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Original Article

Soil erosion management using the Soil and Water Assessment Tool (SWAT) model in Semantok Watershed

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Abstract
The land use characteristics in the Semantok watershed significantly impact the reservoir's usable age. According to the land use patterns, including teak woods, rice fields, moorlands, dry fields, and residential areas, the Semantok watershed can carry sediment when it rains. One of the models to analyze surface runoff and sediment is the Soil and Water Assessment Tool (SWAT). SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods. The purpose of this research is to quantify the amount of erosion and sedimentation that results from land use changes in the Semantok watershed in 2015 and 2021 and to determine management scenarios that can reduce the value of erosion and sedimentation that can implemented upstream of the Semantok dam using SWAT. The data used for the research are climatology data, DEM map, landuse map, and river data. The erosion at the Semantok watershed outlet increased from 7.00 mm/year in 2015 to 14.18 mm/year in 2021. Based on Forestry Ministerial Regulation No. P.61/Menhut-II/2014, the Semantok watershed's carrying capacity is 3.95 falling into the pretty bad category (3.5 < DDD < 4.3). Three scenarios were compared to carry out control efforts: revegetation, check dams, and combining revegetation and check dams. The most efficient way to reduce erosion by up to 30.51% is to combine revegetation and check dam.
Keywords: SWAT, Semantok Watershed, Erosion, Sedimentation, Watershed Carrying Capacity

1. Introduction

The Semantok Dam is located in the Semantok River, Kedungpingit Hamlet, Sambikerep Village, Rejoso District, Nganjuk Regency. The construction starts from 2017 to 2022. Inauguration of the Semantok Dam on 20th December 2022. The ability of the land to hold water will be impacted by changes in land use in the upstream of the Semantok Dam. The condition of land cover in the Semantok catchment consists of teak forests, rice fields, moorlands, dry fields and residential which have the potential to carry sediment when it rains. The success of managing a watershed lies in the arrangement and management of the upstream part of the watershed (Karim et al., 2014). According to research published by Safitri et al. (Safitri, 2018) in 2018, the erosion rate in the Semantok watershed in 2017 was 7.14 mm/year, and based on the results of the analysis using SDR, the sediment distribution in the upstream Semantok dam was categorized as heavy.

According to Suripin (2004), the factors that influence erosion are: (1) climatic factors that have a big influence on erosion are rain, temperature and climate, (2) the physical properties of the soil that influence include: texture, structure, infiltration and organic matter content soil, in relation to whether or not the soil experiences erosion easily, (3) As the slope and the length of the slope increase, topography will become an influence on erosion, (4) vegetation, soil cover vegetation protects the soil surface from the impact of rainwater, reduces the speed and volume of surface flow/runoff, holds soil particles in place through the root system, maintains the stability of the soil's capacity to absorb water, (5) acts of human intervention, human activities

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are an important factor in the occurrence of rapid and intensive erosion. Activities that influence erosion include changes in land cover due to deforestation for settlements and agricultural land.

One of the models to analyze surface runoff and sediment is the Soil and Water Assessment Tool (SWAT). SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time. The purpose of this research is to quantify the amount of erosion and sedimentation that results from land use changes in the Semantok watershed in 2015 and 2021 and to determine management scenarios that can reduce the value of erosion and sedimentation that can implemented upstream of the Semantok dam using SWAT.

SWAT

The necessary input data for SWAT consist of climatology data, Hydrologic Response Unit (HRU) data, groundwater data, and data about to watershed characteristics, land cover, and soil types within the HRU (Asmaranto, 2014). The simulation process is carried out after the process of combining HRU with climate data is complete. Hydrological simulations are carried out based on daily periods. The equation used in SWAT to predict surface flow is the SCS Curve Number method (Neitsch et al., 2011). Sediment yield calculations in SWAT are estimated for each HRU using the Modified Universal Soil Loss Equation (MUSLE). MUSLE uses the amount of runoff to simulate sediment yield while USLE uses rainfall as an indicator of erosion energy. This replacement produces a number of benefits, one of which is increased prediction accuracy (Neitsch et al., 2011).

Testing ArcSWAT Simulation Results

The accuracy of the model discharge will be evaluated by testing it against the AWLR discharge data. The study employed the Nash-Sutcliffe Efficiency (NSE) and Correlation Coefficient (R^2) methods for testing purposes.

$$NSE = 1 - \frac{\sum_{i=1}^{n}(X-Y)^2}{\sum_{i=1}^{n}(X-\overline{X})^2}$$

Where,

NSE = Nash-Sutchliffe Efficiency coefficient
Y = value from model (m^3/dt)
X = value from observation (m^3/dt)
$\overline{X}$ = average value from observation (m^3/dt)
n = amount of data

Table 1. Nash-Sutchliffe Efficiency Coefficient Value

Nilai NSE	Interpretation
NSE > 0,75	Good
0,36 < NSE < 0,75	Satisfy
NSE < 0,36	Not satisfy

The Nash-Sutcliffe efficiency test is utilized to evaluate the accuracy of the model based on the criteria given in Table 1 (Motovilov, et al, 1999).

