APPLYING SEMI DISTRIBUTION HYDROLOGICAL MODEL TO ASSESS HYDROLOGICAL REGIME IN LAI GIANG CATCHMENT, BINH DINH PROVINCE, VIETNAM

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Abstract- The discharge of water is considered as one of the most significant hydrological parameters as it defines the stream course, size, and shape. The information related to flood forecasting and prediction of sediment load can be thus obtained from observing flow discharge. The present study is carried out to determine the effects of various factors including climatic circumstances, topography, land use, type of soil on the water discharge in Lai Giang River Basin, Vietnam by using Geographic Information System (GIS), and semi distribution hydrological model (SWAT). In this process, GIS supplies spatial input files for the SWAT model set up and calibration. The simulation of water discharge in Lai Giang river basin was carried out between the years 1995-2009, has shown comparatively good results because R^2 and E values were above 0.7.

Keywords- Flood forecasting, GIS, SWAT, sediment load.

1 INTRODUCTION

One of the main factors affecting the water discharge and sediment load is land use & land cover (LULC), these factors are playing a vital role of water discharge change in flow regime [1] [2] [3]. In Vietnam, form mid of the 1980s, the Government has started series of economic reforms, which means that their aim is to re-define the allocation of land use to enhance the development of economy, that results in the most remarkable policy named: "New Economic Zones program" [4]. Indeed, this policy displaced many living areas by uninhabited areas to expand the agricultural areas. This action led to the conversion of LULC in Vietnam for the period after the 1980s [5].

Water discharge is basically defined as the volumetric flow of water moving through a given cross-section of an area over a set time period [6]. The discharge of water is considered as one of the substantial hydrological parameters, for the fact that it defines the stream course, size, and its shape [7]. The outcomes obtained from monitoring water discharge could be valuable for flood forecasting and predicting sediment load [8]. Currently, along with the development of GIS, there are many techniques that can be helpful to calculate water discharge, precisely and fast, as compared to other old fashioned measurement methods [9]. The development of SWAT (Soil and Water Assessment Tool) model is one of the best ways to solve research related to LULC and it is becoming the most effective method nowadays. It is a small watershed to river basin-scale model which enables to enhance the accuracy of the simulated end result of water discharge from physical parameters of the basin and rainfall data. The model uses spatial input files for model setup and calibration to simulate different physical processes in the basin. In this model, a watershed is separated into many sub-watersheds. Similarly, an individual sub-watershed is divided further into unique soil/land-use characteristics called as hydrologic response units (HRUs). Moreover, through HRUs data in sub-watershed, the information related to the flow generation, sediments, and non-point source loadings can be obtained [10].

The Lai Giang river is one of the biggest rivers in the Binh Dinh Province. It formed from the merger of two rivers, An Lao river, and Kim Son river. The An Lao river and Kim Son river meets at the border area between Hoai An and Hoai Nhon districts in order to merge into the Lai Giang river. The Lai Giang River is flowing in the Southwest - Northeast direction, its height is about 400 - 825m. The overall area of the Lai Giang river basin is 1,269 km² approximately and the average height of its basin is approximately 300 m with the average slope is less than 0.25 degrees (Figure 1).

Previously, there were not many studies undertaken that assess the hydrological system of this study area due to a lack of data. This research aims to use the combination of remote sensing and observed data along with the semi distribution hydrological SWAT to figure out the change of LULC. Besides, this paper would hope to gain deeper insight into the change in river flow and sediment load at Lai Giang catchment, that plays an important role in Binh Dinh province, Vietnam. Due to the lack of observed data in central Vietnam, this study could be a leading study that can be applied to similar areas of Vietnam.

