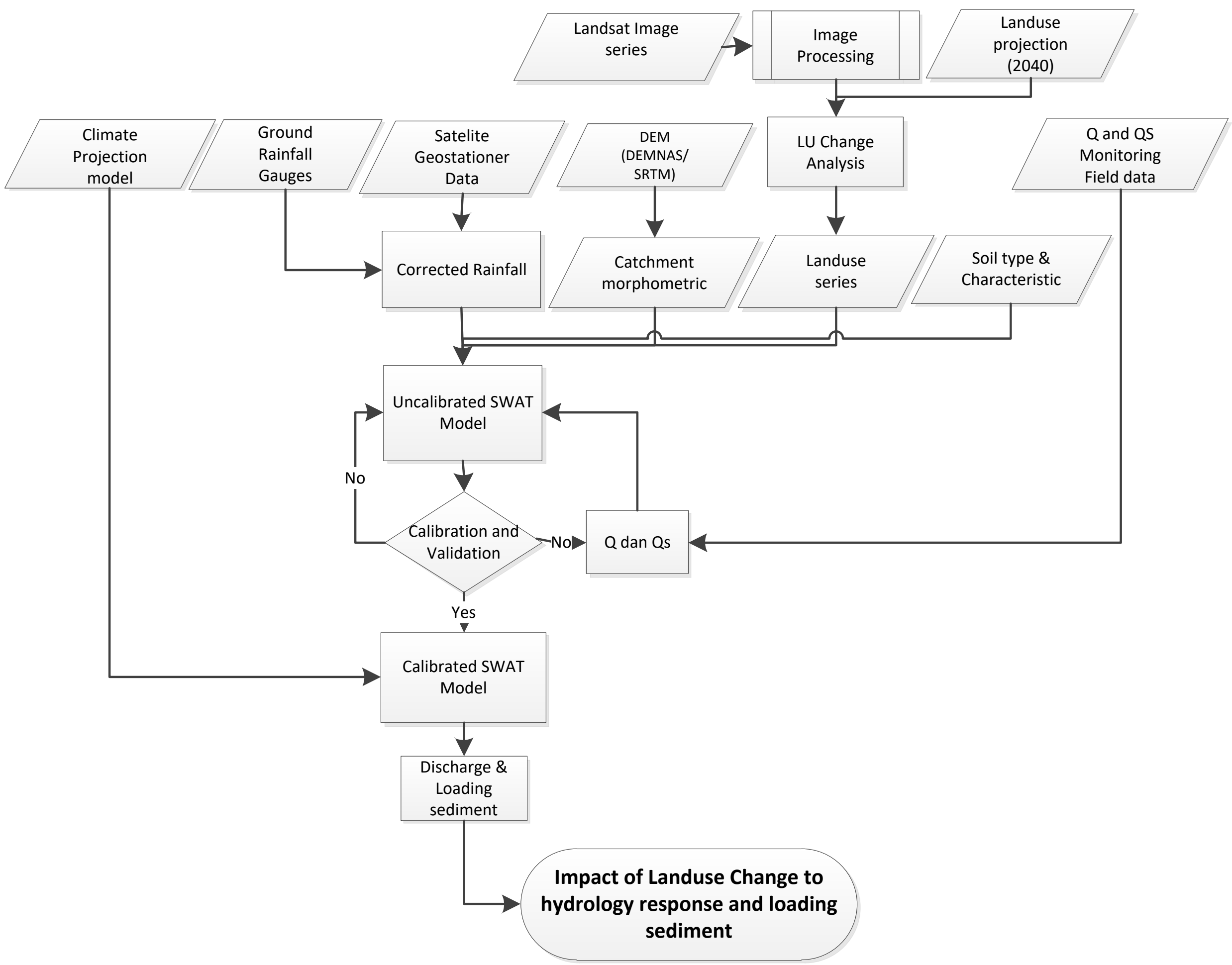


FIGURE 2. Research Framework (Q: water discharge, QS : Loading sediment)

TABLE 1. Summary of data requirements

No	Data	Data format	Sources
1	Digital elevation model (DEM)	Grid (cell size 30 × 30 m)	Shuttle Radar Topography Mission (SRTM) of USGS
2	Soil map scale 1:250.000	Vector map(.shp)	Research Center for Agro-climate and Hydrology, Ministry of Agriculture
3	Meteorological data (2005-2008)	Table (text)	Meteorological, Climatological and Geophysical Agency CHIRPS (calibrated by ground rain gauge)
4	Climate Projection	Table (text)	RCM (RCP 4.5) and MRI-AGCM 20-km (RCP 8.5)
5	Landuse map (1990, 1997, 2005 and 2015)	Raster	Landsat, USGS and ground check
6	Landuse projection Map	Raster	Utami, Sapei & Apip (2017)
7	Soil properties for SWAT database	Numeric	Field sampling and laboratory analysis
8	Daily discharge and sediment loading	Table (.dbf and txt)	Ministry of Public Work and Housing and Field data

outlet is located at the fork of the Batanghari river which divides into two streams, the first flows to Nipahpanjang and the other flows further north which is the transportation route for large ships. The figure also shows suspended solid sampling point for estimate distribution of sediment after the river separated and flowing to the sea.

DATA REQUIRED FOR HYDROLOGY MODEL

This study used data according to SWAT hydrological modeling, while land-use projections used data from the Batanghari Watershed (Utami, Sapei & Apip 2017). Table 1 shows the data requirements for SWAT modeling in the Batanghari watershed. Water discharge and sediment load were obtained from the Ministry of Public Works, while suspended solid concentrations in outlet model location were analyzed using the gravimetric method.

EXISTING AND FUTURE LAND USE

We used Landsat images to produce existing time series maps of Land use for 1990, 1997, 2000, 2005, and 2015. Those time series maps were used to generate a future (2040) Land use projection following Utami, Sapei and Apip (2017). In addition, the Land use map of 2005 was also used to calibrate and validate the Soil and Water Assessment Tools (SWAT) hydrological modeling with the corresponding climate data.

