Assessing the Impacts of Land use/ Land cover Changes and Practices on Water Discharge and Sedimentation using SWAT: Case study in Dong Nai watershed – Vietnam

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ABSTRACT

The Soil and Water Assessment Tool (SWAT) has been widely applied for modeling watershed hydrology and simulating the movement of non-point source pollution. The SWAT is a physically – based continuous time hydrologic model with Arcview GIS interface developed by the Blackland Research and Extension Center and the USDA-ARS (Arnold et al., 1998) to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex basins with varying soil type, land use and management conditions over long periods of time. This study is aimed at assessing factors contributing to reservoir sedimentation, water discharge using SWAT model in Dong Nai watershed as case study. It is especially important in the Dong Nai watershed where the soil is highly erodible and forest conversion for agricultural cropping is in serious condition. This study was also focused on how surface runoff and sediment yield was impacted when land use in the watershed resource is changed. The SWAT model was applied to evaluate the effect of main input data of SWAT (land use, soil, human practices) to sediment yield in Tri An reservoir, Dong Nai watershed, Vietnam.
Keyword: Land use/Land cover change, Surface discharge, Sedimentation, SWAT, Dong Nai watershed

INTRODUCTION

Impact assessment of land use change, population growth and watershed development to soil loss, water quality and quantity is one of the most important topics in a watershed. The rapid increase of population and the driving force of economic growth further accelerate the need for various land uses within the watershed. To contemplate the scope of such problems, as experienced in many other developing countries, the efforts of pursuing integrated optimal planning to achieve the sustainable uses of these watershed resources becomes critical. Many studies have been made of multi-objective land-use planning under various conditions, such as those applied in an industrial complex, a watershed, a river basin. However, very few of them focus on the evaluation of the optimal balance between economic development and environmental quality within a watershed. Hence, this research attempts to solve the selected Dong Nai watershed in context of surface runoff, sediment yield through the SWAT (Soil and Water Assessment Tool) approach.

OBJECTIVES

To provide decision makers with a scientific tool for supporting them in making decisions on reservation of water and soil resources by delivering appropriate policies about land use allocation, the details of objectives as follows:

1. To apply SWAT model to assess the impact of land use change and practices in Dong Nai watershed on surface runoff, sediment yield to the Tri An reservoir;

2. To make policy recommendations to policy maker on land use change impact to surface runoff, sediment yield.

METHODOLOGY

1. Location of the study area

The Dong Nai watershed locates in the southern part of the country including 10 provinces and Ho Chi Minh City. It is situated between $10^0 31^{'}$ - $11^0 35^{'}$ latitude and $106^0 42^{'}$ – $107^0 35^{'}$ longitude. The region occupies an area of approximately 3,878,787 ha as shown in Figure 1. Three forms of topographical formations can be identified in the area: a mountainous area in the north, a basaltic plateau in the south, and between them is a transition zone of alluvial valleys. The average elevation is about 500 msl. The major part in the North is only slightly undulated with a slope of less than 10^o, resulted from the layers of basaltic deposition while high slopes are found in the Northeastern mountainous part near the border with Lam Dong province. The lowland areas of the Dong Nai watershed are subject to annual flooding in the wet season and salinity intrusion in the dry season while mountainous highland areas goes up to 1,600 m. The Dong Nai watershed has 5 major river systems: the Dong Nai mainstream, the Be, the Sai Gon, and the La Nga as major tributaries, and the Vam Co Dong system that joins the Dong Nai just before the outlet into the Sea.