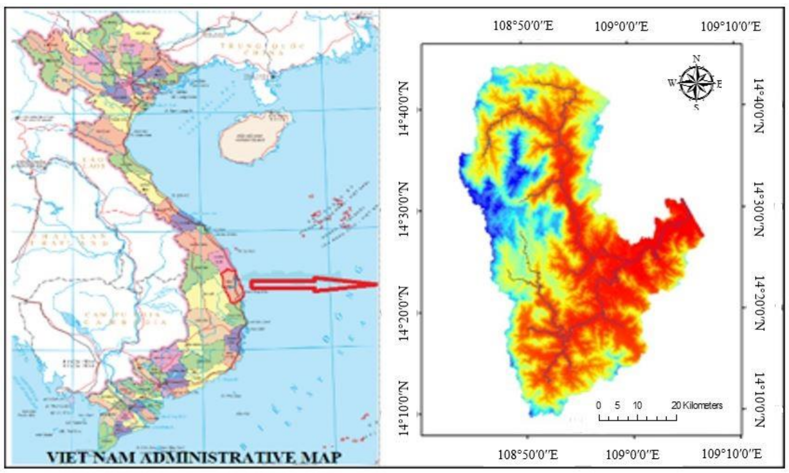


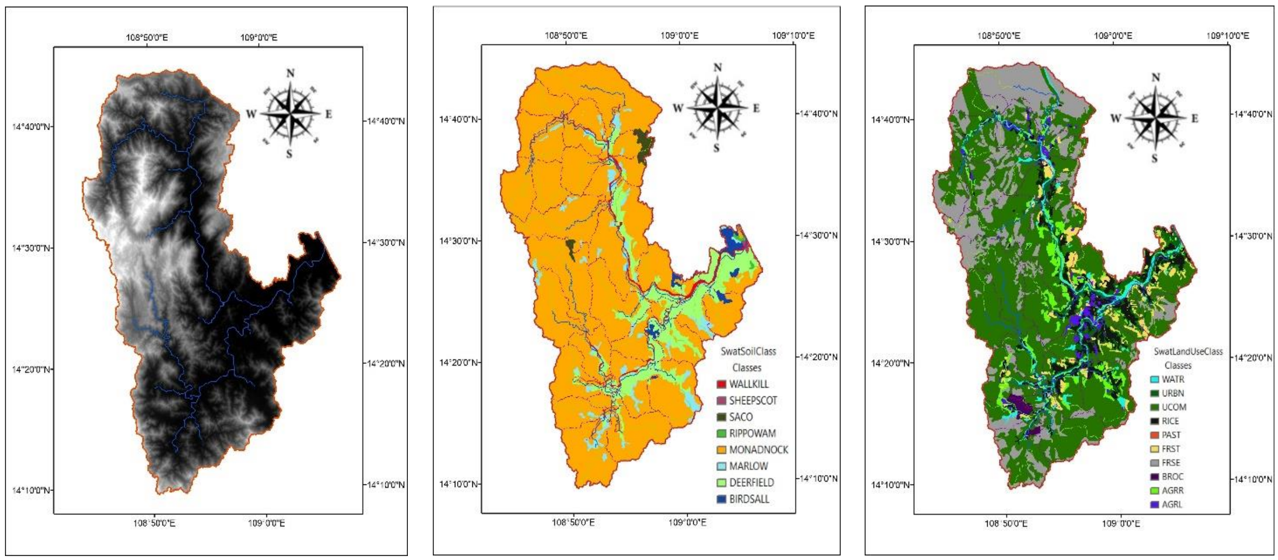
Figure 1: Lai Giang river basin in Central Vietnam

2 MATERIAL AND METHODS

For this survey, overall, 10 factors were considered for data input which included soil type, wind speed, Digital Elevation Model (DEM), rainfall, Land use, relative humidity, solar radiation, temperature, discharge, and sediment discharge. This paradigm is calibrated and validated on the basis of the data observed at An Lao station over years (1995-2009).

For the purpose of outlining sub-basins for the area under observation, an elevation model with 90 m resolution (DEM) was used which is available at National Map Seamless Data Distribution System (USGS) [11]. An elevation map (Figure 2a) was acquired by relying on the DEM. Landsat 8 OLI images (from 15 September 1990), with 30 m resolution, were used to generate a land use map (Figure 2b). For the ease, of interpretation and transformation of modifying the image, an enhancement process for refining (number) of images including multi-channel data combination was also taken into account for the creation of a new image. By using the probability of parameters and the most likelihood functions i.e. Maximum Likelihood method was used to carry out the image classification using ENVI 4.5 software. Consequently, 11 classes, with the inclusive accuracy of 90 %, were determined from the land use map: Water (WATR), Commercial (UCOM), Forest-Evergreen (FRSE), Residential (URBN), Pasture (PAST), Rice (RICE), Agricultural Land-Generic (AGRL), Broccoli (BROC), Agricultural Land-Row Crops (AGRR), Forest-mixed (FRST). For this survey, the soil type map, with a scale of 1:848,982 (Figure 2c) was extracted from National Pedology map.

