ASSESSING WATER DISCHARGE IN BE RIVER BASIN, VIETNAM USING SWAT MODEL

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ABSTRACT

The water discharge is an important hydrological parameter because it defines the shape, size and course of the stream. The results of monitoring flow discharge can be useful information for flood forecasting, predicting sediment loads and assessing the impact of climate change to water resource. The study focused to quantify the impact of topography, land use, soil and climatic condition on water discharge in Be River Basin, Vietnam using GIS technology and SWAT model. In this integration, GIS supplies input data included elevation, soil properties, land use and weather data and creates graphical user interface for SWAT, while SWAT operates input data, delineates watershed, simulates different physical processes, displays output data as discharge. The simulation results in the period 1979 to 2007 represented fluctuation of discharge relatively well with both R^2 and NSI values were above 0.7 in the period 1979 to 1994. This result can be used for predicting the effect of land use change and management practices on water discharge within the basin, helping to water quantity and quality assessment.

1. INTRODUCTION

Water discharge is the volume of water moving past a cross-section of a stream over a set period of time. It is usually measured in cubic meter per second (m^3/s). For river basins, water discharge is an important hydrological parameter because it defines the shape, size and course of the stream. The results of monitoring water discharge can be useful information for flood forecasting, predicting sediment loads and assessing the impact of climate change to water resource.

Nowadays, together with the development of GIS (Geographic Information System), there are many hydrological models to help calculate the water discharge more accurately, easily and quickly than the traditional measurement methods. One of them is SWAT (Soil and Water Assessment Tool). This is a basin-scale model integrated with GIS technology which helps improve the accuracy of simulated result of water discharge from rainfall and physical properties of the basin. In this integration, GIS supplies input data and creates graphical user interface for SWAT, while SWAT operates input data to simulate different physical processes in the basin.

This study aims to assess fluctuations and find out the rule of water discharge in Be river basin through simulating the stream flow from digital elevation model (DEM), land use, soil and weather data using SWAT model and GIS technology.

2. MATERIALS AND METHODS

2.1 Study Area Description

Be river basin, with an area of 7,650km^2 and water discharge of 255m^3/s, is one of the four main tributaries of Dong Nai watershed. It is located between 11^{o}06'-12^{o}22' north latitude and 106^{o}35'-107^{o}31' east longitude. Administratively, Be river basin passes through four provinces of Vietnam, including Binh Phuoc, Binh Duong, Dong Nai, Dac Nong and a small part of Cambodia (Figure 1).

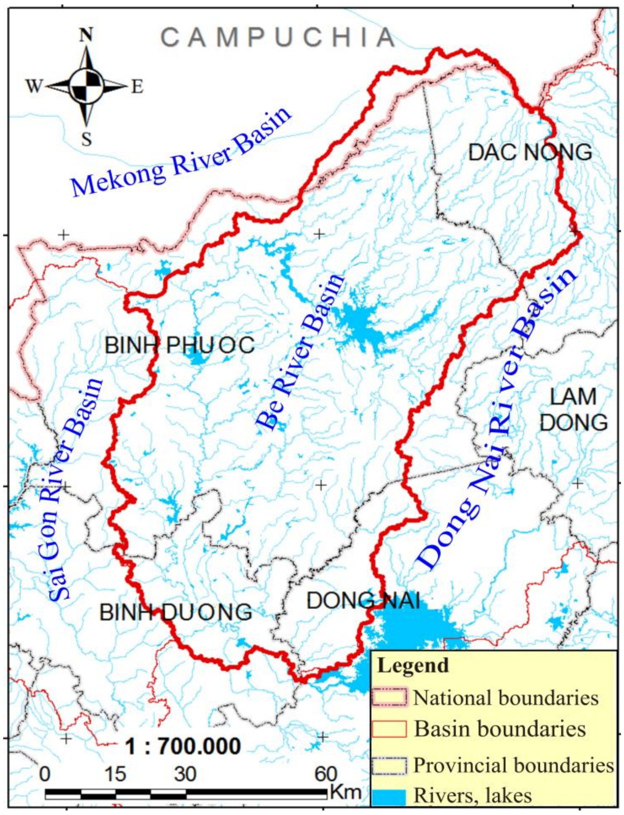

Figure 1. Overview of Be river basin

The terrain of Be river basin changes very complex with many forms of topographical formation: mountainous, midlands interspersed some small narrow plains and some cauldrons. The height of Be river basin decreases gradually in northeast - southwest direction from 750-1,000m in the upstream down to 80-100m in the downstream and increases from 80-150m in the west to 250-700m in the east.

In aspect of climate, Be river basin has tropical monsoon climate with the average annual temperature ranging from 25.5-26.7^{0}C, and average yearly precipitation from 2,200-2,600mm.

