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Land Use Change Effects on Discharge and Sediment Yield of Song Cau Catchment in Northern Vietnam

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1 Introduction

Vietnam, one of the Southeast Asian countries with total area of about 33 million ha

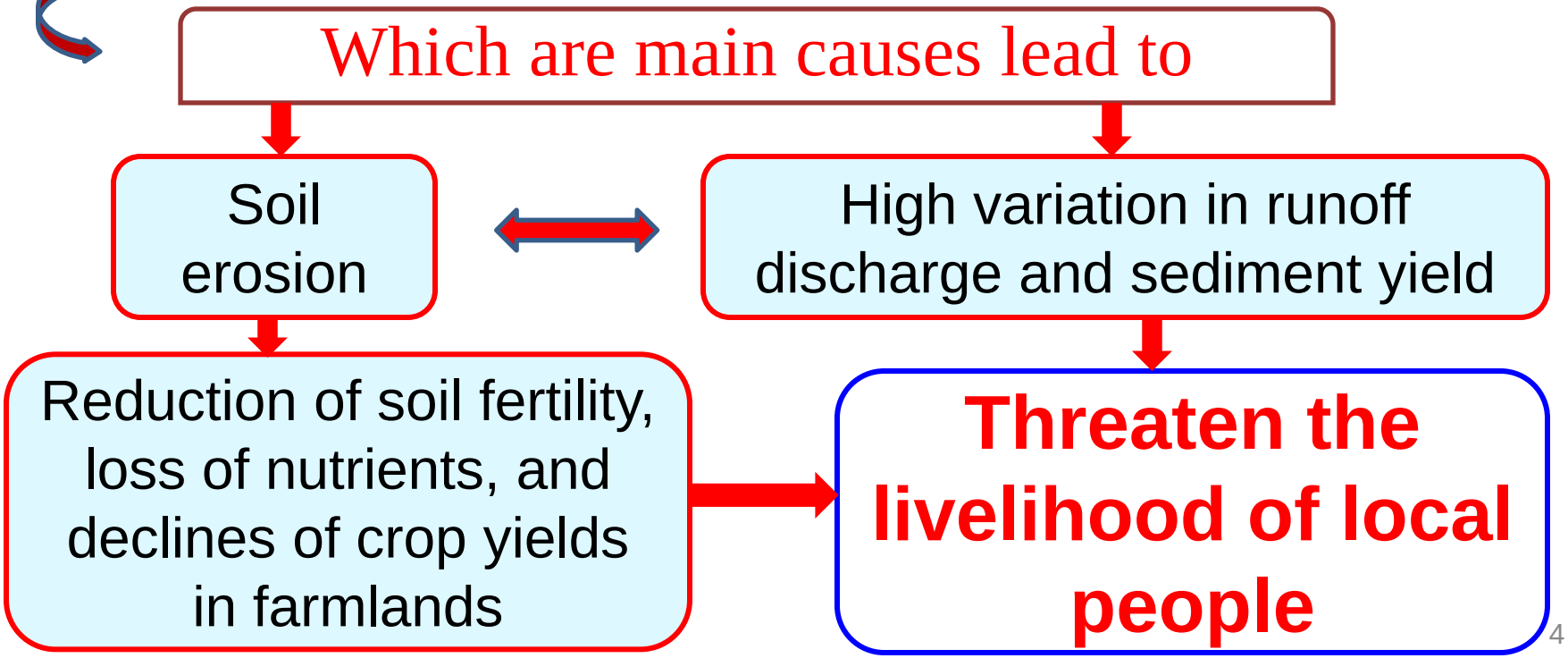
Out of which almost one fourth (8.7 million ha) is either irrigated area or rained land under permanent or semi-permanent cultivation (ESCAP, 2004)

About 70% of the country's area (23 million ha) can be considered hilly to mountainous terrain (Ton, 2006)

The average cultivation area per capita is only 1000m^2 (GSOV, 2008)

The Song Cau catchment is located in northern Viet Nam. Nowadays, it is facing with the problems that:

- The rapid increase of population
- Land use changes with negative orientation within the watershed



The objectives of this research are:

To apply SWAT in Song Cau catchment to analyze the impact of land use changes on runoff discharge and sediment yield.

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To make policy recommendations for decision makers regarding the impacts of land use changes on runoff discharge and sediment yield