2. Brief description of SWAT model

The Soil and Water Assessment Tool (SWAT) has been widely applied for modeling watershed hydrology and simulating the movement of non-point source pollution. The SWAT is a physically – based continuous time hydrologic model with Arcview GIS interface developed by the Blackland Research and Extension Center and the USDA-ARS (Arnold et al., 1998) to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex basins with varying soil type, land use and management conditions over long periods of time. The main driving force behind the SWAT is the hydrological component. The hydrological processes are divided into two phases, the land phase, which control amount of water, sediment and nutrient loading in receiving waters, and the water routing phase which simulates movement through the channel network. The SWAT considers both nature sources (e.g. mineralization of organic matter and N-fixation) and anthropogenic contributions (fertilizers, manures and point sources) as nutrient inputs (Somura, H. et.al. 2009). The SWAT is expected to provide useful information across a range of timescales, i.e. hourly, daily, monthly, and yearly time-steps (Neitsch et al., 2002).

Figure 1. Dong Nai watershed map

3. Data collection

Available data and information related to the SWAT modeling in Dong Nai watershed such as maps, statistic data, forest area, forest cover, population, soil erosion parameter, precipitation, water quality and other the related data was collected by the offices of local authorities and relevant professional institutions and our team. The types of data and their sources are shown in Table 1.

Table 1: Data collection and their sources for SWAT model

Types of data	Sources of data
1. Physical Data	Department of Land Development, Dong Nai Province
Topography	
Precipitation	Dong Nai Meteorological Department
Soil erosion	Institute of Water Resource Research in HCMC
Parameter	Department of Land Development, Dong Nai Province
2. Biological Data	
2.1. Land use maps	
2.2.Forest, Agriculture	Department of Agriculture and Rural Development, Dong Nai
3. Socio-economic Data	Province
Population	Dong Nai Statistical Department
Income	
4. Water quality (BOD, COD, DO, SS, . . .)	Department of Natural Resources and Environment, Dong Nai province

4. The Scenario Planning Process for SWAT Model

The SWAT model approach applied to the case study area of Dong Nai watershed is shown in Figure 3, 4. The principal planning task is aiming at the efficient planning of future in Dong Nai watershed. The objectives of each plan will assist in deciding upon the socio-economic, physical and environmental data that required formulating the different planning scenarios. The derived objectives are also used later in the methodology to evaluate the efficiency of each proposed planning scenario.

The next step of the planning process is to formulate possible land-use scenarios. Two land-use planning scenarios are formulated for Dong Nai watershed as input of SWAT model.

Scenario A: Dong Nai watershed Land use map in 2000.

Scenario B: Existing land use map (2008).

Impact assessment of changes in land use practices and human practices in Dong Nai watershed on surface water, sediment contribution to the Tri An reservoir during the period from 2000 – 2008.

The SWAT model requires methodological data such as daily precipitation, maximum and minimum air temperature, wind speed, relative humidity, and solar radiation data. Spatial data sets including digital parameter layers such as parameters (R, K, C, P) and topography (LS) was digitized from the associated maps. LS factor of the watershed is derived from digital elevation model (DEM) obtained from topography.

The SWAT model was applied in Dong Nai watershed as shown in Figure 2, 3.