We selected Landsat Thematic Mapper (TM), Enhanced Thematic Mapper + (ETM+), and Operational Land Imager (OLI) in this study due to their high spatial resolution (30 m) and long-term data availability. The Batanghari watershed area consists of five scenes, with the path/row; 125/61, 125/62, 126/61, 126/62, and 127/61; therefore, we downloaded 20 Landsat TM/ETM+/OLI images from the United States Geological Survey (USGS) website (retrieved from USGS Earth Explorer 11 March 2021).

The image processing includes classification for 1990, 1997, 2000, 2005, and 2015, accuracy assessment, and future Land use prediction of 2040. The six Land use classes are; Water, Developed/settlement, Agriculture, Bush/Shrubland, Barren area, and Forest. We test the accuracy using overall accuracy and kappa statistics as the level of agreement indices. We carried out Land use projections using trend extrapolation, with the constraint being that the national park forest is undisturbed. Firstly, we develop a linear regression equation to predict the Land use class demand from 1990 to 2005 and assess the accuracy using the existing 2005 Land use. The developed equations were then used to project the 2040 Land use, assuming that Land use change patterns remain the same for up to 30 years. A crosstabulation technique was used to analyze the landuse change.

CLIMATE AND FUTURE CLIMATE CHANGE SCENARIO

Precipitation is the climate parameter as an input for the hydrological model. This study used a daily rainfall data grid from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS). The CHIRPS was developed to support the United States Agency for International Development Famine Early Warning Systems Network (FEWS NET), and the use of rainfall data from satellites has been proved to improve simulation results for the better, especially in watersheds where rainfall data is less available (Sharannya et al. 2020; Sirisenaa at al. 2018; Venkatesh et al. 2020). The CHIRPS data calibration was conducted by Handoko et al. (2018) using 39 monitoring stations data from several institutions.

In order to quantify the impact of climate change on the water and sediment yield of the watershed, we used the daily climate data series, especially for the rainfall, which represents the present (1979-2004); near future (2030-2050), and future climate condition (2075-2099) as the model input.

The present and future climate conditions are represented by using the products of a super-high-resolution Atmospheric General Circulation Model version 3.2 (AGCM 3.2S) outputs with 20-km grid resolution (Mizuta et al. 2014). This AGCM product considered the future climatic condition under the emission scenario of Representative Concentration Pathway (RCP) 8.5 (Araya & Cabral 2010). Due to the near future climate product unavailability of the AGCM 3.2S RCP 8.5, daily rainfall data series from a Regional Climate Model (RCM) product under the RCP 4.5 scenario is used to model the near future climate condition.

WATER AND SEDIMENT YIELD MODELLING
SOIL AND WATER ASSESSMENT TOOLS (SWAT) MODEL SETUP

The SWAT model is a process-based model that can divide a watershed into numerous sub-watersheds and further divide them into Hydrological Response Units (HRUs) based on Land use, soil type, and slope. In this research, the 2005 Land use map was obtained from Landsat 7 ETM+ images. The soil map contains infiltration and permeability information to determine the Hydrology Soil Group (HSG), maximum root depth, horizon thickness, bulk density (BD), moisture content (AWC), hydraulic conductivity in a saturated state, organic C, soil fraction content, and moist soil albedo. The scale of the soil map is 1:250,000, dominated by Umbrisols (52%) and Nitisols (29%); the remaining soil types are Altisols, Gleisols, Histosols, Latosols, Mollisols, and Regosols. The slope map was derived from the Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission of USGS (retrieved from USGS Earth Explorer 03 May 2019) with a spatial resolution of 30 m × 30 m. The slope map was classified into five classes (i.e., 0-8%, 8-15%, 15-30%, 30 -45% and > 45%). As the SWAT model setup input, we used precipitation data from the corresponding year of Land use. Figure 3 shows the maps of sub-watershed division, slope, soil type, and Land Use in the Batanghari watershed.

CALIBRATION AND VALIDATION

Calibration in this research is a process to optimize the values of hydrological parameters in the simulation to produce results approximate to the observation data that represented the actual field events. SWAT-CUP (*SWAT Calibration and Uncertainty Program*) with the SUFI-2 (Sequential Uncertainty Fitting ver.2) procedure was used to obtain a parameter correction value that ranged between the minimum and maximum values been adjusted to the Absolute SWAT Value. Moreover, the parameterization process must be performed to observe the sensitivity and significance of the simulation results.

Sensitivity analysis is performed on the parameters used in model calibration. Consequently, the analysis obtained 12 parameters that were sensitive to flow discharge and 6 parameters that were sensitive to sediment loading in the Batanghari watershed. These results were obtained in a simulation using the SWAT-CUP application with the SUFI-2 procedure in the 60^{th} iteration, while the total simulation performed in this process was 350 iterations.

The parameterization results above show the parameters CH_K2.rte, ALPHA_BF.gw, CH_N2.rte, CH_COV.rte, OV_N.rte, and GW_DELAY.gw had the highest sensitivity and strongest significance. Also, this shows that these parameters are the most influential on the hydrological characteristics of the Batanghari watershed, and a slight change will affect the hydrological response in the form of a simulated discharge generated.