The R^2 coefficient of determination test is the square of the correlation coefficient (R) which aims to see the relationship between the two variables (observation results and calculation results). The optimal value for R2 is close to one.

$$R = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[n\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2]}}$$

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Where,
R = coefficient corelation
Y = value from model (m^3/dt)
X = value from observation (m^3/dt)
n = amount of data

Total Load

Total sediment (Total Load) can be calculated using the Engelund Hansen method. The sum of the bed load and suspended load is the total load. This method is used to obtain satisfactory results based on the measurement of D50 1 mm [6].

$$Q_b = B \cdot q_s$$

$$q_s = 0{,}05\gamma_s V^2 \left[\frac{d_{50}}{g\left(\frac{\gamma_s}{\gamma} - 1\right)}\right]^{\frac{1}{2}} \left[\frac{\tau_0}{(\gamma_s - \gamma)\, d_{50}}\right]^{\frac{3}{2}}$$

Where,
τ_0 = shear stress (kg/m^2)
τ_0 = γ . D . S
d_{50} = diameter of the grains that pass through the sieve 50 mm
V = flow velocity (m/dt)
V = $\frac{1}{n}$. $R^{2/3}S^{1/2}$
R = hydraulic radius (m)
S = slope
qs = sediment transport concentration (kg/m.dt)
Q_b = sediment load (kg/s)
B = river width (m)
γ = specific gravity of water (tons/m^3)
γ_s = specific gravity of sediment (tons/m^3)

2. Materials and Method

Materials

The study location is the Semantok watershed which has an area of 52 km^2. Geographically, the Semantok watershed is located between -7^o 26' 8.18" to -7^o 30' 17.61" LS and 111^o 47' 55.85" dan 111^o 53' 50.26" BT. Administratively, the research is located in three (3) regency areas—the dominant Nganjuk Regency and a small portion of Madiun and Bojonegoro Regencies; three (3) subdistricts—Rejoso, Saradan, and Bubulan; and seven (7) village areas—Tritik Village, Sambikerep Village, Bendosari Village, Sambungrejo Village, Krondonan Village, Pajeng Village, and Klangon Village. In this research, supporting data are required in order to examine current issues.

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Table 2
Data and Sources of Data Used

No.	Data	Specification	Sources
1.	DEM map (Digital Elevation Model)	• Zona UTM 49 S • Format Raster	DEMNAS https://tanahair.indonesia.go.id/demnas
2.	Soil type map for year 2007	• FAO	Indonesia Geospasial https://www.indonesia-geospasial.com/2021/03/download-shapefile-jenis-tanah-seluruh.html
3.	Landuse map for year 2015 and 2021	Landsat 8 (*Collection 2-Level 2*) for year 2015 dan 2021 pansharpened x,y 15,15	USGS https://earthexplorer.usgs.gov/
4.	Daily climate data in 2010-2021	• Minimum temperature • Maximum temperature • Solar radiation • Average wind speed • Average humidity	BMKG online https://dataonline.bmkg.go.id/
5.	Daily rainfall data in 2010-2021	• Kedungpingit station • Matokan station • Rejoso station • Gondang station	Nganjuk Regency Public Works and Spatial Planning Service
6.	Grain diameter sample data from the Semantok river		Brantas River Region Hall
7.	Inflow discharge data for 2020		Brantas River Region Hall
8.	Semantok dam technical data		Brantas River Region Hall

Methods

Runoff and sedimentation modeling analysis in this study uses the Soil and Water Assessment Tool (SWAT) model using software ArcMap 10.8.2 and ArcSwat Ver 2022/Rev687. The rain data used comes from four rain stations as in Table 2. The four rain stations will be tested for hydrological parameters against historical data which includes consistency tests, no trend tests, stationary tests and persistence tests. The data is presented in the form of a text file or CSV file, in order to create a weather generator that can be applied to ArcSWAT simulations. The data that can be processed in the analysis of land use predictions and ArcSWAT is data with a raster or features format. While the image data from landsat obtained is still in the form of bands, so the image data must be processed first.

ArcSWAT Analysis

The analysis procedure using the ArcSWAT program is as follows:

1. Delineation watershed

   Delineation proceeds by the utilization of DEM data obtained from contour data processing carried out with ArcGIS software. The delineation of the observation area will be predicated upon the watershed's natural topographic boundary. The method used in the delineation

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process is the threshold method, where the size of the threshold value used will determine the number of river networks formed.

2. Establishment of HRU (Hydrological Response Unit)
   HRU shows the impact of a region on hydrological variables. HRU is formed by overlapping (overlay) land cover maps, land maps, and land slope maps.
3. Weather data definition
   After establishing the unit of analysis, the procedure for combining HRU and climate data is carried out. At this stage, the simulation period is determined first and then climate data entry is carried out.
4. Set up and run
   The Setup procedure consists of set up the simulation's start and the end dates, as well as the simulation type (daily, monthly, or yearly), device type, and desired output format.