The various soils in this basin are rhodic ferralsols (54.21%), ferralic acrisols (18.4%), xanthic ferralsols (8.30%), and the others (Dystric Fluvisols, Chromic Luvisols, Dystric Gleysols, Haplic Andosols, Umbric Gleysols and rivers, lakes) (1.59%).

2.2 Brief Description of SWAT

Soil and Water Assessment Tool (SWAT) is a river basin, or watershed, scale model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (ARS) in the early 1990s (Susan L. Neitsch *et al.*, 2009). This model is designed 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 model is a set of regression calculations to show relationship between value of input parameters and output parameters. SWAT allows a number of different physical processes to be simulated in a watershed. For modeling purposes, a watershed may be partitioned into a number of subbasins, which are then further subdivided into HRUs that consist of homogeneous land use, management, and soil characteristics.

2.3 Data collection

Data required for this study were collected from the local source (Southern Institute For Water Resources Planning) and global source (METI/NASA, FAO) including topography, land use, soil, weather and observed discharge:

- DEM data was extracted from ASTER Global Digital Elevation Model (ASTER GDEM) of METI/NASA, with a spatial resolution of 30m.
- Land use map was obtained from Southern Institute For Water Resources Planning including 14 land use/ land cover classes: Broadleaf evergreen closed natural forest, Broadleaf evergreen closed planted forest, Broadleaf evergreen closed-open natural forest, Broadleaf evergreen open natural forest, Bamboo closed natural forest, Mixed closed natural forest, Grasslands/shrublands, Sparse woodland, Mixed perennial crops/residential land, Mixed annual crops/residential land, Mixed upland crops/residential land, Residential land, Natural lakes and Artificial lakes.
- An electronic copy on diskette or as e-mail attachment, in PDF format.
- Soil map was taken from the global soil map of FAO (1995) at 10km spatial resolution. In the research watershed, there are five types of soil, including Ferralic Acrisols, Gleyic Acrisols, Rhodic Ferralsols, Thionic Fluvisols and Pellic Vertisols;
- For weather data, based on distribution characteristics, duration and data quality of meteorological monitoring stations in Be river basin and its surrounding areas, eight gages as Bu Nho, Chon Thanh, Dac Nong, Dong Phu, Loc Ninh (Song Be), Phuoc Hoa, Phuoc Long, and So Sao were used. The data was obtained from Southern Institute For Water Resources Planning.
- Discharge data was prepared at two monitoring stations named Phuoc Long and Phuoc Hoa in the basin. The data was furnished by Southern Institute For Water Resources Planning.

2.4 Model Setup

The SWAT model approach applied to the case study area of Be river basin is shown in Figure 2. According to that, the procedure includes such main steps as: watershed delineator, HRU analysis, write input tables, run SWAT and model evaluation.