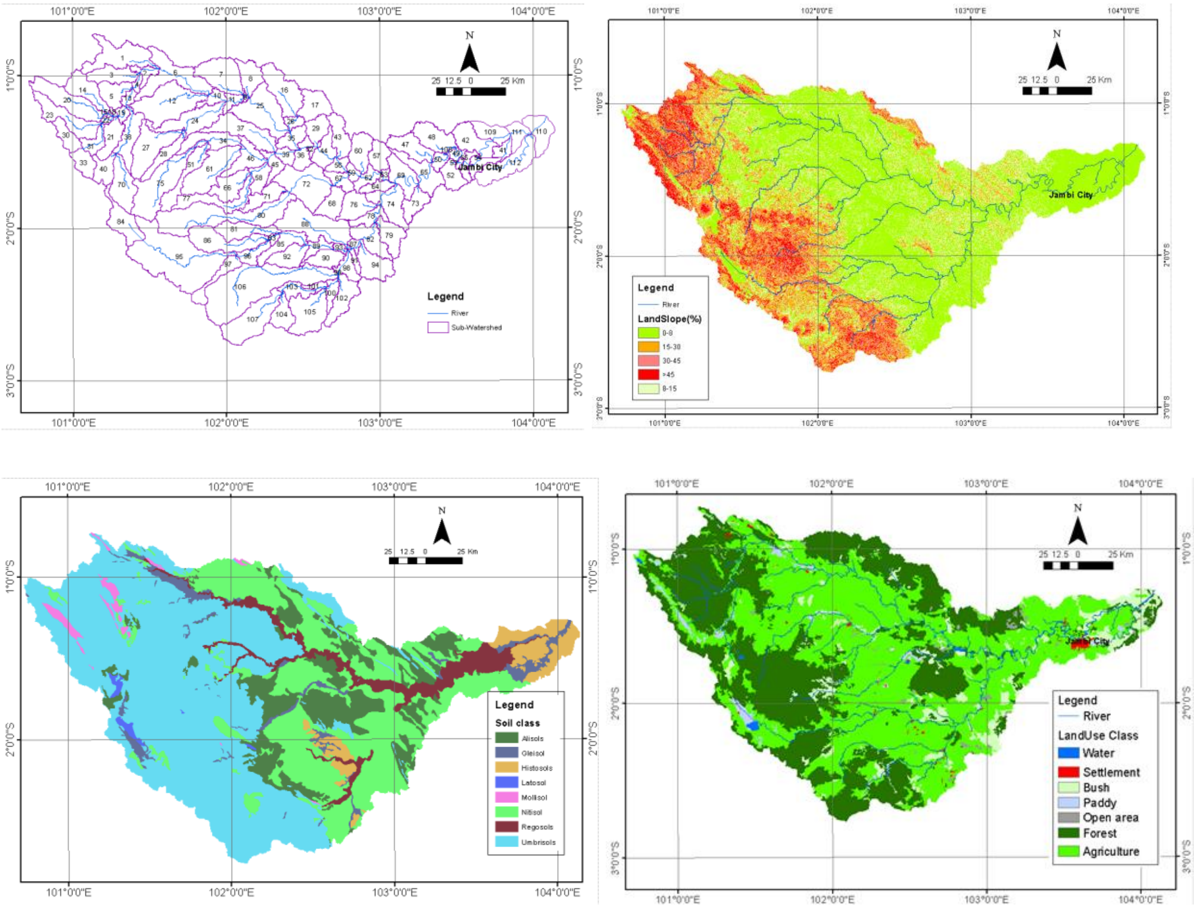


FIGURE 3. The maps of sub-watershed division, slope, soil type, and Land use in the Batanghari watershed

ACCURACY ASSESSMENT

We used the Nash-Sutcliffe model efficiency coefficient (NSE) (Nash & Sutcliffe 1970) and correlation coefficient (R^2) to assess the accuracy of the SWAT hydrological model. The NSE value denotes the predictive power, and the R^2 value measures the strength of the linear relationship between predicted and observed values. These indices are defined as follows:

$$NSE = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}(O_i - \hat{O}_i)^2}$$

$$R^2 = \left\{ \frac{\sum_{i=1}^{n}(O_i - \hat{O})(S_i - \hat{S}_i)}{\left|\sum_{i=1}^{n}(O_i - \hat{O})^2\right|^{0.5} \left|\sum_{i=1}^{n}(S_i - \hat{S})^2\right|^{0.5}} \right\}$$

where O is the observed discharge; S is the model simulation discharge; $\hat{O}$ is the average of the observed discharge; $\hat{S}$ is the average of model simulation discharge; n is the number of samples. Furthermore, a value of NSE and R^2 close to 1 indicates complete harmony between the observed and simulated river flow results. Moriasi et al. (2007) divide the criteria for statistical scores for NSE for monthly time step as follows: 0.75<NSE<1.00 (very good), 0.65<NSE<0.75 (good), 0.5<NSE<0.65 (satisfactory) and NSE 0.50 (unsatisfactory).

ESTIMATION OF WATER AND SEDIMENT YIELD BASED ON FUTURE LAND USE AND CLIMATE

Subsequently, the SWAT model was calibrated and appropriately validated using Land use and climate data

TABLE 2. Areal coverage and comparison of Land use change in 1990, 1997, 2005, and 2015

Landuse class	1990		1997		2005		2015		Land use change (Km^2)			
	km^2	%	km^2	%	km^2	%	km^2	%	1990 - 1997	1997 - 2005	2005 - 2015	1990 - 2015
Settlement	395.8	0.9	737.8	1.7	868.0	2.0	1354.5	3.1	342.0	130.3	486.5	958.8
Agriculture	12,424.5	28.2	14,524.8	33.0	20,249.5	46.0	25,865.3	58.7	2,100.3	5,724.8	5,615.8	13,440.8
Bush	4,075.3	9.3	3,097.0	7.03	1,126.5	2.6	630.3	1.4	-978.3	-1970.5	-496.3	-3445
Open area	487.5	1.1	1441.5	3.3	2,376.8	5.4	2,950.0	6.7	954.0	935.3	573.3	2,462.5
Forest	26,222.0	59.6	23,804.0	54.1	18,984.3	43.1	12,805.0	29.1	-2418.0	-4819.8	-6,179.3	-13,417.0
Water	423.3	1.0	423.3	1.0	423.3	1.0	423.25	1.0	0	0	0	0
Total	44,028.3	100.0	44,028.3	100.0	44,028.3	100.0	44,028.25	100.0				

in 2005. We further used the model setting and replaced the Land use with the existing Land use and 2040 projected Land use and the corresponding existing Climate and the future Climate of 2030-2040. We used a tabular comparison to compare the Hydrology parameter values in response to the Land use and climate variations.

Results and Discussion

RESULT

Existing Land use Changes

Figure 3 shows the Land use distribution in the Batanghari watershed for 1990, 1997, 2005, and 2015. The overall accuracy of the four Land use mapping results is between 80% and 90%; according to Araya and Cabral (2010), the minimum value that must be considered as a reasonable interpretation of accuracy is 85%. Meanwhile, the kappa statistic is between 0.75 and 0.85 (relatively high accuracy).