The Center for Hydro-Meteorological Information and Data under the Vietnam Hydrometeorological Service (VHMS) of MONRE (Vietnam) provided the climatic data for the period of 1995-2009 which was available at 11 meteorological stations: Hoai An, Vinh Kim, An Lao, Vinh Son, Bong Son, Sa Huynh, Ba to, Duc Pho, Phu My, Gia Vuc, and Hoai Nhon. The climatic data used in this study included: daily wind speed (m/s), daily air temperature (maximum, minimum) (°C); daily relative humidity (%); daily solar radiation (MJ/m^2/day); and average rainfall (mm). Microsoft Excel was used to process every factor and after that, for the SWAT model, it was converted to pdf format. Apart from all this, some factors mainly; humidity, sunshine (number of hours), temperature and windspeed were used to obtain solar radiation by observing the max and min of the factors mentioned.



a. b. c.

Figure 2: Maps of Lai Giang River basin, a) DEM, b) Land use, and c) Soil types

The yearly average of sediment load (ton/day) for the period 1995-2009 was collected from An Lao hydrological station (Table 1). The methodology used in this study is shown in Figure 3.

Table 1-The average of sediment-load per year at An Lao station

Station	**The yearly average (ton/day)**	
	Min	Max
An Lao	3.5	113.79

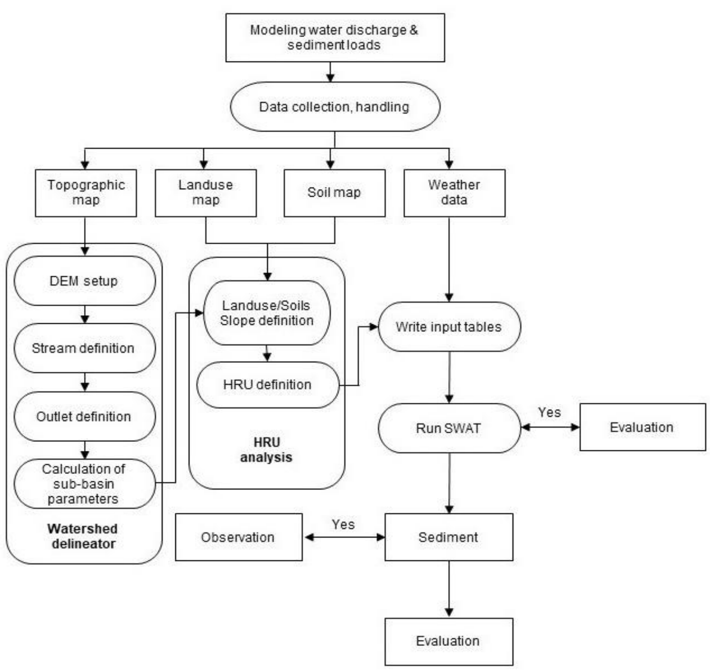


Figure 3: Flow chart of the methodology

The assessment of SWAT model was based on observed discharge data. The root mean squared error (RMSE), Nash - Sutcliffe Index (E), and coefficient of determination (R^2) were used to evaluate the model performance. Specific values for the user to examine results are shown in Table 2.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i}-X_{model,i})^2}{n}},$$

$$R^2 = \frac{\sum_{i=1}^{n}(X_{obs,i}-\overline{X}_{obs})\cdot(X_{model,i}-\overline{X}_{model})}{\sqrt{\sum_{i=1}^{n}(X_{obs,i}-\overline{X}_{obs})^2\cdot(X_{model,i}-\overline{X}_{model})^2}},$$

$$E = 1 - \frac{\sum_{i=1}^{n}(X_{obs,i}-\overline{X}_{model,i})^2}{\sum_{i=1}^{n}(X_{obs,i}-\overline{X}_{obs})^2},$$

Where X_{obs} is an abbreviation of observed discharge at time (i) and X_{model} is the simulated discharge at time (i).

Table 2-Statistical indices [12]

R^2	>0.95	0.85-0.95	0.75-0.85	<0.75
E	>0.85	0.65-0.85	0.5-0.65	<0.5
Simulation level	Very good	Good	Medium	Poor

3 Results and discussion

3.1 Model Calibration and validation

Figure 4 shows the simulated and observed values for discharge at An Lao station and the comparison results were very good. The R coefficients in the calibration period are 0.82 and 0.71. On the other hand, the E coefficients in the validation period are 0.89 and 0.74, respectively. These values indicate good model performance. The RMSE coefficients in both the periods are relatively small 40.78m^3/s and 44.03m^3/s. The values distribution of observed and simulated discharge at the station are shown in Table 3.

The water discharge counted by month from 1995-2009 is shown in Figure 5a, the flow is mainly concentrated in the 4 months of the flood season (from months of September to December), and the largest in November. The flow parameters of the SWAT model for the river basin are shown in Table 4.