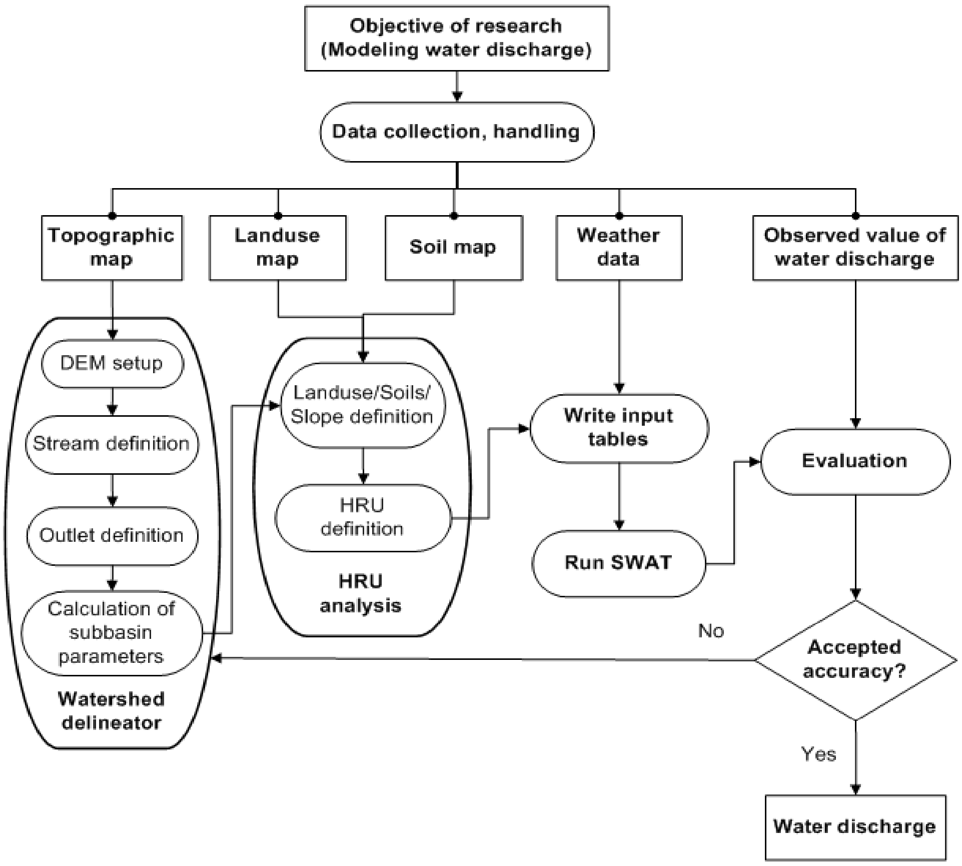

Figure 2. Flow chart of modeling water discharge in Be river basin

2.5 Model Performance Evaluation

The SWAT model was evaluated using observed discharge data. The coefficient of determination (R^2) (P. Krause *et al.*, 2005) and Nash–Sutcliffe Index (NSI) (Nash, J.E. and J.V. Sutcliffe, 1970) were used to evaluate the model performance. R^2 value ranges from 0-1, shows the correlation between the observed versus the simulated values. NSI value ranges from -∞ to 1, indicates how well the plot of the observed versus the simulated values fits the 1:1 line. If the R^2 and NSI values are less than or very close to zero, the model performance is considered unacceptable or poor. In contrast, if the values are equal to one, then the model prediction is considered to be perfect.

The formula for R^2 and NSI calculations are as follows (Equation 1 and 2):

$$R^2 = \left(\frac{\sum_{i=1}^{n}(O_i - \bar{O})(P_i - \bar{P})}{\sqrt{\sum_{i=1}^{n}(O_i - \bar{O})^2}\ \sqrt{\sum_{i=1}^{n}(P_i - \bar{P})^2}} \right)^2 \quad (1)$$

$$NSI = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2} \quad (2)$$

where O_i is the observed discharge at time I, $\bar{O}$ is the average observed discharge, P_i is the simulated discharge at time i, $\overline{P}$ is the average simulated discharge, and n presents the number of registered discharge data.

3. RESULTS AND DISCUSSIONS

3.1 Model Evaluation

Comparing the observed with simulated discharge at two subbasins as Phuoc Long and Phuoc Hoa during the period of 1979 - 1994 shows that the simulation results were relatively well. In this stage, the R^2 was 0.769 at Phuoc Long, 0.822 at Phuoc Hoa and NSI of 0.720; 0.794 were Phuoc Long, Phuoc Hoa, respectively. Distribution chart of observed and simulated discharge at two stations is shown as Figure 3.

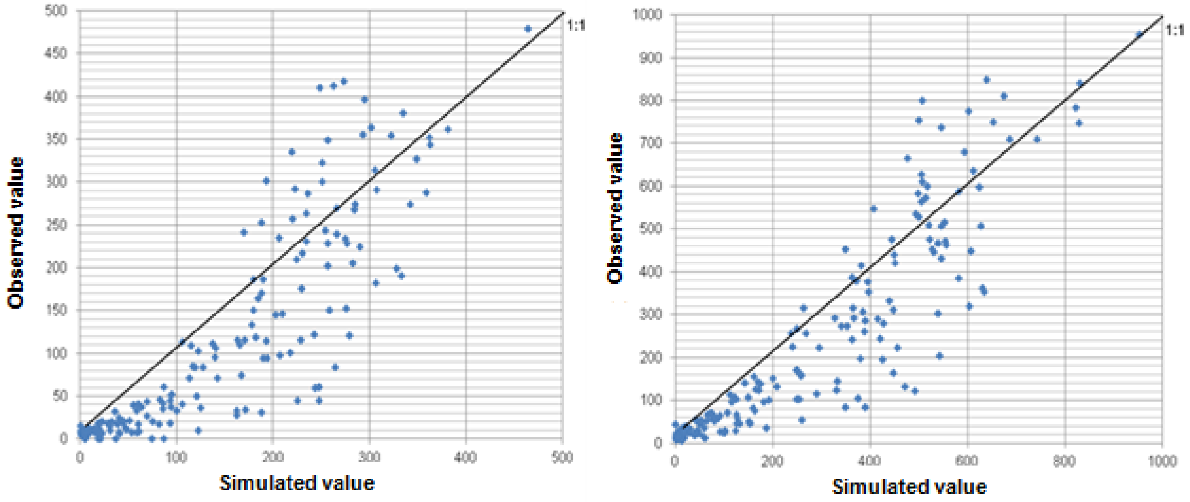

Figure 3. Observed vs simulated discharge at Phuoc Long (left) and Phuoc Hoa (right)

3.2 Discharge Variation

Based on Figure 4, obviously, the overall pattern of discharge variation at Phuoc Long, Phuoc Hoa is determined by the fluctuation of precipitation. During months of heavy rain, the discharge is usually greater. Almost, the discharge at Phuoc Long was less than about twice the discharge at Phuoc Hoa although the precipitation at Phuoc Long was greater.