Table 2 shows the Land use composition in the Batanghari watershed for 1990, 1997, 2005, and 2015 and its change. Forest dominated the Land use in 1990, 1997 but not in 2005, 2015; it continuously decreased with the percentage of 59.6%, 54.1%, 43.1%, and 29.1%, respectively. As the forest continuously decreased, on the other hand, Agriculture continuously increased and replaced the forest domination in 2015, and the percentage was 28.2%, 33%, 46%, and 58.7%, respectively.

PREDICTING LAND USE OF 2040

Figure 4 shows the distribution of projection Land use in the Batanghari watershed in 2040. This projected land use was validated in 2015 using the Kappa statistic value of 0.73%, and this value indicates that the model is good enough and can be used for prediction simulation, due to the limitations of land use series data, land use projections were simulated until 2040. Table 3 shows the composition of land use in the Batanghari watershed in 2040 which shows a 3.8% (1589.5 km^2) increase in residential areas. The agricultural area also increased to 28,532 km^2 or 64.8%, while the forest area decreased with an area of 12,218 km^2 or 27.7%. Compared to 2015, there was still a decrease in forest areas and an increase in agricultural and residential areas.

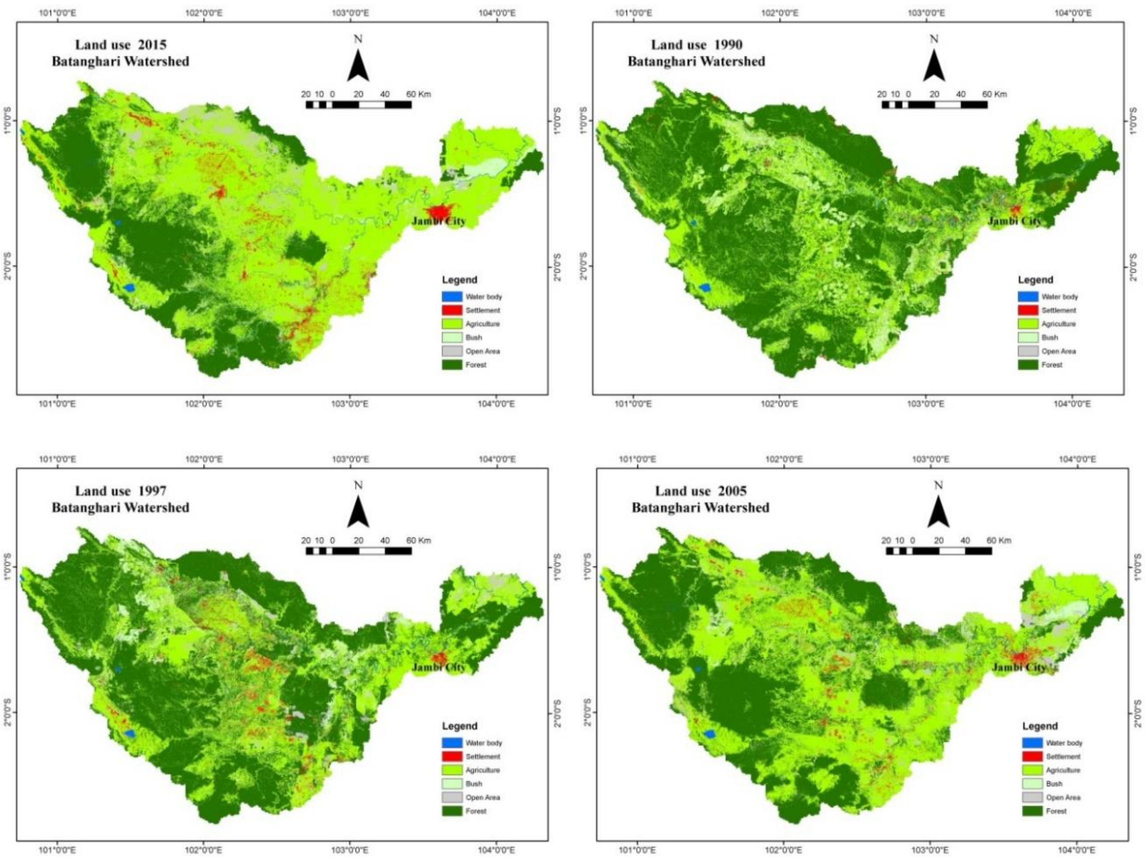


FIGURE 4. Spatial distribution of Land use in the Batanghari watershed for 1990, 1997, 2005, and 2015

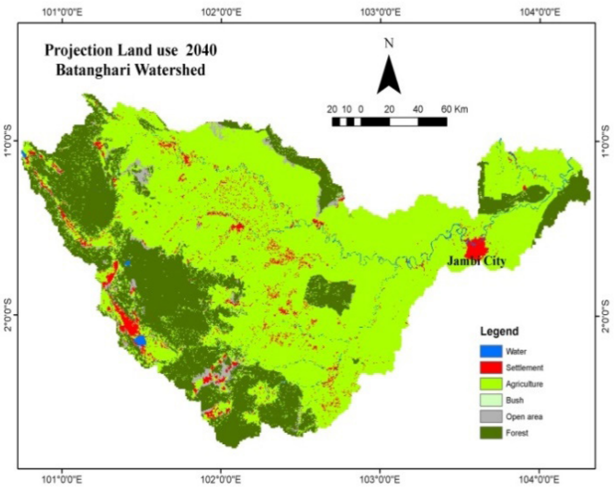


FIGURE 4. Land use Projection on 2040 [30]

TABLE 3. Land use composition results in 2040 model projection results

Landuse class	2040	
	km^2	%
Settlement	1,589.5	3.6
Agriculture	2,8532	64.8
Bush	199	0.5
Open land	1,066.5	2.4
Forest	1,2218	27.8
Water	423.3	0.96
Total	44,028.3	100

PERFORMANCE OF THE SWAT HYDROLOGICAL MODEL IN PREDICTING WATER AND SEDIMENT YIELD

Table 4 shows the minimum and maximum ranges of parameters in the SUFI-2 uncertainty technique. These results were obtained in a simulation using the SWAT-CUP application with the SUFI-2 procedure in the 60th iteration, while the total simulation performed in this process was 350 iterations. The parameterization results below show that the parameters CH_K2.rte, ALPHA_BF.gw, CH_ N2.rte, CH_COV.rte, OV_N.rte, and GW_DELAY.gw had the highest sensitivity and strongest significance. Also, this shows that these parameters are the most influential on the hydrological characteristics of the Batanghari watershed, and a slight change will affect the hydrological response in the form of a simulated discharge generated.