2 Methodology

Study site

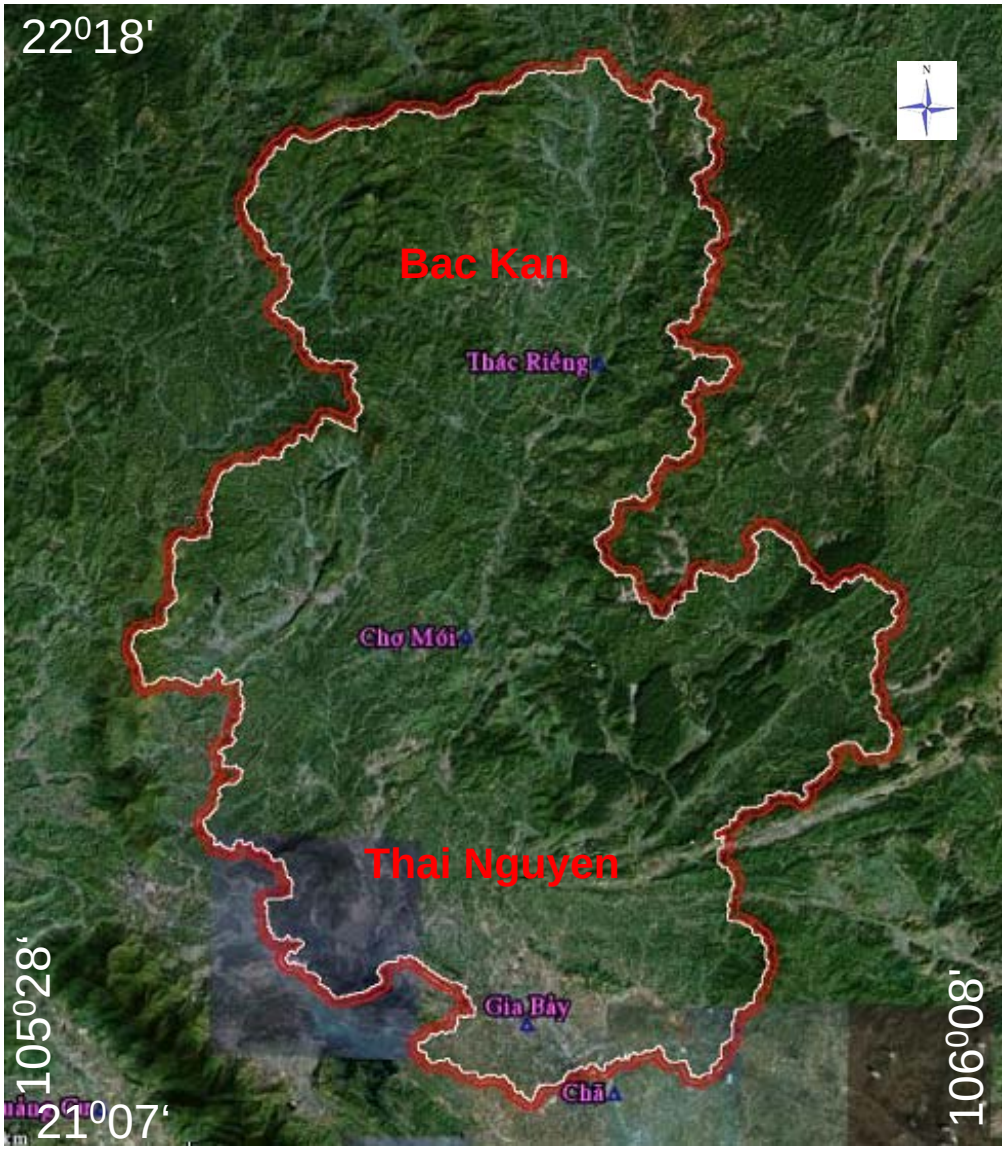


Figure 1. Location of Song Cau Catchment in Northern Viet Nam.

(Source: http://www.pickkatrail.com/jupiter/map/vietnam.gif and Google Earth)

Data collection

Table 1. Sources and Types of Data Collected for SWAT.

N^0	Types of data	Sources of data
1	Precipitation (rainfall)	Thai Nguyen, Bac Can, and Dinh Hoa weather stations
2	Temperature and others meteorological data	Thai Nguyen, Bac Can,and Dinh Hoa weather stations
3	Runoff discharge (observed data)	Gia Bay, Thac Buoi, and Thac Gieng gauging stations
4	Sediment yield (observed data)	Gia Bay gauging station
5	Topography (DEM)	Department of Information and Communication Technology for Natural Resources and Environment, Ministry of Natural Resources and Environment
6	Soil map	Viet Nam Soil and Fertilizers Research Institute
7	Land use map	Department of Information and Communication Technology for Natural Resources and Environment, Ministry of Natural Resources and Environment plus field survey data
8	Forest, Agricultural land	Department of Natural Resources and Environment of Thai Nguyen and Bac Can provinces

Land use scenarios

Table 2. Land Use Planning Scenarios for Song Cau Catchment.

SWAT Code*	Baseline		Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
WATR	39948.11	13.58	39948.11	13.58	39948.11	13.58	39948.11	13.58	39948.11	13.58
URMD	16384.72	5.57	16384.72	5.57	16384.72	5.57	16384.72	5.57	43075.18	14.65
FRSD	15214.7	5.17	15214.70	5.17	15214.70	5.17	0.00	0.00	15214.70	5.17
FRSE	38391.23	13.05	38391.23	13.05	38391.23	13.05	38391.23	13.05	38391.23	13.05
FRST	17332.68	5.89	17332.68	5.89	84867.29	28.86	0.00	0.00	17332.68	5.89
RICE	26690.46	9.08	26690.46	9.08	26690.46	9.08	26690.46	9.08	0.00	0.00
PAST	135069.2	45.93	67534.61	22.96	67534.61	22.96	135069.21	45.93	135069.21	45.93
AGRL	126.82	0.04	126.82	0.04	126.82	0.04	126.82	0.04	126.82	0.04
AGRR	4928.73	1.68	72463.34	24.64	4928.73	1.68	37476.11	12.74	4928.73	1.68
	294086.66	**100**	**294086.66**	**100**	**294086.66**	**100**	**294086.66**	**100**	**294086.66**	**100**