Calibration and Validation

To test and determine the level of acceptance and application of the SWAT model, it is necessary to calibrate the SWAT model to resemble the real situation in the field. At the calibration stage, several parameters are determined from the characteristics of the research location's watershed. The parameters used in this study for calibration contains the following: CN (Curve Number) for each land use, soil evaporation value (ESCO), soil layer water value (SOL_AWC), and ground water value (GW) comprising the following values: GW_DELAY, ALPHA_BF, GWQMN, GW_REVAP, and REVAPMN. The methods used at the validation stage are the Nash-Sutchliffe method (NSE) and the correlation coefficient (R2). The variation between the model values and the field observation findings is less when the parameters are set correctly. The discharge value of the Automatic Water Level Recorder (AWLR) in the river is commonly used as the calibration structure in this study.

Determine the total amount of sediment in the river

After calibrating and validating the model results against AWLR discharge data, the output of erosion and sedimentation that occurred in the wateshed in the sub-watershed class was obtained. The erosion value is then added to the sedimentation value that occurs in the river. The amount of sedimentation that occurs in rivers is calculated using the Englund-Hansen method.

Evaluation of watershed performance

In this study, the watershed performance evaluation will be carried out based on secondary data and simulation data with the ArcSWAT model. Watershed performance evaluation will be carried out based on Forestry Ministerial Regulation No. P.61/Menhut-II/2014

Analyze erosion control by using ArcSWAT

An analysis of erosion control was conducted utilising three scenarios: revegetation, check dam addition according on the highest sub-basin erosion value, and a combination of revegetation and check dam addition.

3. Results and Discussion

Hydrological analysis

There are four rain stations used in the analysis, including the Kedungpingit station, Matokan station, Rejoso station, and Gondang station. Hydrological analysis was carried out using four statistical test methods on annual rainfall data from 2010 to 2021. These tests are the consistency test, the absence of a trend, the stationary test and the persistence test. Based on the consistency test using the double mass curve method at each rain station, it is known that there are deviation in the data, so rain data correction is carried out so that the data is considered consistent. Based on the absence of a trend test using the Spearman Method at each rain station, the rain data shows no trend (independent). The stationary tests consist of the F test, which

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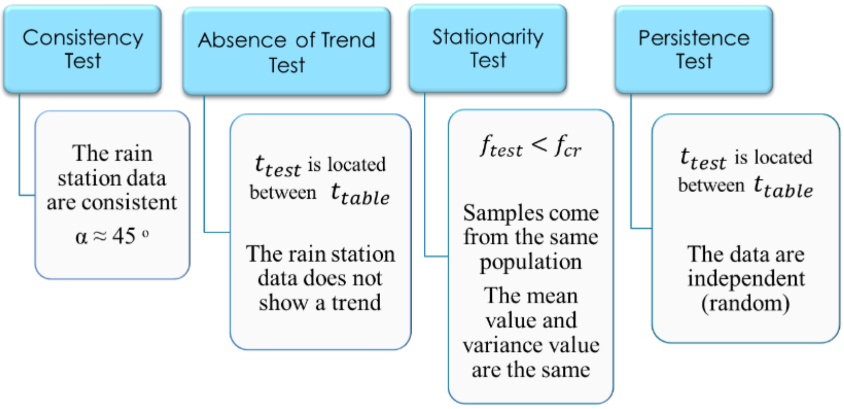
evaluates the independence or homogeneous of a periodic series consisting of more than two samples, and the T test, which evaluates the mean of two sample groups by calculating the sample's average value. Based on the stationary test shows samples come from the same population and the mean value and variance value are the same. Based on persistency test using the Spearman Method at each rain station, the rain data shows no trend (independent).

Figure 1

Results of statistical test analysis of hydrological data



Based on the results of statistical tests on hydrological data, it can be concluded that the data is stationary, the variance and average are homogeneous, and there is no discernible trend. It is independent (random). Consequently, additional analysis can be performed using the periodic series data.

Spatial Data Processing Analysis

The goal of the spatial data processing analysis is to obtain topographic maps of the study area, soil maps, and land use maps for the years 2015 and 2021.

Processing of land use maps based on Landsat 8

Land use maps for 2015 and 2021 were processed using ArcMap 10.8.2 software, utilizing data from Landsat 8 (Collection 2-Level 2).