WATER AND SEDIMENT YIELD BASED ON EXISTING LAND USE AND CLIMATE

WATER YIELD BASED ON EXISTING LAND USE AND CLIMATE

The calibration results at the three observation stations had different values. The Ancol station has the highest values of R^2 and NSE (0.71 and 0.65). Meanwhile, the Muara Kilis station has the lowest values of R^2 and NSE (0.64 and 0.64). The validation data shows the highest R^2 and NSE is in the Ancol station (0.70 and 0.63) and the lowest is in the Sei Duren station (0.67 and 0.51). Table 5 shows the calibration and validation results of the SWAT model in the Batanghari watershed. The model validation results at all discharge observation stations showed satisfactory criteria (0.5 - 0.65). Figure 5 compares observed and simulated daily discharge with the corresponding daily precipitation. Figure 5 also shows that there was a data gap at the Sei Duren observation station from January 2005 to December 31, 2005, this was due to sensor damage, so it was not involved in model validation calculations.

SEDIMENT YIELD BASED ON EXISTING LAND USE AND CLIMATE

Figure 6 compares observed and simulated monthly loading sediments in Sei Duren Station. We observed a similar pattern of observed dan simulated monthly loading sediment was observed, with R^2 and NSE values of 0.72 and 0.68, respectively (Table 5).

The results of the analysis of suspended solids taken from Batanghari coastal areas also show a value in the range of model simulation results (50 mg/L to 500 mg/L) and the sampling point shows in Figure 1 taking in May 2021, the concentration of suspended solids reached 298.7 mg/L in R. Batanghari before dividing into two rivers, this value is lower than the concentration of suspended solid in September which reached 134.7 mg/L.

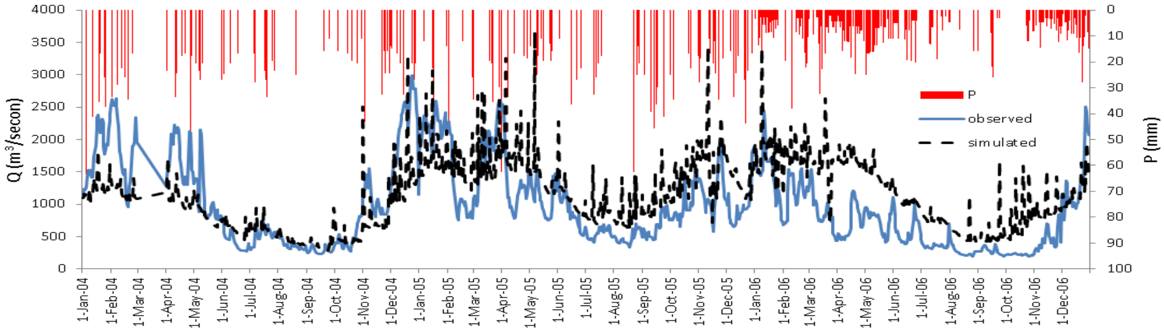
TABLE 4. Optimum calibration parameters for Streamflow and sediment model

	No	Parameter_Name	Desription	Fitted_ Value	Min_ value	Max_ value
Stream flow parameters	1	r_CN2.mgt	SCS-CN for moisture condition II	-0.10	-0.2	0.2
	2	v_ALPHA_BF.gw	Base flow alpha factor (1/days)	0.73	0	1
	3	v_GW_DELAY.gw	Groundwater delay time (days)	42.6	30	450
	4	v__GWQMN.gw	Threshold depth of water in the shallow aquifer required for return flow to occur (mm H_2O)	1.26	0	2
	5	v_GW_REVAP.gw	Groundwater revap coefficient	0.028	0	0.2
	6	v_ESCO.hru	Soil evaporation compensation factor	0.89	0.8	1
	7	v_CH_N2.rte	Manning's "*n*" value for the main channel	0.12	0	0.3
	8	v_CH_K2.rte	Effective hydraulic conductivity in main channel alluvium (mm/h)	233.7	5	500
	9	v_ALPHA_BNK.rte	Base flow alpha factor for bank storage (days)	0.89	0	1
	10	r_SOL_AWC.sol	Soil available water storage	10.7	-15	15
	11	r_SOL_K.sol	Soil hydraulic conductivity	-5.85	-8	8
	12	r_SOL_BD.sol	Soil bulk density	1.4	-0.5	2
Sediment parameters	13	r_USLE_K.sol	USLE equation soil erodibility (K) factor	0.29	-0.3	0.4
	14	r_USLE_P.sol	USLE equation support practice factor	0.39	-0.3	0.5
	15	v_CHERODMO.sol	Channel erodibility coefficient	-0.27	-0.3	0.6
	16	v_CH_COV1.rte	Channel erodibility factor	0.04	-0.01	0.5
	17	v_PRF_BSN.bsn	Peak rate adjustment factor for sediment routing in the main channel	1.49	0.2	1.5
	18	r_RILL_MULT.bsn	Multiplier to USLE_K for soil susceptible to rill erosion	1.3	1.2	1.5