22.96%

22.96%

* *WATR: Water bodies including natural and manmade ponds and reservoirs, URMD: Urban residential medium density, FRSD: Forest-Deciduous, FRSE: Forest-Evergreen, FRST: Forest-Mixed, RICE: Rice cultivation, PAST: Pasture, AGRL: Agricultural Land-Generic, AGRR: Agricultural Land-Row Crops (almost occupied by Tea).*

Model performance evaluation

Nash-Sutcliffe efficiency (NSE), observation's standard deviation ratio (RSR) and percent bias (PBIAS) were use to evaluate model performance:

$$NSE = 1 - \{\sum^{n}_{i=1}(Q^{i}_{obs} - Q^{i}_{sim})^2\} / \{\sum^{n}_{i=1}(Q^{i}_{obs} - Q_{obs\text{-}mean})^2\} \quad (1)$$

$$RSR = RMSE/STDEV_{obs} = \{\sqrt{\sum^{n}_{i=1}(Q^{i}_{obs} - Q^{i}_{sim})^2}\} / \{\sqrt{\sum^{n}_{i=1}(Q^{i}_{obs} - Q_{obs\text{-}mean})^2}\} \quad (2)$$

$$PBIAS = \{\sum^{n}_{i=1}(Q^{i}_{obs} - Q^{i}_{sim}) \times 100 / \sum^{n}_{i=1}(Q^{i}_{obs})\} \quad (3)$$

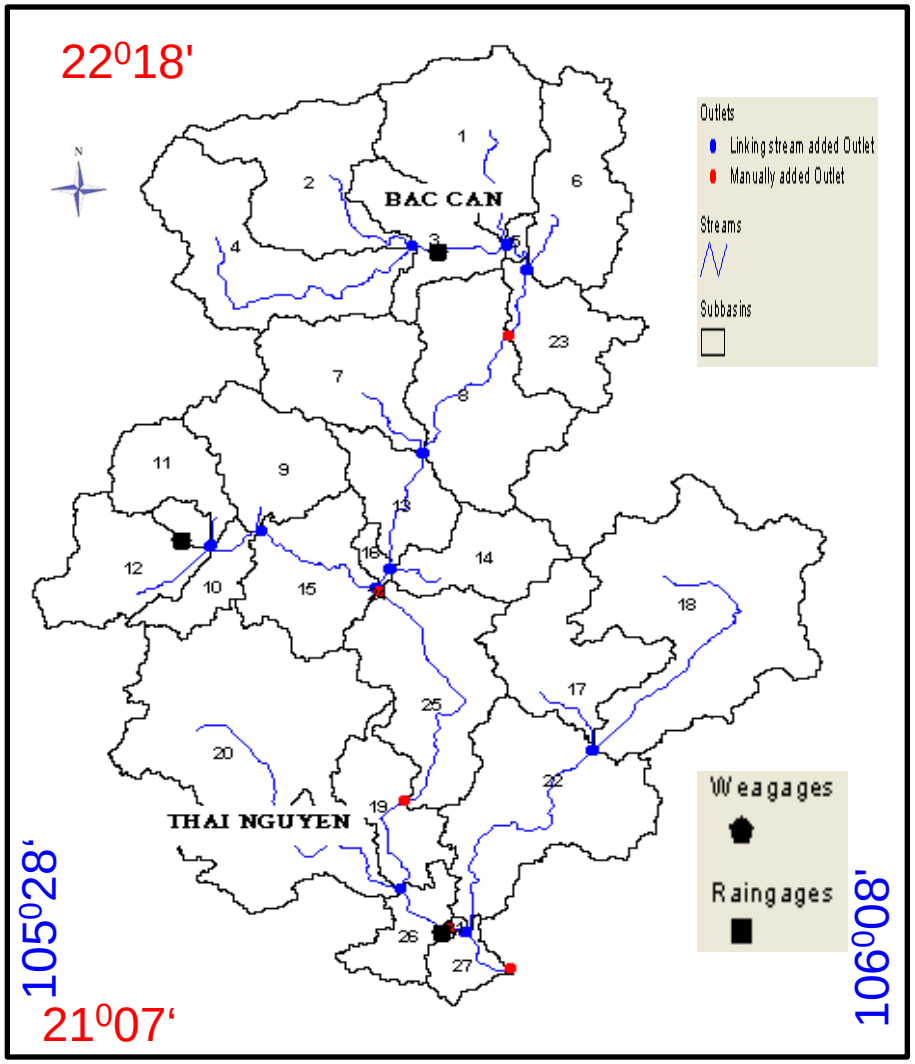
Where: ***n*** is the number of registered data points,

Q^{i}_{obs}, and Q^{i}_{sim} are the observed and simulated data, respectively, on the i^{th} time step, and

$Q_{obs\text{-}mean}$ is the mean of observed data (Q^{i}_{obs}) across the ***n*** evaluation time steps.