Figure 2

Land use map for 2015

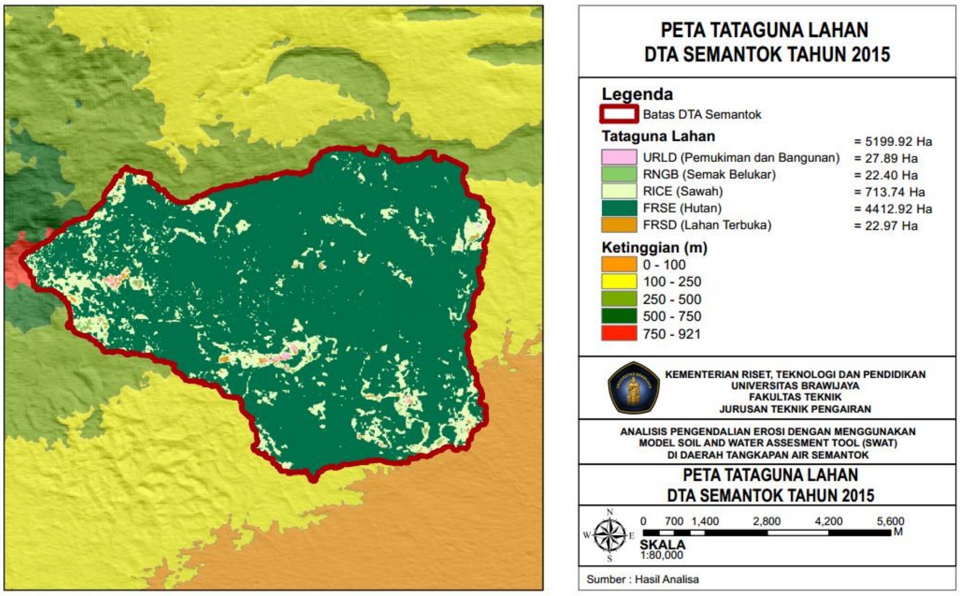


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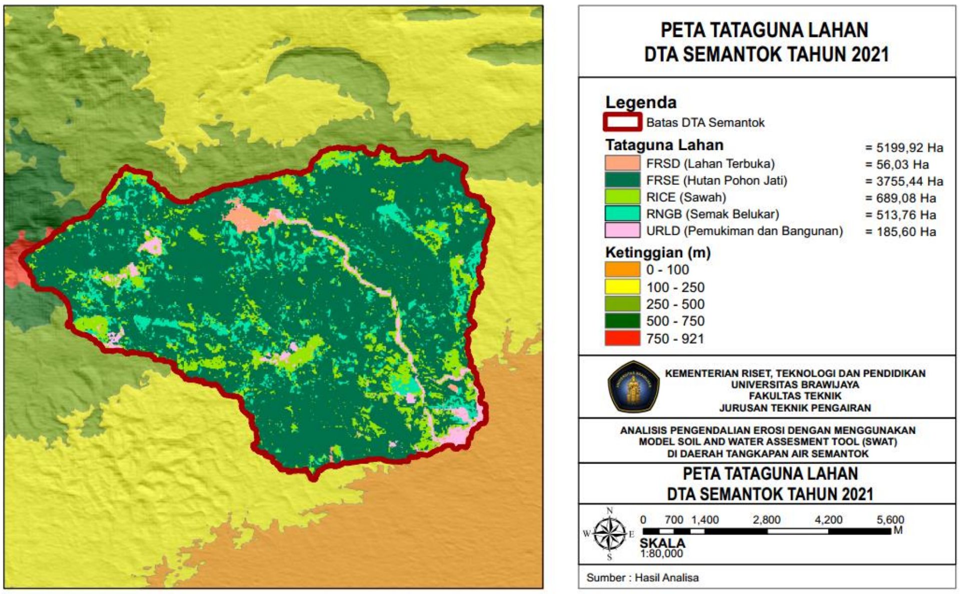
Figure 3
Land use map for 2021



Based on the results of land use identification to obtain a land use map, a comparison of land use in 2015 (Figure 2) and 2021 (Figure 3) is obtained as in Table 3 below.

Table 3
The Results of area calculations for each land use in 2015 and 2021

No	Landuse	2015		2021	
		Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)
1	Residential	27.89	0.54	185.60	3.57
2	Rice	713.74	13.73	689.08	13.25
3	Forest	4412.92	84.86	3755.44	72.22
4	Range-brush	22.40	0.43	513.76	9.88
5	Forest Deciduous	22.97	0.44	56.03	1.08
	Jumlah	5199.92	100	5199.92	100

Based on Table 3. there was a decrease in the use of rice land by 24.66 Ha and a reduction in the use of forest by 657.47 Ha. Residential land use increased by 157.71 Ha, range-brush by 491.361 Ha, and forest deciduous by 33,06 Ha.

Soil Map Processing Based on Map FAO

In this study, the soil map was processed based on the 2007 FAO map with ArcMap 10.8.2 software. Based on FAO soil map data there was only one type of soil found, designated I-Lv-3b. "I" is the symbol for the Lithosol soil type and "Lv" is the symbol for the Vertic Luvisol soil type while 3b is the area code for Java Island. The characteristics of the lithosol soil type are very shallow (< 25 cm) on solid rock [3]. The vertic luvisol soil type is characterized by its fine texture, good drainage, and varying depth, with the majority of it being very deep, terracing is advised to provide sufficient erosion protection in order to preserve agricultural.