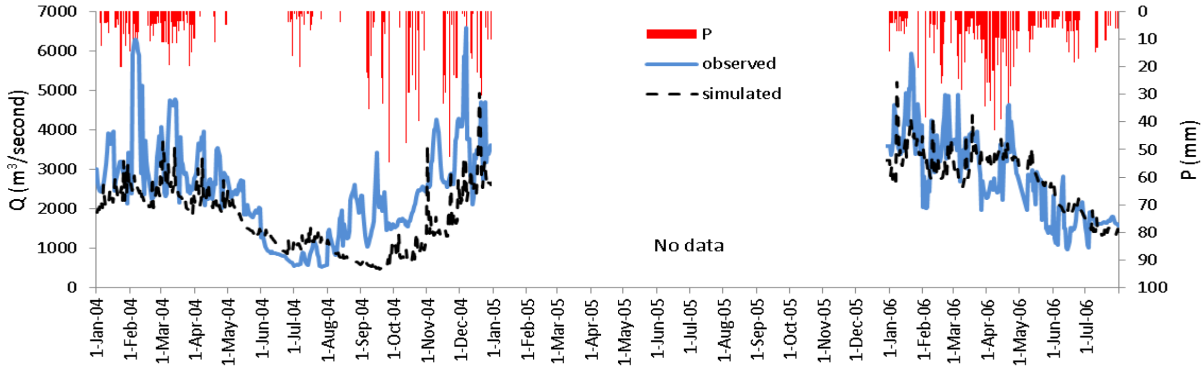
TABLE 5. Result of validation model in Batanghari Watershed

Parameter	Location	Resolution	Coefficient of determination (R^2)		Nash-Sutcliffe model efficiency (NSE)	
			Calibration	Validation	Calibration	Validation
Discharge	Muara-kilis	daily	0.64	0.58	0.64	0.61
	Sei Duren		0.69	0.67	0.61	0.51
	Ancol		0.71	0.70	0.65	0.63
Sediment	Sei Duren	Daily	0.57	0.55	0.5	0.45
		Monthly	0.84	0.75	0.72	0.68

Muara Kilis River Gauge



Sei Duren River Gauge



Ancol River Gauge

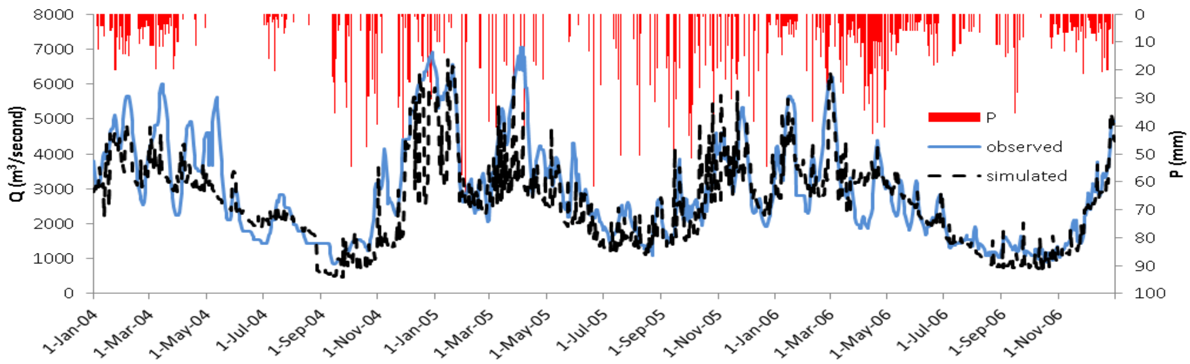


FIGURE 5. Comparison of daily observe and simulation discharge on three river gauges (Muara kilis, Sei Duren and Ancol)

The suspended solid concentration value in the downstream of the two channels also shows that the flow concentration towards Nipahpanjang has a higher compared to the flow towards Muaraberbak. This resulted in a greater loading of sediment flowing into Nipahpanjang as evidenced by the condition of the river mouth which has islands resulting from sediment deposition. Table 6 shows the results of the analysis of SS concentrations on the Batanghari Coastal Area.

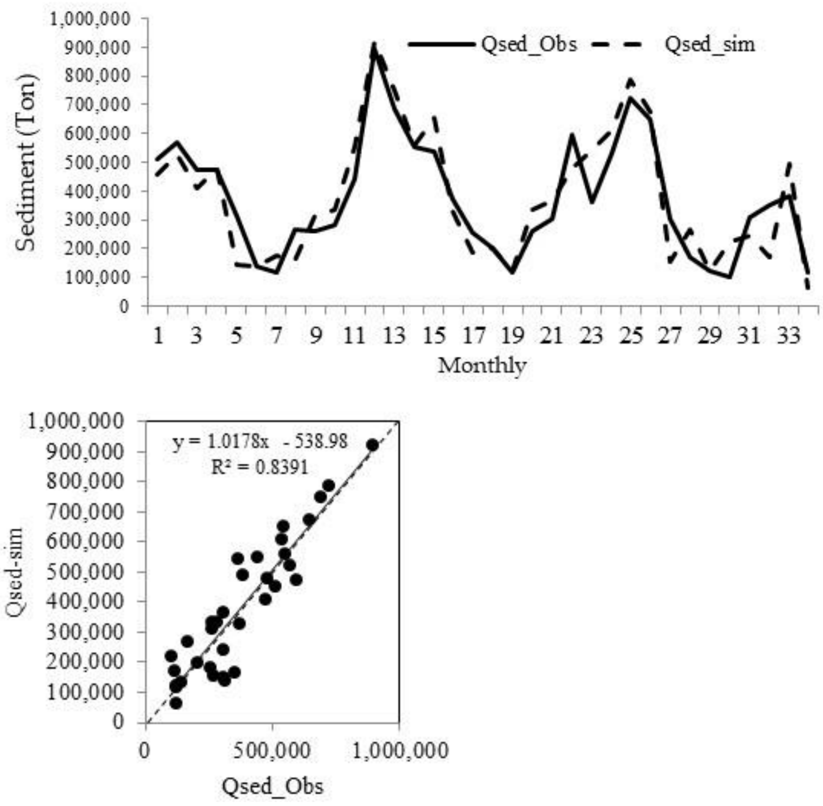


FIGURE 6. Comparison of sediment loading simulation and observation data in Sei Duren River gauge

WATER AND SEDIMENT YIELD BASED ON FUTURE LAND USE AND CLIMATE

The simulation results show that changes in hydrological components, including the surface runoff, tend to increase from 218 mm/year in 1990 to 259 mm/year in 1997 and 389 mm/year in 2015. Based on the simulation with Land use projection input in 2040, the surface runoff parameter increases to 413 mm/year. This process was inversely proportional to the base flow values, where from 1990 to 2015, Land use had a declining trend with values as follows; 1,103 mm/year, 1,068 mm/year, 1,042 mm/year, and 979 mm/year. Likewise, the simulation results on the projected Land use in 2040 decreased to 962 mm/year.