General model of water discharge at two subbasins reaches the peak twice during the rainy season, the rest (especially during the dry season) the discharge is very small. However, water discharge values differ for each year. In particular, during the simulation period (1979-1994), on both subbasins, there were three years when the water discharge reaches maximum, including August 1986, August 1992 and September 1994. At Phuoc Long, the values were 463.8; 380.4 and 358.3m^3/s, respectively. At Phuoc Hoa, the values were 951.9; 830.5; 822.6m^3/s, respectively.

In general, the flood season on both sub-basins usually lasts from June to November with an average water discharge of 224.55m^3/s (Phuoc Long) and 458.53m^3/s (Phuoc Hoa). In the dry season (from December to May of the following year), water discharge was low, reaching only 30.85m^3/s (Phuoc Long) and 60.49m^3/s (Phuoc Hoa).

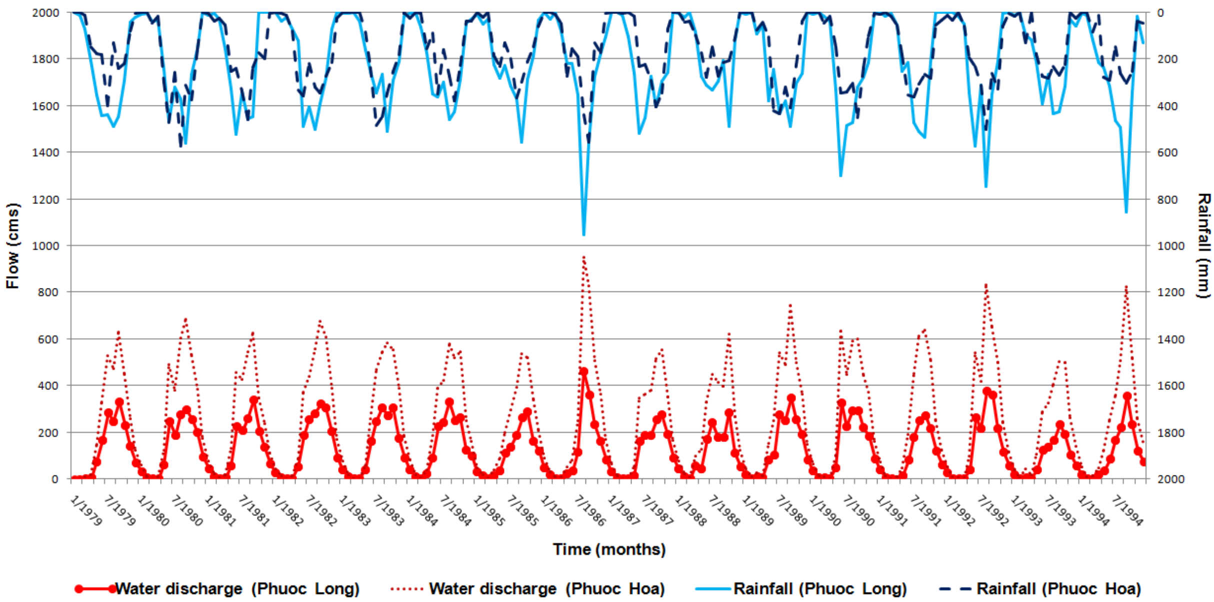

Figure 4. The variations of rainfall and water discharge at Phuoc Long and Phuoc Hoa

4. CONCLUSIONS

The study simulated the water discharge of Be river basin in the period from 1979-2007 by SWAT model with relatively well results (R^2 and NSI values were above 0.7 in the period from 1979-1994). From those results, the flood season on both sub-basins was defined as lasting from June to November with an average water discharge of 224.55m^3/s (Phuoc Long) and 458.53m^3/s (Phuoc Hoa). In the dry season (from December to May of the following year), water discharge was low, reaching only 30.85m^3/s (Phuoc Long) and 60.49m^3/s (Phuoc Hoa). The results proved that it is suitable to integrate GIS technology and SWAT model for simulating the water discharge in Be river basin and can be applied for other river basins.

A future direction for this study is to calibrate and validate the model again to identify the appropriate parameters for water discharge which can predict accurately changes of water discharge in the basin.

5. REFERENCES

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