Database Project

Land use and climate data are needed to be added to the SWAT database. Use FAO data that has been imported into the SWAT database for soil type information. Climate data is saved in .txt format which consists of several files, namely daily rainfall data (pcp), daily maximum and minimum temperature (tmp), daily solar radiation (slr), daily relative humidity (hmd) and

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daily wind speed (wnd) as well as information on the coordinate of rain stations and climatology stations that influence the study location. The data is in SWAT data format and includes customized data information.

Table 4

Customized Land Use Database for the SWAT Model

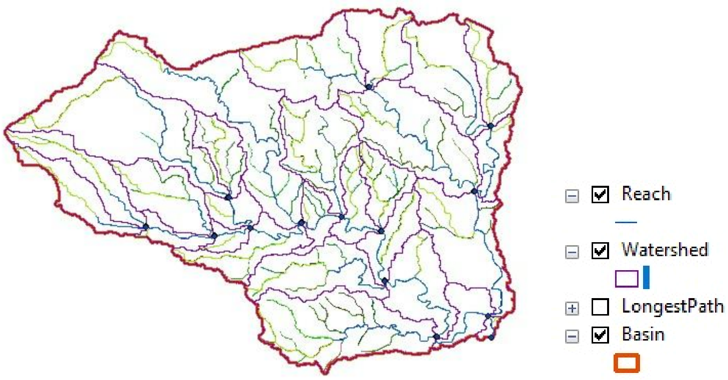
Value	Landuse	Landcover Swat_Code	Landuse Swat_Code
1	Residential	URBN	URBN
2	Rice	CROP	RICE
3	Forest	CROP	FRSE
4	Range-brush	CROP	RNGB
5	Forest Deciduous	CROP	FRSD

Watershed Delineation

Watershed delineation was carried out using input DEM map SRTM model dwith a resolution of 30 meters obtained from DEMNAS and river polyline files in shp format. Sub-basin will form at multiple stages during the watershed Delineation process.

Figure 4

The Result of delineation watershed



Based on the watershed delineation stages using land use in 2015 and 2021, 27 sub-basin have been formed.

HRU (Hydrologic Response Unit) Analysis

HRU is a hydrological analysis unit that has specific soil characteristics and land use, so that it can be separated from one HRU to another. HRU can be obtained by overlaying slope maps, soil maps and land use maps, that have been reclassified HRU (Neitsch et al., 2011).

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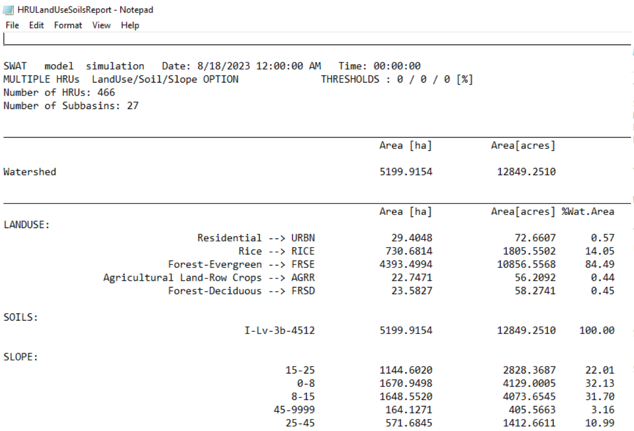
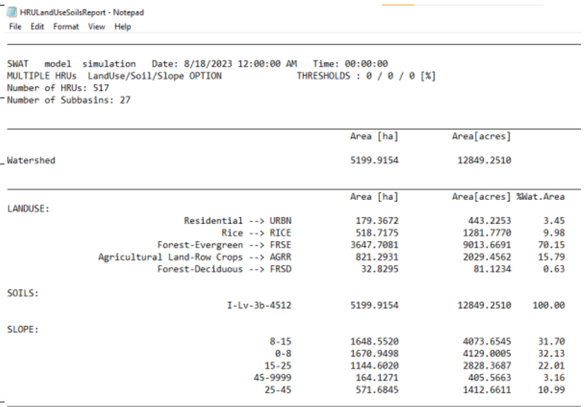
Figure 5
HRU Analysis Results for 2015 (left), HRU Analysis Results for 2021 (right)



```
HRULandUseSoilsReport - Notepad
File  Edit  Format  View  Help

SWAT   model  simulation   Date: 8/18/2023 12:00:00 AM   Time: 00:00:00
MULTIPLE HRUs  LandUse/Soil/Slope OPTION            THRESHOLDS : 0 / 0 / 0 [%]
Number of HRUs: 466
Number of Subbasins: 27

                                                  Area [ha]        Area[acres]
Watershed                                         5199.9154         12849.2510

                                                  Area [ha]        Area[acres] %Wat.Area
LANDUSE:
                        Residential --> URBN        29.4048            72.6607      0.57
                               Rice --> RICE       730.6814          1805.5502     14.05
                   Forest-Evergreen --> FRSE      4393.4994         10856.5568     84.49
       Agricultural Land-Row Crops --> AGRR         22.7471            56.2092      0.44
                   Forest-Deciduous --> FRSD        23.5827            58.2741      0.45

SOILS:
                                I-Lv-3b-4512      5199.9154         12849.2510    100.00

SLOPE:
                                       15-25      1144.6020          2828.3687     22.01
                                         0-8      1670.9498          4129.0005     32.13
                                        8-15      1648.5520          4073.6545     31.70
                                     45-9999       164.1271           405.5663      3.16
                                       25-45       571.6845          1412.6611     10.99
```



```
HRULandUseSoilsReport - Notepad
File  Edit  Format  View  Help

SWAT   model  simulation   Date: 8/18/2023 12:00:00 AM   Time: 00:00:00
MULTIPLE HRUs  LandUse/Soil/Slope OPTION            THRESHOLDS : 0 / 0 / 0 [%]
Number of HRUs: 517
Number of Subbasins: 27

                                                  Area [ha]        Area[acres]
Watershed                                         5199.9154         12849.2510

                                                  Area [ha]        Area[acres] %Wat.Area
LANDUSE:
                        Residential --> URBN       179.3672           443.2253      3.45
                               Rice --> RICE       518.7175          1281.7770      9.98
                   Forest-Evergreen --> FRSE      3647.7081          9013.6691     70.15
       Agricultural Land-Row Crops --> AGRR        821.2931          2029.4562     15.79
                   Forest-Deciduous --> FRSD        32.8295            81.1234      0.63

SOILS:
                                I-Lv-3b-4512      5199.9154         12849.2510    100.00

SLOPE:
                                        8-15      1648.5520          4073.6545     31.70
                                         0-8      1670.9498          4129.0005     32.13
                                       15-25      1144.6020          2828.3687     22.01
                                     45-9999       164.1271           405.5663      3.16
                                       25-45       571.6845          1412.6611     10.99
```