The results in the Batanghari Watershed show that the conversion of forest functions to agricultural area and the development of settlement area was still happening and its impact on hydrological parameters still tended as in the model simulation on the input land-use series from 1990 to 2015. In the Land use model projection simulation, the surface runoff was 413 mm/year, the base flow decreases to 961 mm/year and the sediment load was 73 mm/year.

The decrease in the hydrological function of the watershed as a result of changes in Land use can be seen from the average Curve Number which increased in value. In 1990, the average value of CN was 56.9 and this value increased to 58.2, 60.8, and 63.8, while in 2040, the value will be 65.3. The increase in the average value of CN was also directly proportional to the increase in the max-min ratio which in 1990 was 29.4 and then rose to 30.8, 32.8, and 41.5 until 2015. Meanwhile, once the simulation used projections in 2040, the max-min ratio of flow rate becomes 45.1. Table 7 shows the hydrological model result on Land use changes.

Land-use change can affect the sediment yield in the Batanghari Watershed. The simulation results of the SWAT model show an increase in the potential for erosion,

TABLE 6. Concentration of suspended solid at Batanghari coastal area

No	ID Sample	Suspended solid (mg/L)	
		May-2021	Sep-2021
1	Batanghari River	298.7	134.67
2	Batanghari River to Muaraberbak	91.3	81.3
3	Batanghari River to Nipahpanjang	196.7	114,6
4	St4 lama	107.5	95
5	Muaraberbak bridge	79.3	88,5
6	Rantaurasau village	104.6	79,6
7	Nipahpanjang	68	66,67

TABLE 7. Hydrological model simulation results on Land use in 1990, 1997, 2010, 2015 and Land use 2040

Hydrology par.	Land use 1990		Land use 1997		Land use 2005		Land use 2015		Land use 2040	
	mm/year	%	mm/year	%	mm/year	%	mm/year	%	mm/year	%
Surface run off (mm/year)	218	9.1	259	10.8	305	12.7	389	16.2	413	17.2
Lateral flow (mm/year)	267	11.2	267	11.1	267	11.1	263	11.0	254	10.6
Base flow (mm/year)	1,103	46	1,068	44.6	1042	43.5	979	40.8	962	40.1
Epa. And transparation	750	31.3	745	31.1	728	30.4	717	29.9	718	29.9
Recharge to deep aquifer (mm/year)	59	2.4	57	2.4	55	2.3	53	2.2	52	2.2
Precipitation	2396		2396		2396		2401		2399	
CN Average	56.9		58.2		60.8		63.8		65.3	
Sediment load (T/ha)	5.8		13.7		31.3		54.2		72.8	
Min Q (m^3/days)	355.3		348.8		347.7		320.4		302.7	
Max Q (m^3/days)	10450		10740		11420		13290		13640	
Max Q/Min Q	29.4		30.8		32.8		41.5		45.1	

where the input model in 1990 had a potential sediment load of only 5.8 tons/ha/year and increased in 1997, 2005, and 2015 to 13.7 tons/ha/year. In the simulation with input projections in 2040, the results show an increase to 72.8 tons/ha/year. Additionally, the results of the simulation of sediment yield show an increasing number, while the results for 10 years show an increasing pattern for each series of Land use as shown in Figure 7. The simulation results also show an increase in sediment loading in 2007 which was caused by the highest rainfall in the 2001-2010 period and indicated as strong la Nina.

The future hydrological condition model was modeled using two climate conditions of rainfall i.e., (1) 'the near future scenario' (2040-2050) and (2) 'the future scenario' (2080-2090) on the projected Land use of 2040. The present average annual rainfall is 2,399 mm/year, increasing to 2,412 mm/year and 2,636 mm/year for the near future and future scenarios, respectively.

The results of the model simulation show a better composition of water balance. The base flow is greater than the surface flow with a significant increase in the rate of max-min ratio flow (86.1 and 210.0 for the near future and future scenarios, respectively). This occurs due to lower flow rates in the dry season and higher flow rates in the rainy season. Table 8 shows a simulation result of climate change on projected Land use.

TABLE 8. Simulation results of climate change impact on projected Land use in 2040

Hydrology par.	Present		Near Future		Future	
	mm/year	%	mm/year	%	mm/year	%
Surface runoff (mm/year)	412	17.2	170	7.1	201	8.4
Lateral flow (mm/year)	254	10.6	280	11.7	305	12.7
Base flow (mm/year)	962	40.1	1335	55.7	1,487	62.0
Epa. And transparation	718	30	562	23.5	566	23.6
Recharge to deep aquifer (mm/year)	52.2	2.2	66	2.7	78	3.2
Precipitation	2399		2412		2636	
Sediment load (T/ha)	72.8		49.2		49.2	
Min Q (m^3/days)	302.7		230.7		224	
Max Q (m^3/days)	13640		19865		47030	
Ratio Max-Min	45.1		86.1		210.0	