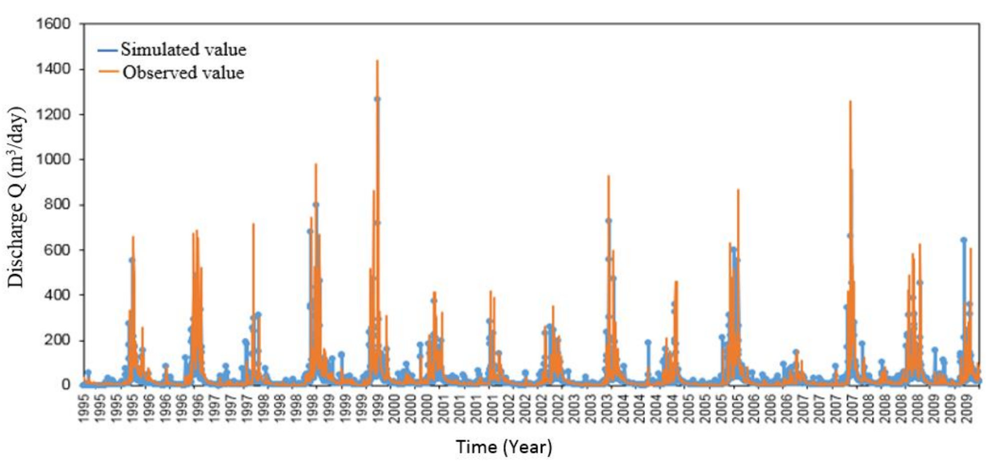


Figure 4: Calibrated (1995-2002), and validated (2003-2009) hydrographs of discharge at An Lao station

Table 3-The performance of the model for the simulation of flow-out at An Lao station

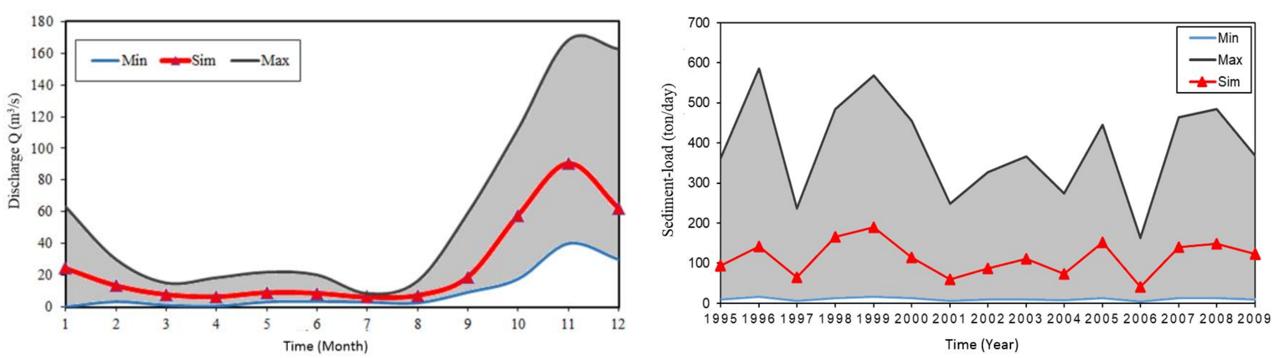
Station	**Calibrated (1995 - 2002)**			**Validation (2003 - 2009)**		
	RMSE (m^3/s)	R^2	E	RMSE (m^3/s)	R^2	E
An Lao	40.78	0.82	0.71	44.03	0.89	0.74

Table 4-Simulated values of using the parameters in SWAT model for streamflow

No.	Description of parameters	Parameter	Range of value	Fitted value
1	Initial SCS CN II value	CN2	35 - 98	40
2	Shallow aquifer's threshold water depth (flow)	GWQMN	0 - 5000	5000
3	Baseflow alpha factor	ALPHA_Bf	0 - 1	0.85
4	Channel effective hydraulic conductivity ($mm.h^{-1}$)	CH_K(2)	− 0.01 - 500	100
5	Groundwater "Revap" coefficient	GW_REVAP	0.02 - 0.2	0.1
6	Groundwater delay (days)	GW_DELAY	0 - 500	500
7	Surface runoff lag time (days)	SURLAG	1 - 24	10
8	Maximum canopy storage (mm)	CANMX	0 - 100	80
9	The shallow aquifer's threshold water depth (Revap (mm))	REVAPMN	0 - 500	0
10	Manning's "n" value for the main channel	CH_N2	− 0.01 - 0.3	0.01

From the calibration results and a good test of the flow, the details of the input data are detailed, fully describing the properties of each soil type through the parameters. The values of the parameters referenced by the data in the SWAT model library and the basins with similar soil types have been studied.