3 Results and Discussion

Watershed Delineation



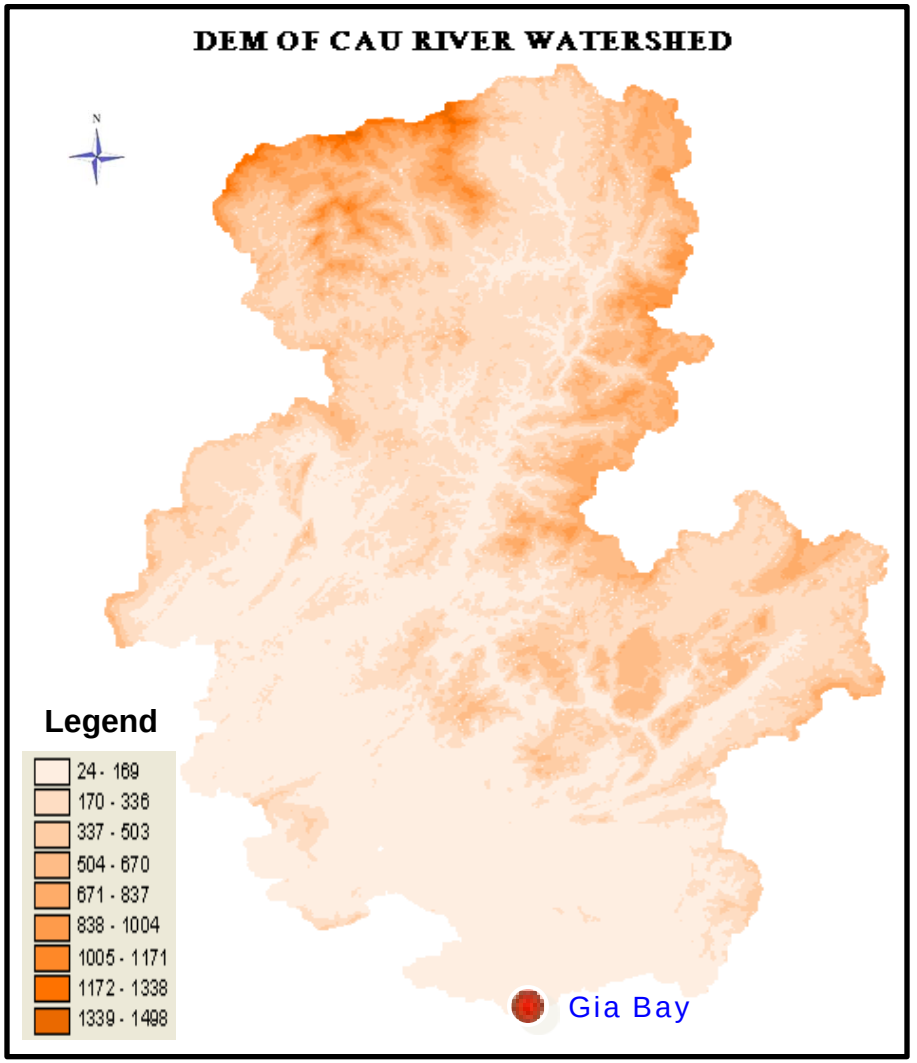
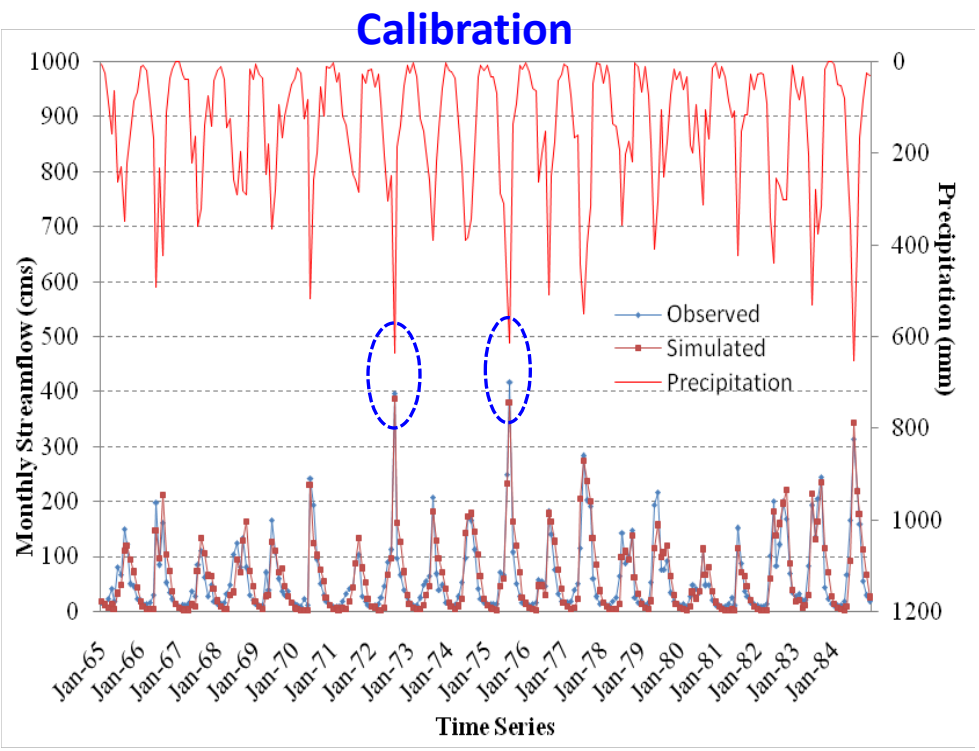


Figure 2. Watershed Delineation and DEM of Song Cau Catchment.