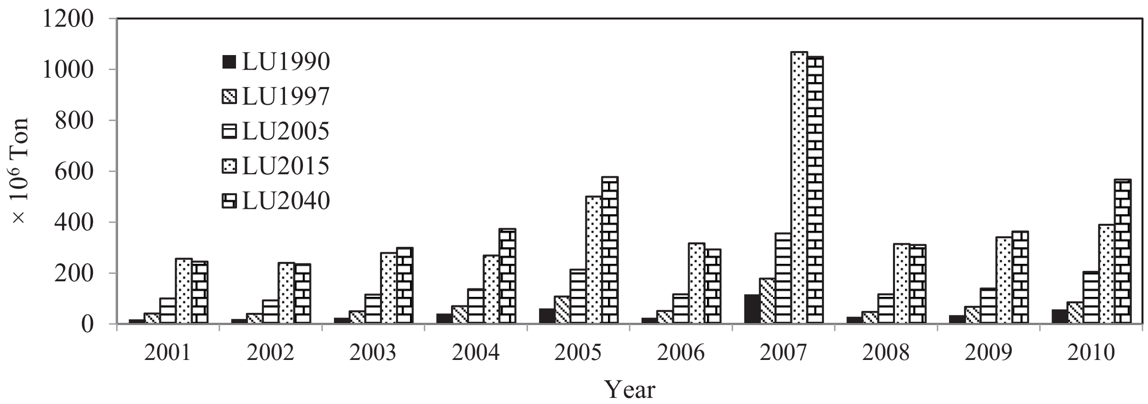


FIGURE 7. Loading sediment from The Batanghari Watershed base on Land use in 1990, 1997, 2005, 2015, and 2040

DISCUSSIONS

The results of Land use classification show good yield criteria based on the Kappa index and can be used to analyze changes in the Batanghari watershed. Furthermore, change analysis shows a reducing forest cover or deforestation, especially in the 2005-2015 timeframe. The reduction in forest area is in line with the addition of agricultural cultivation land (58.7%) in 2015 compared to the forest area of 29.1%. The decrease in forest area is in line with the results of research by Nahib and Suwarno (2017); Nurwanda, Zain and Rustiadi (2016), where almost the entire Sumatera Island during the period 2000 - 2009 has decreased by 3.71 million ha, as the impact of agricultural area development policy.

Prediction of future Land use is needed to structure the area and model spatial policy scenarios. Also, it can be an option for implementing a balanced spatial plan between nature conservation and cultivation. The modeling results were used to calculate the impact of future Land use developments on water resources. Modeling with CLUE-S has been widely performed, and based on the kappa index, the model produces good validation in the Batanghari watershed. Therefore, this study is concerned with the impact of settlement growth and deforestation on water and sediment yield. Coupled with the SWAT hydrological model and the CLUE-S model, it is suitable for management in areas dominated by agricultural land, such as model simulations in the Miyun watershed, China, in optimizing non-point source loading from the watershed (Zhang et al. 2020).

The SWAT hydrological model calculated the impact of Land use and climate change is calibrated using the SUFI-2 procedure in the SWAT-CUP application. The calibration results show good criteria for the flow rate at the three discharge measurement stations. Meanwhile, the loading sediment results were not satisfied with a good monthly sediment value. Furthermore, the results of parameterization with SWAT-CUP showed that the parameters CH_K2, ALPHA_BF.gw, CH_N2.rte and CH_COV.rte were sensitive to changes in discharge. This is different from the Cisadane and Cimanuk watersheds located on the island of Java, which is sensitive to flow rate, which is the Curve Number value (CN). The results of the SWAT hydrological model simulation showed a decrease in the hydrological function of the watershed, especially seen in the more significant surface runoff and decreased water infiltration into the subsoil characterized by a smaller base flow. This pattern was similar to what happened in the Cimanuk and Cimandiri watersheds (Ridwansyah et al. 2020, 2014; Ridwansyah, Yuliati & Wibowo 2019). The use of calibrated CHIRPS rain data is one factor that improves the simulation results; input rain data with CHIRPS can improve the lack of rain measurement stations, in addition to having long data from 1981 (Pang et al. 2020; Zhang et al. 2020).

The simulation of the SWAT hydrological model is not simulated up to the estuary, but up to Batanghari River before it splits into two streams due to limited data and the morphological conditions of the river which tend to be flat. The two rivers that flow into the sea have different interests where the northward flow that passes through Muaraberbak is a transportation route for large ships, even barges carrying coal also pass through this route. Meanwhile, the route that flows to the sea through Nipahpanjang can only be passed by smaller ships. This is because the northward flow is deeper and less sedimentated compared to the straight seaward flow. The results of the analysis of suspended solids conducted in May and September 2021 show that the concentration of suspended solids going to Nipahpanjang is greater than that to Muarasabak, as well as estuary conditions which show sedimentation results in the form of islands in the Nipahpanjang region, as shown in Landsat 9 in 2020 (Figure 1).

In the simulation with rain input, climate change forecasts increase the average amount of rain, 2,399 mm/year at present, increasing to 2,412 mm/year in the near future and in the future to 2,635 mm/year, this will change the water balance in the future (Ficklin et al. 2017). In the medium climate change scenario (RCP 4.5) there is no water shortage, it is different if using the high climate change scenario (RCP 8.5) (Touseef, Chen & Yang 2021). This simulation with the projected Land use input in 2040 also produces the same pattern of decreasing hydrological functions. The surface runoff has lower value, and base flow has higher value. The decline in watershed function is also seen with the higher ratio of Max-min flow discharge, this is the higher the risk of drought and flooding in the Batanghari watershed (Tarigan 2016; Tarigan, Wiegand & Sunarti 2017). Slightly different results are seen in the simulation with future climate inputs, where the water yield and sediment patterns show better values than using the current rain input, but when viewed from the max-min ratio of flow rate, the value appears to be higher. This indicates that there will be more frequent droughts and floods disaster in the future. Hydroclimatological disasters such as landslides, floods, and flash floods in line with a similar research using the SWAT model in India (Anand & Oinam 2019). In addition, Handoko et al. (2018) mentioned that climate change in the Batanghari Watershed has occurred to impact a more frequent floods and droughts.

CONCLUSION

The Batanghari Watershed, located on the Sumatra Island, has a pattern of changing forest land use to agricultural areas, while settlement areas are also increasing. Using the SWAT hydrological model, which is automatically calibrated with SWAT-CUP, 12 parameters are used for flow discharge calibration and six for sediment loading. The validation results produce satisfactory criteria to be used to assess the impact of land and climate change in the Batanghari Watershed. The simulation with the projected land use input in 2040 also produces the same pattern of decreasing hydrological functions. Moreover, this decline in watershed function is indicated by the higher Max-min ratio of flow discharge ratio, increasing the risk of drought and flooding in the Batanghari watershed.

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