Based on the results of HRU formation (Figure 5), it was determined that there were 466 HRUs in 2015 and 517 in 2021, as well as 27 sub basins in both years.

Simulation Result

Sediment estimates for the Semantok watershed are calculated from sediment quantities in each sub basins, the sediment is transported through tributaries before ultimately reaching the main river. Based on the results of simulations carried out from January 1th, 2010 to December 31th, 2021, then we obtain the yearly fluctuations in the erosion and sedimentation rates. The highest sedimentation value occurred in 2021. The results of this simulation will be calibrated using trial and error SWAT parameters based on the AWLR recorded discharge data, and verified using the NSE and R^2 methodologies. The trial-and-error calibration parameters for SWAT are CN2, ESCO, SOL_AWC, GW_DELAY, ALPHA BF, GWQMN, GW_REVAP, REVAPMN. The simulation process for calibration purposes consists of two periods based on land use: period I for 2015 and period II for 2021. The input parameters for land use in 2015 and 2021 shown in Table 5, respectively.

Table 5
Land use input parameters for 2015 AND 2021

Parameter		Land use	Lower Bound	Upper Bound	Value for 2015	Value for 2021
Mgt	CN2	AGRR	35	98	65	89
		FRSE	35	98	52	92
		RICE	35	98	56	93
		FRSD	35	98	55	98
		URBN	35	98	84	87
HRU	ESCO	All land use	0	1	0.5	0.95
Sol	SOL_AWC	All land use	0	1	0.098	0.098
GW	GW_DELAY	All land use	0	500	150	100
	ALPHA_BF	All land use	0	1	0.049	1
	GWQMN	All land use	0	5000	1000	1000
	GW_REVAP	All land use	0.02	0.2	0.03	0.02
	REVAPMN	All land use	0	1000	750	700

Parameter calibration has an important impact on changes in model discharge. The results of model calibration using trial and error of SWAT parameters based on Tables 5 produced a

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discharge model for simulation periods I and II with an R2 each follow as 0.9093 and 0.8897 where is the value close to 1 and NSE each follow as 0.7292 and 0.8149 where is the value > 0.36. So that the discharge model was close to the measured discharge. This indicates that the discharge model is quite accurate and can be used as a baseline for calculating sediment, runoff, and erosion in the research area.