The average sediment load in many years at An Lao station is 113.79 ton/day (with the range of statistics from 11.52 ton/day - 388.37 ton/day) (Figure 5b). The sediment load parameters of the SWAT model for the river basin are shown in Table 5.



a. b.

Figure 5: a) The monthly average of flow, and b) The yearly average of sediment load at An Lao station

Table 5-The sediment related parameters of SWAT model

No.	Description of parameters	Parameter	Range of value	Fitted value
1	USLE equation soil erodibility, (ha.MJ.mm)	USLE_K	-0.34 - 0.2	0.1
2	The lowest value of USLE_C for water erosion (land cover/plant)	USLE_C	0.001 - 0.37	0.015
3	USLE equation support practice factor	USLE_P	-1.5 - 0.5	0.25
4	The exponential parameter for calculation of sediment restrained in channel routing	SPEXP	1 - 1.5	1.1
5	Maximum sum of sediment transported from a reach segment	SPCON	0.0001 - 0.01	0.01
6	Channel cover factor	CH_COV	0 - 1	0.5
7	The monthly erodibility factor of the main channel [cm/h/Pa]	CH_ERODMO	0 - 1	0.5

3.2 The sediment load calculation

In the Lai Giang river basin, statistics displays typically the sediment load in the entire examined area. Specifically, the results of the average sediment load counted in a year is shown in Figure 6.

Based-on the results of sediment load at Lai Giang river basin, the volume of sediment load was gathering into reservoir with 4 months in flood-season (from September to December in the same year). The highest volume of it is in the month of November. The average of sediment load during flood-season (from September to December) at Lai Giang river basin is 10706.66 ton and this volume is equal to 76.73% the total of the average sediment load per year (Table 6).

By the following statistics in the Table 6, the annual average volume of sediment load gathering to Lai Giang basin is 13954.17 ton.

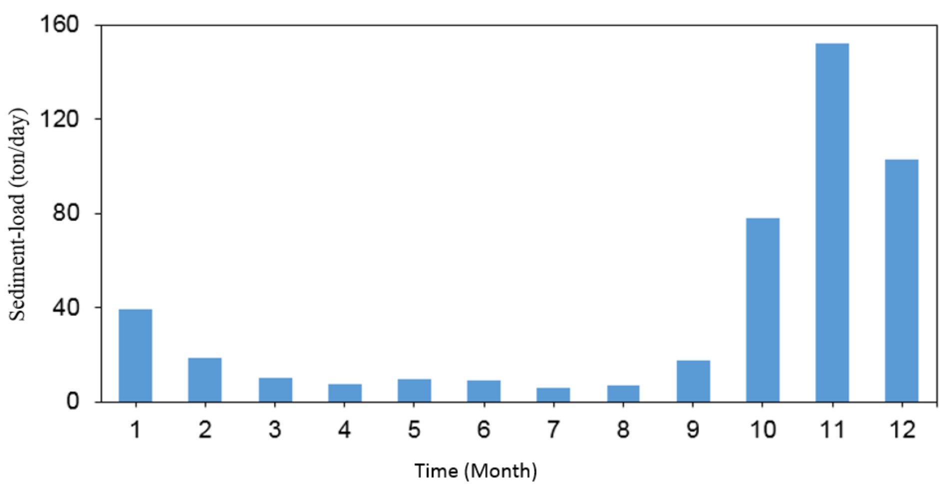


Figure 6: Monthly average sediment load

Table 6-The volume of sediment load at station

Station	The average volume of sediment load				
	Dry season (I-VIII)		Flood season (IX-XII)		The annual average volume of sediment (ton)
	The average volume of sediment (ton)	Percentage (%)	The average volume of sediment (ton)	Percentage (%)	
An Lao	3247.51	23.27	10706.66	76.73	13954.17

With regards to the practical implementation or application, the output of the paper could be considered as useful data for river and irrigation management in this study area.

4 CONCLUSION

Following conclusions can be drawn from the conducted study:

- The simulation of water discharge in Lai Giang river basin was carried out between the years 1995-2009 using SWAT model with comparatively good results because R^2 and E values were above 0.7. Therefore, it is appropriate to integrate GIS technology and SWAT model for water discharge simulation in Lai Giang river basin as well as for other river basins.
- The development of the volume of sediment load is suitable with the tendency of development of flow discharge. The average of sediment load during flood-season (from September to December) at Lai Giang river basin is 10706.66 ton and this volume equal to 76.73% the total of the average sediment load per year. The highest volume of it is in the month of November.

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