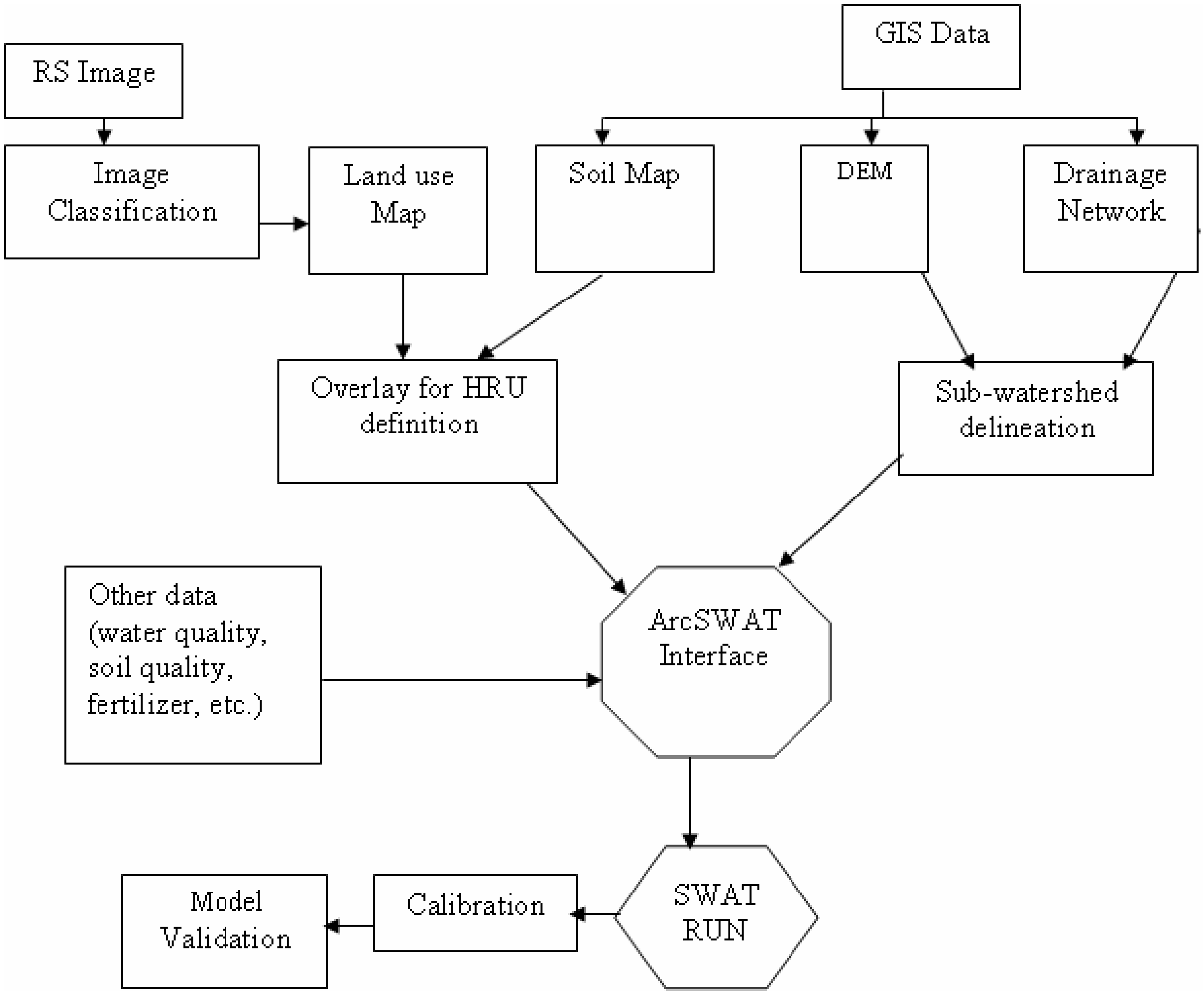

Figure 2. The SWAT model

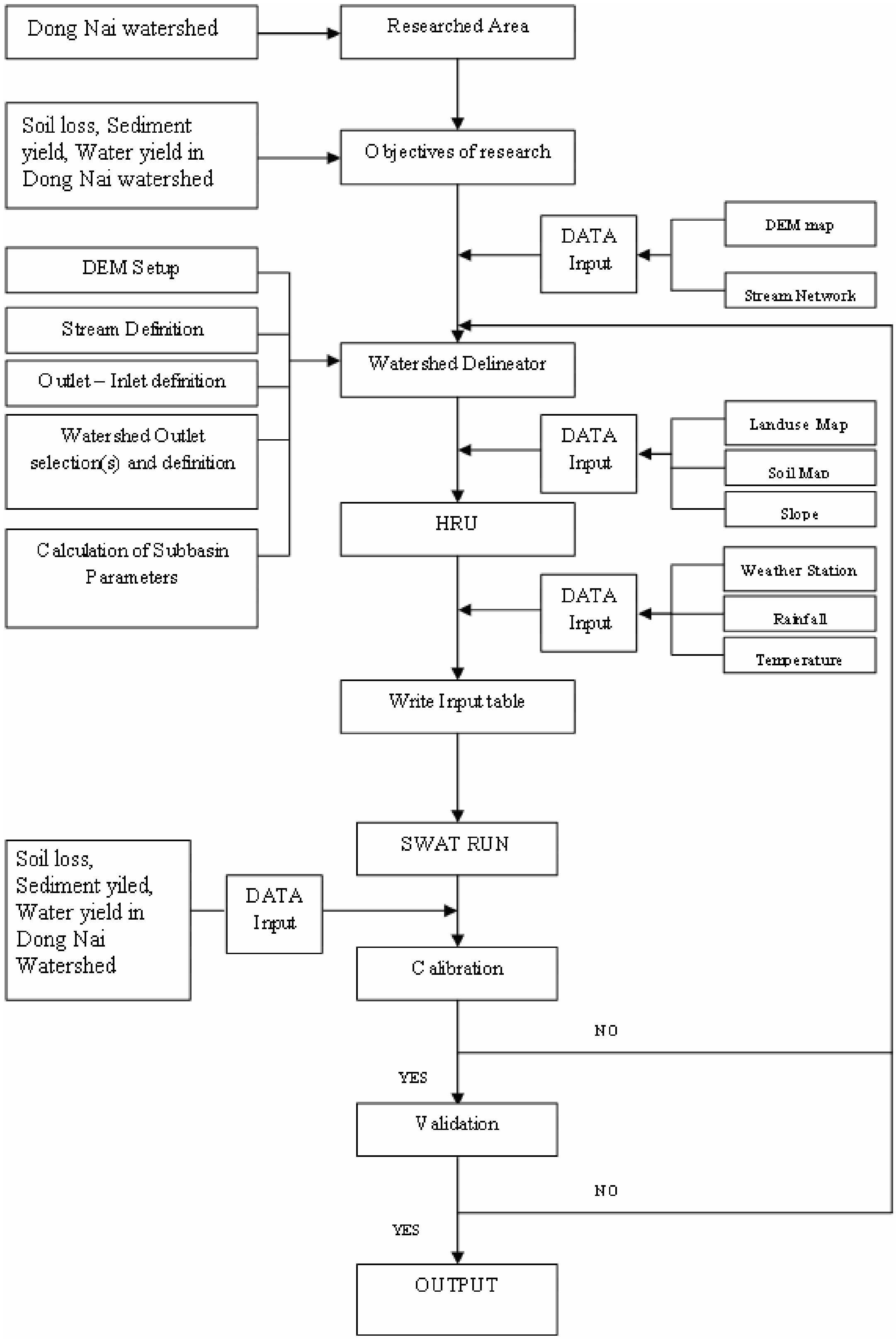

Figure 3. Application of SWAT model in Dong Nai watershed

RESUTLS AND DISCUSSIONS

1. Land Use and Land Cover Change (LUCC) between 2000 and 2008

The LUCC between 2000 and 2008 is conducted by matrix operation as shown in Table 2. The interaction of land use and land cover types pattern can be explained as shown in Figure 4 which be able to briefly describe as follows:

Forest: about 21% forest area in 2000 were converted to agriculture in 2008, and about 2.7% forest area were changed to bare land.

Agriculture: 10% of agricultural land in 2000 were changed to urban / settlement in 2008.

Urban / Settlement: area of urban / settlement in 2000 did not changed to other types in 2008.

Bare land / Open land: about 34% areas of bare land / open land in 2000 were mainly changed to forest areas and special land in 2008, while about 2.8% area of bare land in 2000 were changed to agriculture.

Special land: about 23% of special land in 2000 was converted to agriculture and bare land.

Table 2. Probability coincident matrix of land use/land cover change between 2000 and 2008, Dong Nai Watershed.