Table 6

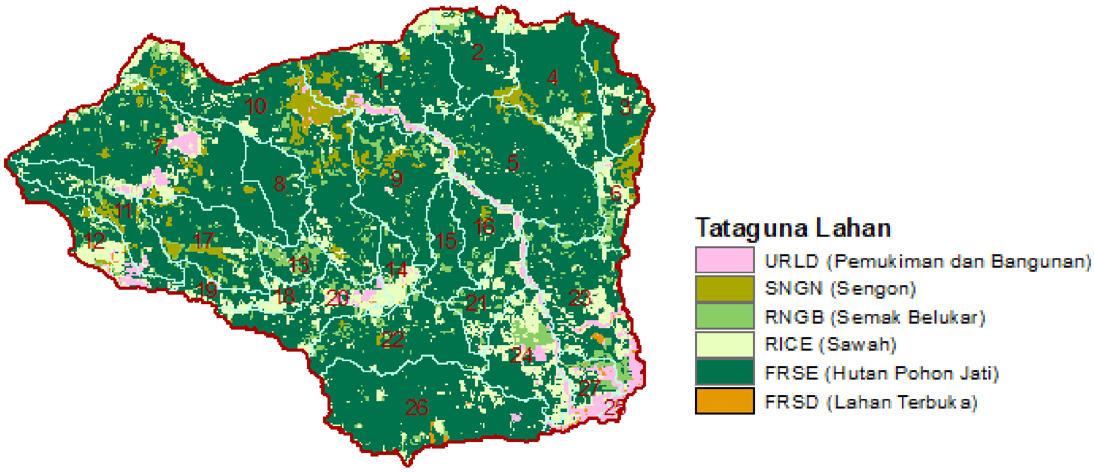
Summary of the yearly sedimentation, erosion, and discharge averages following calibration.

Year	Area (km^2)	Land use for 2015			Land use for 2021		
		Annual sediment (tons/ha/year)	Annual erosion (tons/ha/year)	Discharge averages (mm)	Annual sediment (tons/ha/year)	Annual erosion (tons/ha/year)	Discharge averages (mm)
2012	52	10.76	72.14	10.06	18.97	127.13	10.11
2013	52	14.39	96.48	22.36	25.57	171.37	23.88
2014	52	14.14	94.80	9.12	17.83	119.53	9.46
2015	52	17.24	115.53	9.96	24.80	166.23	10.14
2016	52	17.59	117.90	21.07	33.59	225.10	21.93
2017	52	11.78	78.93	7.05	18.94	126.97	6.91
2018	52	7.20	48.25	8.17	13.53	90.68	8.36
2019	52	16.20	108.56	7.89	23.08	154.67	8.03
2020	52	14.81	99.27	13.39	25.79	172.82	13.34
2021	52	22.00	147.44	31.53	34.90	233.89	33.41

According to Table 6, the sediment yield that occurred in 2015 was 17.24 tons/ha/year, with an erosion value entering the river body of 115.53 tons/ha/year or 364,084.61 m^3/year. While, the sediment yield that occurred in 2021 was 34.90 tons/ha/year, with an erosion value entering the river body of 233.89 tons/ha/year or 737,093.63 m^3/year. Changes in land use over a period of five years have impacted the amount of erosion in the watershed. According to simulations utilizing land use maps from 2021, sub-basins 6 and sub-basins 10 knew the greatest amount of erosion, each of them are as follows 2.84 tons/ha/year and 3.10 tons/ha/year.

Figure 6

Landuse Map for 2021



Based on figure 6, the land characteristics in sub-watershed 6 have an area of range-brush land use of 30.01 Ha and average slope of 19.15%, which is classified as rather steep. Likewise, what happens in sub-basins 10 with extensive land use cover of range-brush and open land of

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69.73 ha and 33.28 ha, respectively and has an average slope of 23.15%, which is classified as quite steep. So, this characteristic influences the high value of sedimentation that occurs on the sub-basins.

Total Erosion at Semantok Watershed Outlet

Total erosion at the Semantok outlet is determined by adding the land erosion to the total sediment in the Semantok river. total sediment in the Semantok river was calculated using the Englund Hansen Method. Based on the calculation results, the total load that occurred in the Semantok river in 2015 was 101.26 tons/year or 0,001 mm/year and in 2021 was 174,39 tons/year or 0.002 mm/year. So, the total amount of erosion at the Semantok watershed outlet in 2015 was7.00 mm/year, and in 2021 it increased to 14.18 mm/year.

Erosion Hazard Index

Based on the FAO soil type classification, the study area has Litosol and Vertic Luvisol (I-Lv) soil types. Vertic in soil classification according to the Bogor Soil Research Center is classified as Grumusol. Luvisol in soil classification according to the Bogor Soil Research Center is classified as Mediterranean.

Soil Type Characteristics:

a) Litosol soil: soil that is only 10 cm thick or less, beneath which there is a solid layer of rock. Harjowigeno (1987)
b) Grumusol soil: the soil solum is quite deep (100-200 cm), there is no eluviation or illuviation horizon, the soil color is gray to black, the structure is dry (topsoil) and blocky (subsoil) and the permeability is quite slow. Harjowigeno (1987)
c) Mediterranean soil: soil with an argillic horizon and a base saturation of 50% or more. Does not have mollic epidon. Harjowigeno (1987).

Based on the type of soil in the DTA location, the permitted erosion value in the Semantok watershed is 7.10 tons/ha/year or 0.43 mm/year.