Streamflow Simulation Results



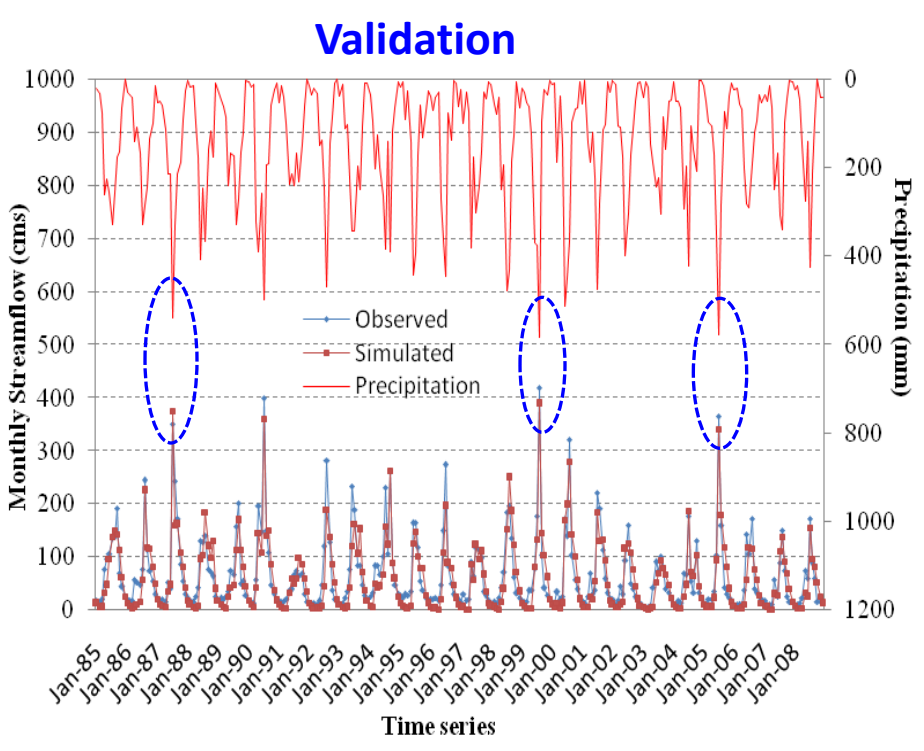


Figure 3. Observed versus Simulated Monthly Streamflow and Precipitation of Song Cau during Calibration and Validation Periods.

Table 3. Monthly streamflow Coefficient of Nash-Sutcliffe Efficiency (NSE), Observation's Standard Deviation Ratio (RSR), and Percent Bias (PBIAS) of Song Cau.

N^0	Items	Period of Record	Monthly NSE	RSR	PBIAS (%)
1	Calibration	1964 - 1984	0.822	0.438	- 1.587
2	Validation	1985 - 2008	0.767	0.425	5.928

Sediment

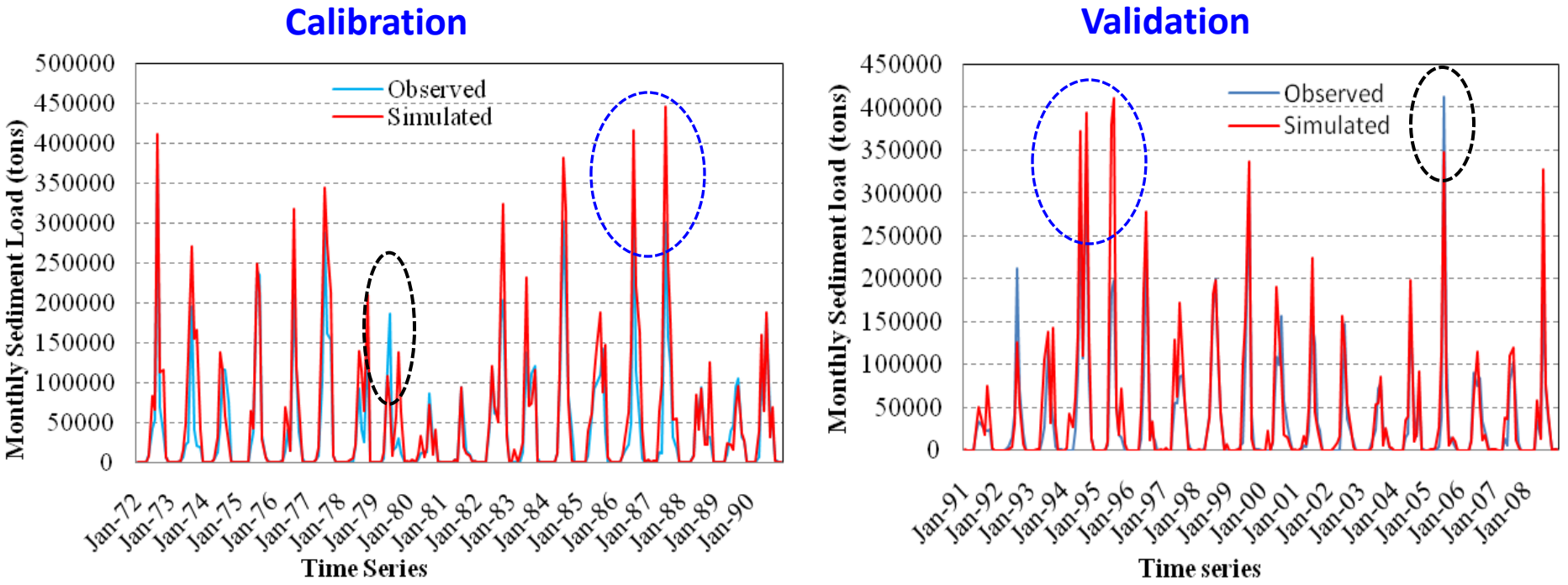
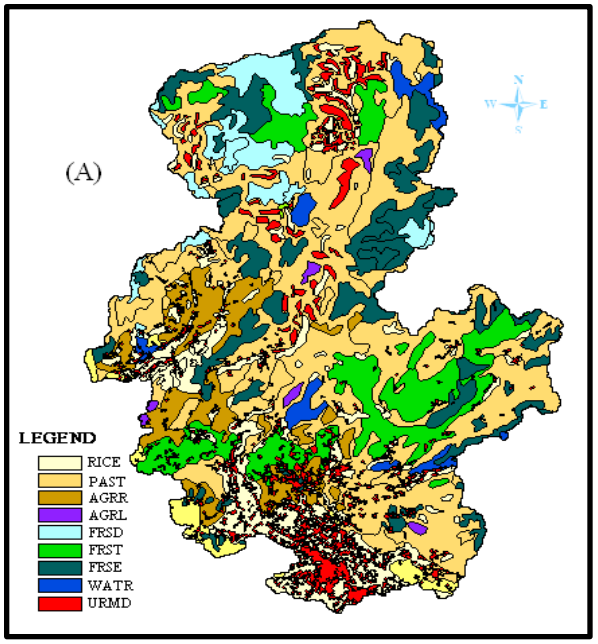