2000\1995	Forest	Agriculture	Urban	Bare land	Special	Total
Forest	0.7600	0.2130	0.0000	0.0270	0.0000	1.0000
Agriculture	0.0050	0.8888	0.1005	0.0011	0.0019	1.0000
Urban	0.0000	0.0000	0.9908	0.0000	0.0000	1.0000
Openland	0.3401	0.0276	0.0000	0.2869	0.3455	1.0000
Special	0.0006	0.0810	0.0084	0.1501	0.7600	1.0000

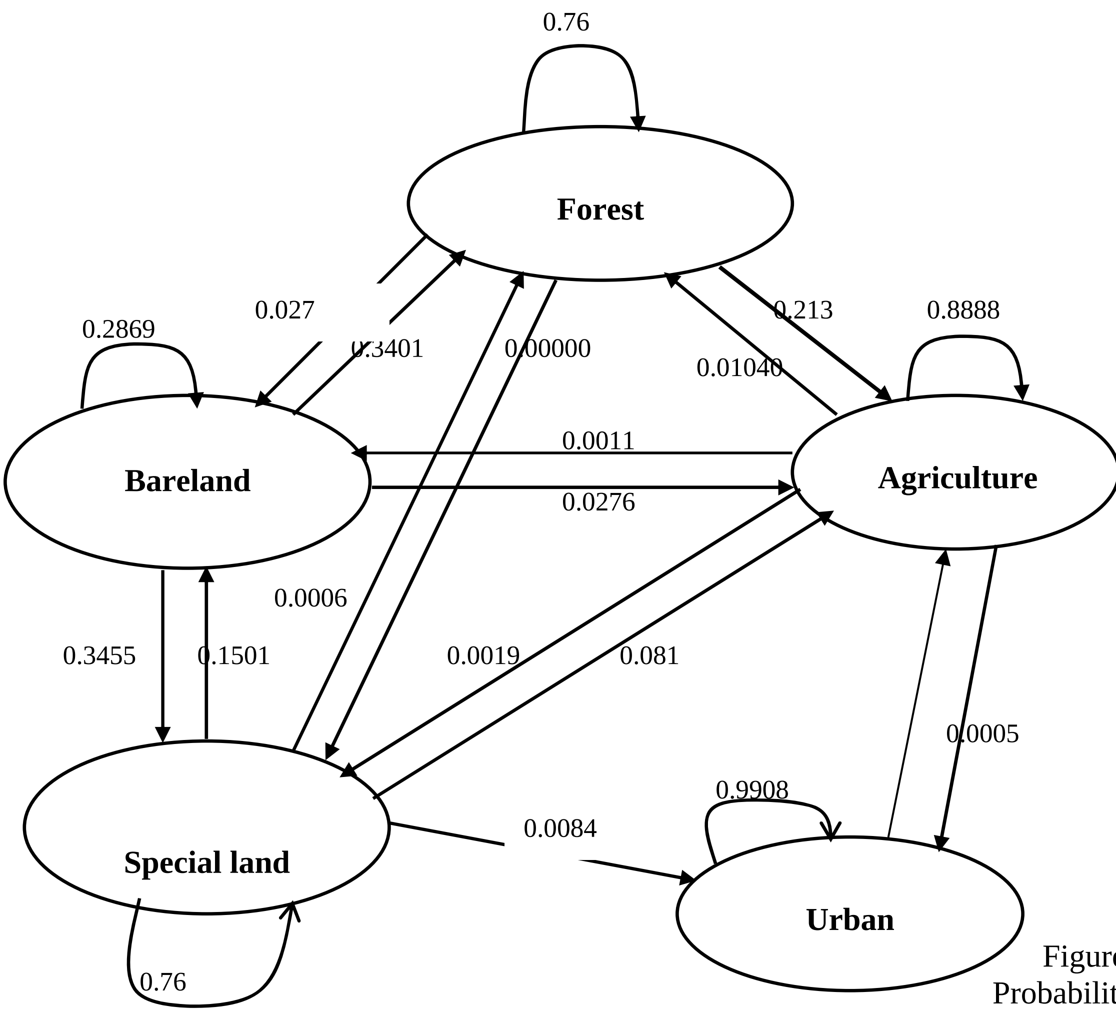

Figure 4. Probability land use / land cover change pattern between 2000 and 2008 in Dong Nai Watershed.