So with the erosion value in the Semantok DTA in 2021 of 233.89 tons/ha/year and the permitted erosion value of 7.10 tons/ha/year, the erosion hazard index obtained is 1.22, which is based on the erosion hazard index classification table according to Arsyad (1989) is classified as moderate.

Assessment of watershed performance

The assessment of watershed performance in this study will be conducted using secondary data and data obtained from simulation results using the ArcSWAT model. The assessment of watershed performance that will be carried out includes land use evaluation and water management evaluation.

Each parameter's value and weight are multiplied together to determine the final watershed performance assessment value. The performance assessment score on the water management criteria is obtained from the analysis of each weight and score of the indicators and their parameters (KRA, KTA, IPA, Y, and flood event). The performance assessment score on land use criteria is obtained from the analysis of each weight and score of the indicators and their parameters (PPV, and IE).

The performance calculations of Semantok watershed, based on it carrying capacity, are summarized in Table 7 below.

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Table 7
Summary of semantok watershed performance parameter calculations

Criteria	Indicators	Weight	Value	Value x Weight
A. Water management	Flow regime coefficient (KRA)	5	5.00	25.00
	Annual flow coefficient (KTA)	5	5.00	25.00
	Water use index (IPA)	4	4.50	18.00
B. Land use	Sediment yield (Y)	2	13.75	27.50
	Flood event	4	5.00	20.00
	Percentage of vegetation cover (PPV)	10	1.25	12.50
	Erosion index (IE)	10	3.00	30.00
	Total	40	37.50	158.00

The final watershed performance results are obtained by multiplying the score by each parameter's weight and then dividing by the total weight percentage, which means that 158.00 / 40 = 3.95. According to the classification of watershed condition value categories, Minister of Forestry Regulation Number: P.61/Menhut-II of 2014, the Semantok watershed falls into the poor category (3,5 < DDD < 4,3).

Erosion Control Scenarios

In order to mitigate the excessive sedimentation in the Semantok Catchment, it is imperative to implement measures to regulate the sediment inflow into the catchment. This will ensure the longevity of the Semantok Dam reservoir. The erosion control scenario that will be applied in this study is based on land use in 2021, specifically vegetation with contouring and mechanical methods by adding check dams carried out with the aid of ArcSWAT software. The scenario that will be carried out is as follows:

a) A scenario in which the revegetation the previous quarry area covering an area of 40.59 Ha which has not yet been revegetated and replacing the bush land cover at several points covering an area of 161.02 Ha. So the total area of land that was simulated was 201.02 Ha. The plant chosen as a revegetation effort is the sengon plant;
b) A scenario in which additional check dams are applied to sub-basin 6 (check dam 1) and sub-basins 10 (check dam 2), which has the maximum erosion value. It is simulated that the reservoir age for check dam 1 is 53 years, and the reservoir age for check dam 2 is 22 years.
c) A scenario in which revegetation and the addition of a check dam are combined.

Table 8
Average sediment and erosion recapitulation with erosion control in 2021

Erosion Control	Sediment		Erosion	
	(mm/year)	(%)	(mm/year)	(%)
Existing	2.11		14.18	
Revegetation	1.57	25.64	10.54	25.63
Check dam	1.97	6.76	13.22	6.76
Revegetation dan Check dam	1.47	30.51	9.85	30.50

Based on Table 8. combining revegetation as well as providing check dams in sub-basins with the highest sediment potential, specifically sub-basins 6 and sub-basins 10 is the best scenario for reducing erosion in the Semantok watershed as it effectively decreases erosion by 30.50%, decreasing the rate from 14.18 mm/year to 9.85 mm/year.

4. Conclusion

Based on the results of the analysis conducted following the problem formulation of this study, the following conclusions can be drawn: From the 2015 and 2021 land use maps, there has been an increase in land use residential (URLD) to 157.71 Ha, brushwood (RNGB) to 491.36 Ha, and open land (FRSD) to 33.06 Ha. Furthermore, rice fields (RICE) decreased to 24.66 Ha, and forests (FRSE) decreased to 657.47 Ha. The erosion rate at the Semantok watershed outlet was 7.00 mm/year in 2015 and increased to 14.18 mm/year in 2021. According to a study conducted by Safitri et al (2018), the erosion rate in the Semantok watershed was measured to be 7.14 mm/year. The Semantok watershed achieved a performance score of 3.95, determined by classifying watershed condition value categories According to Minister of Forestry Regulation Number: P.61/Menhut-II/2014 of 2014, the performance of the Semantok watershed is classified as pretty bad (3.5 < DDD < 4.3). Based on the three erosion control scenarios implemented, the most effective is scenario 3, which involves combining revegetation as well as providing check dams in sub-basins with the highest sediment potential, specifically sub-basins 6 and sub-basins 10 because it can reduce erosion by up to 30.50% from 14.18 mm/year to 9.85 mm/year.

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Declarations
This study was done to get a master's degree and to make significant contributions to the topic of water resources

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