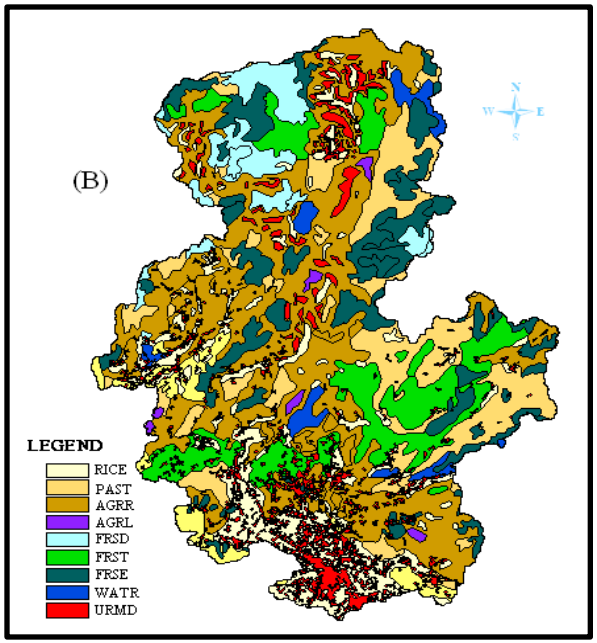
Figure 4. Observed versus Simulated Monthly Sediment Load of Song Cau during Calibration and Validation Periods.

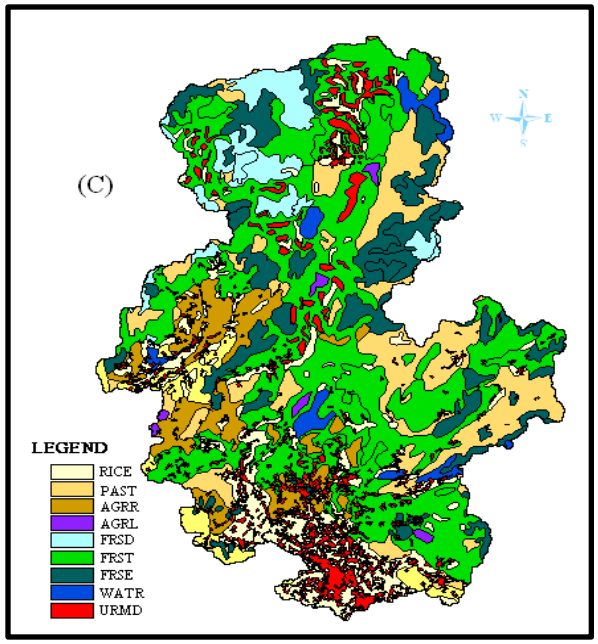
Table 4. Sediment Load Percent Bias (PBIAS), Monthly Coefficient of Nash-Sutcliffe Efficiency (NSE) and Observation's Standard Deviation Ratio (RSR) of Song Cau.