The result derived from the remaining land use in Table 2 imply that between 2000 and 2008 forest area was decreased about 24 percent of the forest area, while the others classes were increased. The largest increased category was agricultural, because the upland of Dong Nai watershed has been a place suffered a rapid increase in population, resulting of massive immigrations since the end of the war in 1975.

2. Evaluation of land use change effect on surface runoff and sediment yield

In Dong Nai watershed have 13 sub-basins as shown in Figure 5 based on SWAT model. In order to develop sound management schemes of protecting the Dong Nai watershed and to have clear picture of the impact of land use changes specifically on surface runoff, and sediment yield. The calibrated model was run to simulate two land use change scenarios. Land use change scenarios are:

Scenario A: Dong Nai watershed Land use map in 2000.

Scenario B: Existing land use map (2008).

For developing the scenarios, the key processes and related model parameters such as P factor of USLE, infiltration rate were modified in the appropriate SWAT input files. An USLE P factor of 0.6 to 1.0 was used in simulations to reflect the condition of the watershed with and without soil conservation intervention. The predicted surface runoff and sediment yield in 2000 and 2008 were summarized in Table 3. The daily simulated surface runoff and sediment yield in the watershed is shown in Figure 6, 7.

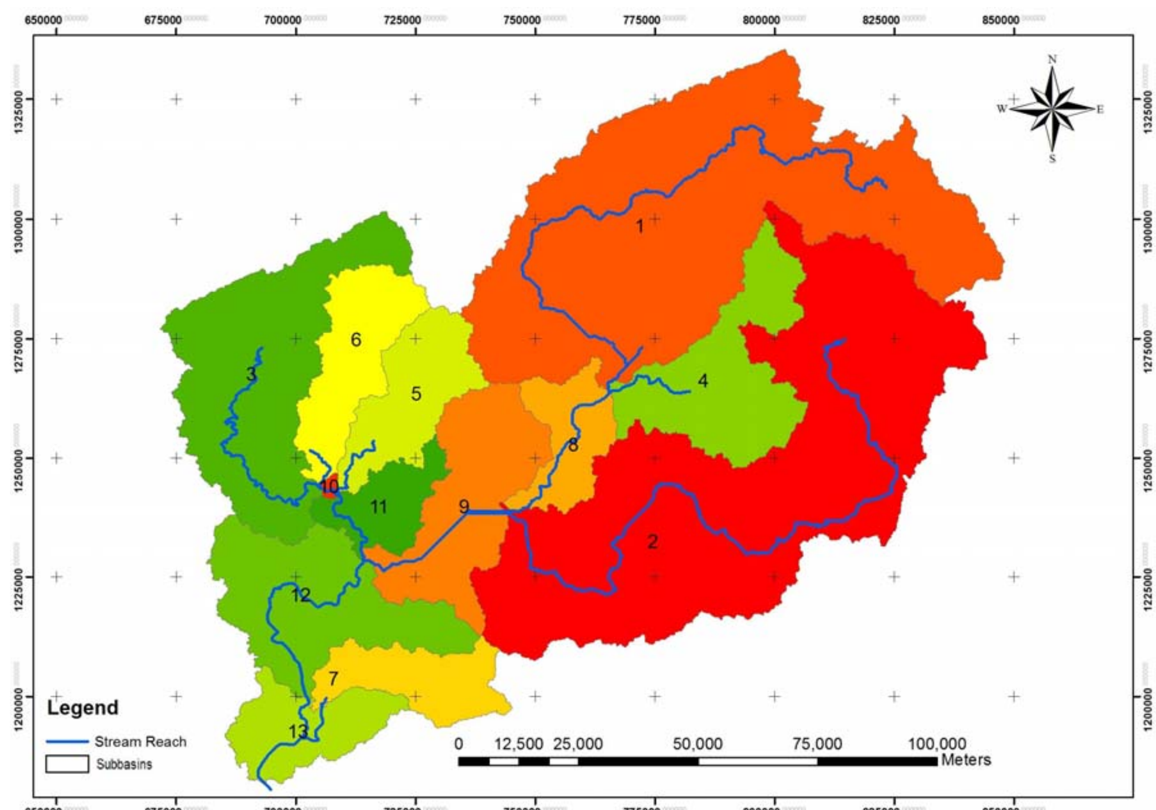

Figure 5. The Dong Nai watershed along with its sub-basin automatically delineated

Table 3. The SWAT output (monthly) with different land use scenarios

Month	Rainfall (mm)		Surface runoff Q (mm)		Sediment yield (ton/ha)	
	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B
1	11.90	21.10	0.01	0.70	0.00	0.59
2	81.01	26.90	17.03	0.26	91.74	0.26
3	66.96	71.78	7.19	11.03	18.42	13.65
4	183.50	70.37	49.18	0.79	45.50	1.41
5	195.47	138.95	37.69	16.41	19.62	8.94
6	126.83	114.55	29.84	19.08	11.50	5.40
7	28.80	89.20	1.53	25.34	0.23	15.48
8	235.76	259.88	90.40	110.54	61.08	130.04
9	93.16	362.71	21.34	176.34	13.56	256.40
10	82.41	59.70	30.65	12.87	28.82	18.87
11	28.80	35.60	0.32	1.87	0.16	1.91
12	68.35	58.15	8.05	7.50	8.84	10.95

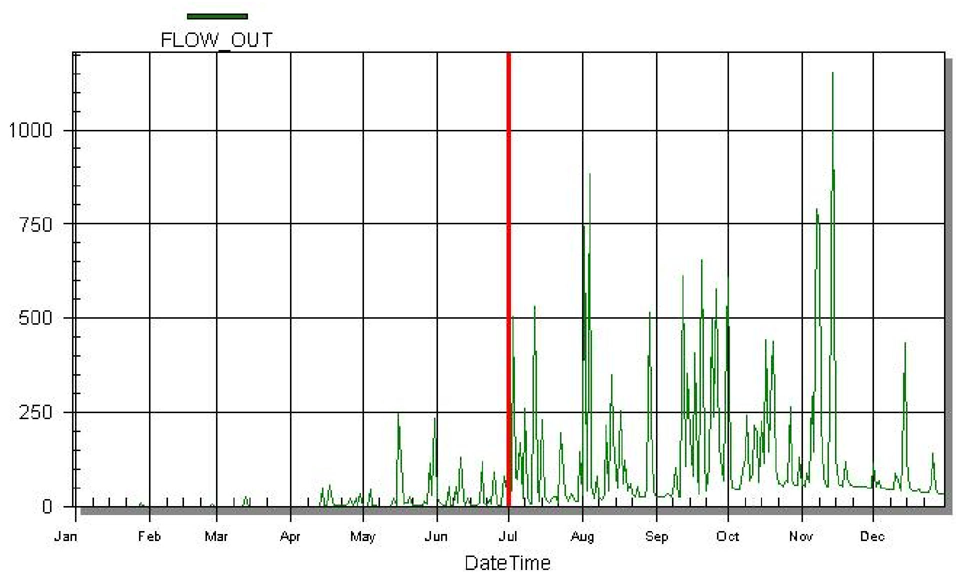

Figure 6. Simulated water flow in sub-basin 4 in Dong Nai watershed

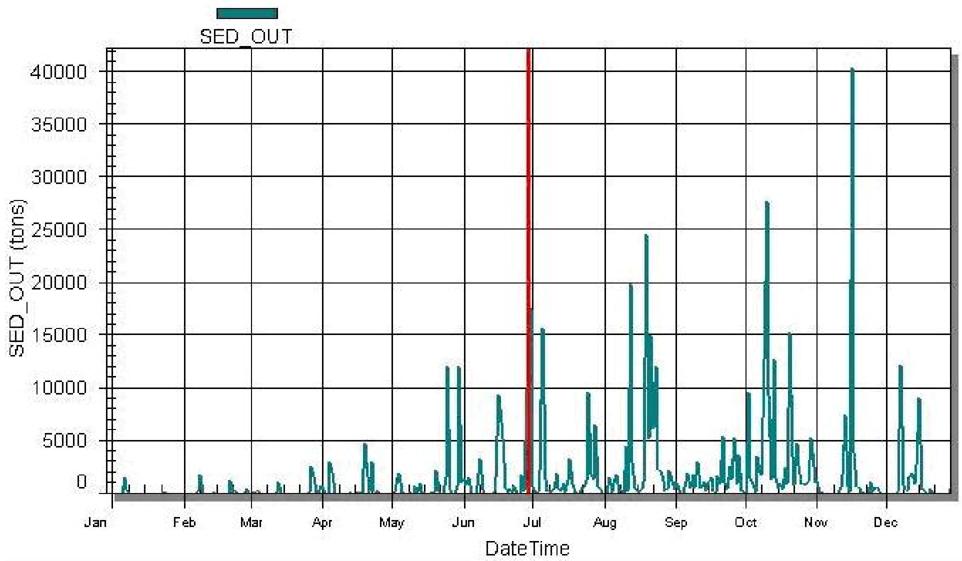

Figure 7. Simulated Sediment yield loading to Tri An reservoir in Dong Nai watershed

Table 4. The SWAT simulated statistics for Dong Nai watershed using land use scenario A (2000) and land use scenario B (2008)

Year	Precipitation (mm)	Surface runoff (mm)	Sediment yield(ton/ha)
2008	1308	31.89	38.66
2000	1202	24.44	24.96

To assess the effects of land use change in the study area, the SWAT model was run to simulate two scenarios of land use changes on surface runoff, sediment yield. Results of the simulation shown that surface runoff increase when forest converted to agricultural land (Table 3&4). An increase about 30% in surface runoff occurs when 21% of the forest area converted to agricultural land. Meanwhile, sediment yield increase about 54.8% compared between 2000 (24.96 ton/ha) and 2008 (38.66 ton/ha).

CONCLUSIONS

This research is just the first step apply SWAT in Dong Nai watershed. The SWAT model performed well in simulating the general trend of surface runoff, sediment yield, at watershed over time for daily, monthly time intervals. The results shown that the land use change and practices was affected surface runoff, sediment yield loading to Tri An reservoir. Results of the simulation shown that surface runoff increase when forest converted to agricultural land. An increase about 30% in surface runoff occurs when 21% of the forest area converted to agricultural land. Meanwhile, sediment yield increase about 54.8% compared between 2000 (24.96 ton/ha) and 2008 (38.66 ton/ha).

These simulated effects of forest conversion to agricultural crops clearly indicate an alarming situation of watershed elsewhere having the same land use pattern. In Dong Nai watershed, we recommend that policies addressing this problem should be formulated both at the local and national level. Parallel to this, an intensive information and education campaign on the consequences of forest conversion and ways of rehabilitating the watershed should likewise be done. Finally, alternative livelihood opportunities for upland farmers should be considered in policy implementation.

While simulation results are subject to further validation, this study showed that the Soil and Water Assessment Tool (SWAT) model can be a useful tool for modeling the impact of land use changes in Vietnam watershed.

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