N^0	Items	Period of Record	Monthly NSE	RSR	PBIAS (%)
1	Calibration	1972 - 1990	0.660	0.583	- 36.127
2	Validation	1991 - 2008	0.690	0.555	- 26.443

Map of land use scenarios







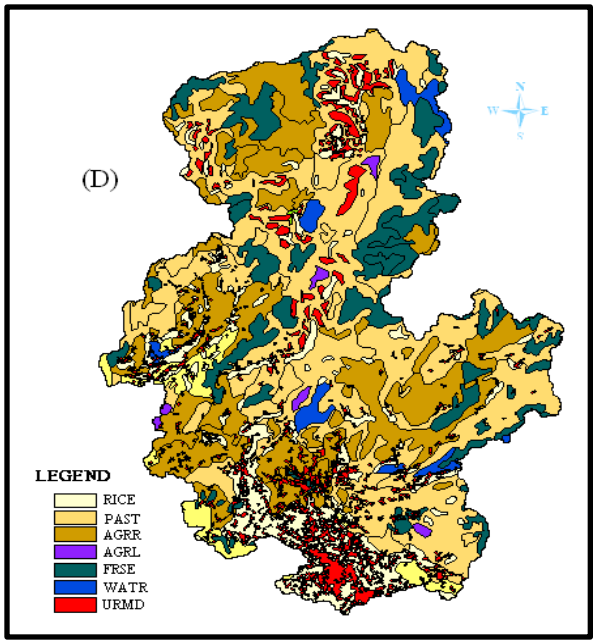
(A) Baseline Scenario

(B) Scenario 1: converted 22.96% Pasture land into Agricultural Land-Row Crops, other unchanged

(C) Scenario 2: converted 22.96% Pasture land to Forest-Mixed land

(D) Scenario 3: converted 5.17% Forest-deciduous and 5.89% Forest-Mixed land into Agricultural Land-Row Crops

(E) Scenario 4: converted 9.08% Rice land to Urban area.



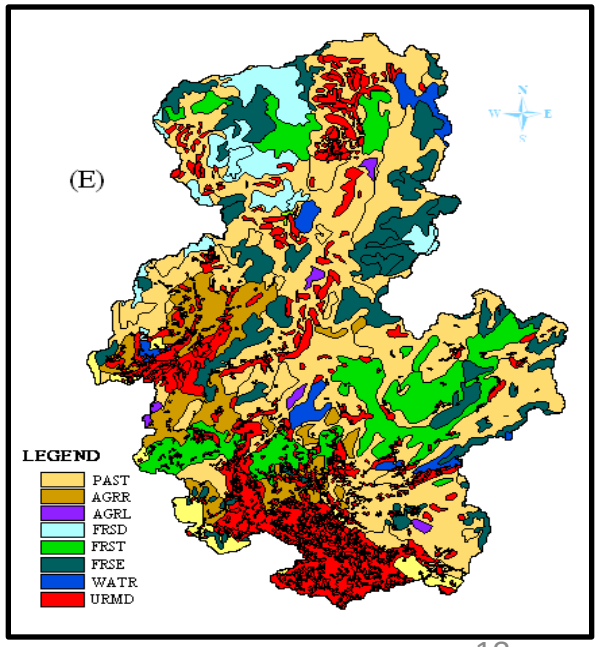


Figure 5. Different Land-use Scenarios Generated for Song Cau Catchment.

Percentage of Flow Change

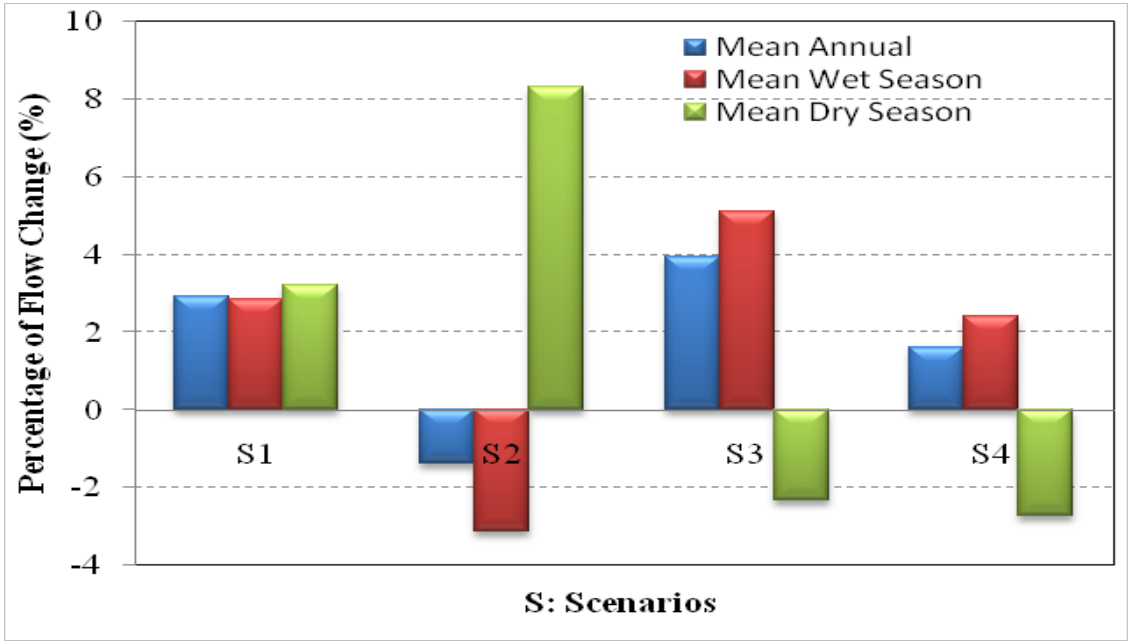


Figure 6. Percentage of Change in Mean Annual, Wet Season (May – October) and Dry Season (November – April) Flow with Respect to Baseline Scenario.

Table 5. Percentage (%) of Flow Change from Baseline (current land use) Scenario for Mean Annual, Wet Season and Dry Season.

Items	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Mean Annual	2.90	-1.37	3.93	1.61
Mean Wet season (May-Oct)	2.84	-3.15	5.08	2.41
Mean Dry season (Nov-Apr)	3.20	8.31	-2.32	-2.73

Percentage of Sediment Load Change

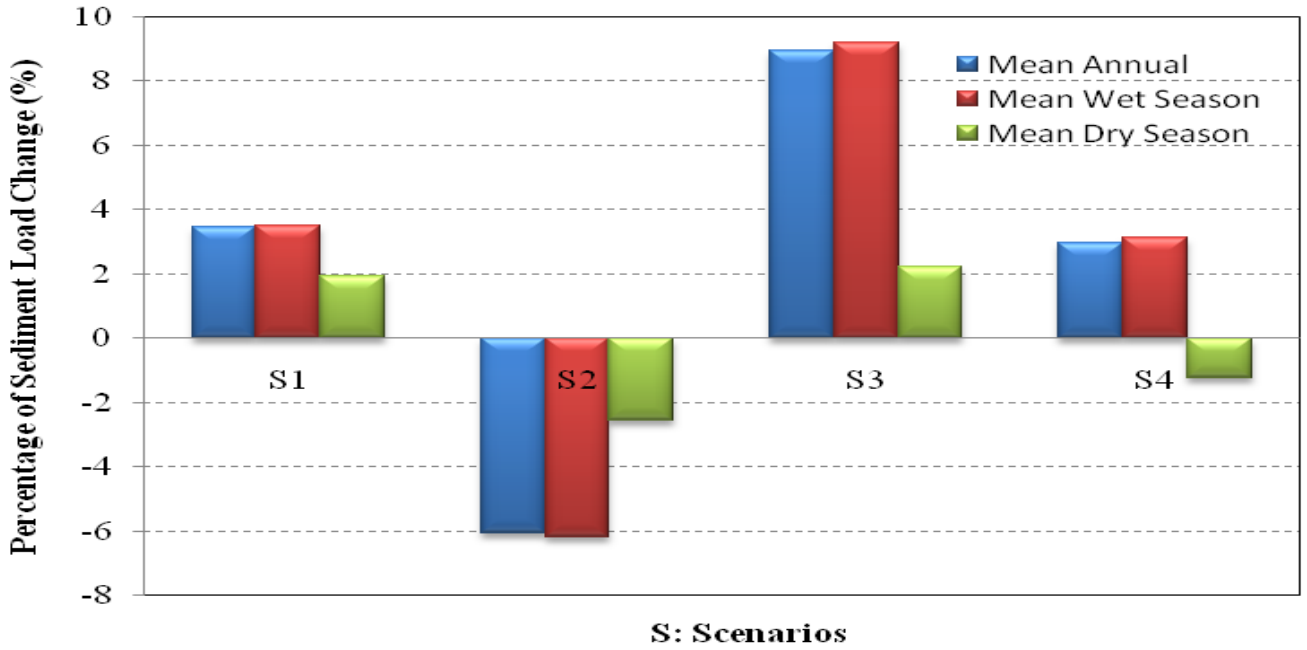


Figure 7. Percentage of Sediment Load Change in Mean Annual, Wet Season and Dry Season with Respect to Baseline Scenario.

Table 6. Percentage (%) of Sediment Load Change from Baseline Scenario for Mean Annual, Wet Season and Dry Season.

Items	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Mean Annual	3.45	-6.08	8.94	2.98
Mean Wet season (May-Oct)	3.51	-6.21	9.18	3.13
Mean Dry season (Nov-Apr)	1.92	-2.56	2.21	-1.25

4 Conclusions and Recommendation

✓ **SWAT was able to successfully simulate streamflow discharge and sediment loads for Song Cau catchment.**

✓ The results showed that monthly Nash-Sutcliffe coefficient of efficiency (NSE) ranged from 0.66 to 0.822, observation's standard deviation ratio (RSR) and percent bias (PBIAS) ranged from 0.425 to 0.583 and -36.127 to 5.928, respectively.

✓ The results strongly suggested the incorporation of pasture with forest-mixed (scenario 2) and pasture with agriculture land low crop (scenario 1) cultivation in the study catchment are among the lists of BMPs . Moreover, cultivation of pasture with forest-mixed resulted in the highest mean annual reduction in sediment yields (-6.08%), and 8.31% increase of stream flows in dry season.

Acknowledgement

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✓ Office of Thai Nguyen, Bac Can, and Dinh Hoa Weather Stations

✓ Taiwan Scholarship program.


BanGioc's Waterfall
CaoBang province
Thank you
for your
attention