International Journal of GEOMATE, Aug. 2019, Vol.17, Issue 60, pp.43-48
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2019.60.4687
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

HYDROLOGICAL AND NITRATE LOADING MODELING IN LAM TAKONG WATERSHED, THAILAND

*Chau Ngoc Tran[1,2] and Chatpet Yossapol[1]

[1]School of Environmental Engineering, Institute of Engineering, Suranaree University of Technology, Thailand;
[2] Faculty of Engineering-Technology-Environment, An Giang University, Vietnam

*Corresponding Author, Received: 15 Dec. 2018, Revised: 02 Feb. 2019, Accepted: 22 Feb. 2019

ABSTRACT: Water pollution is largely associated with the growth of agriculture, urbanization, and industrialization. By the year 2016, the quality of significant surface water sources in Thailand has been evaluated and categorized as 34% good quality, 46% fair quality and 20% poor quality. According to the Pollution Control Department of Thailand, the lower Lam Takong river, one of the critical watersheds of Thailand, is considered to have a poor water quality. In Lam Takong watershed, non-point sources area approximately covered 89% of the total area, those sources became the significant contributors of water pollutants, particularly nutrients to the Lam Takong watershed. Plus, water quality researches of the watershed were carried out with many different watershed models, but the SWAT model has not been applied to allot the pollutant loading from diffuse sources. Therefore, the main objective of this study is to apply the SWAT model to simulate flow and nitrate from 2007 to 2017, and allocate $NO3^-$ loading in upstream is lower than downstream of the Lam Takong watershed. The R^2 values are 0.69 in upstream and 0.64 in downstream of Lam Takong. The results of the study can be a useful tool for the management of surface water resources in the Lam Takong watershed.

Keywords: SWAT, Lam Takong watershed, Nitrate, Diffuse source

1. INTRODUCTION

Lam Takong watershed (LTW) is one of the critical watersheds of Thailand. It is a part of the Mun River watershed, in the Northeastern region of Thailand. In addition, it has a role of drainage, recreation, and environmental conservations. LTW was covered with extended large forests in the past. At the present, most areas have been invaded, deforested and converted into communities, farmland, orchards and deserted areas and others to keep up with local progress.

Lam Takong watershed has a high economic growth rate but is still facing water scarcity. Wijitkosum [1] analyzed the water situation in the Watershed which was subject to the economic plan of the government. LTW was on the brink of a water shortage and this problem was at the peak during the maximum water usage and minimum water asset. As a result of the economic value, it is necessary to conduct a hydrological and water quality modeling research in Lam Takong watershed. The results show the accuracy of the flow simulation, helping planners to come up with a reasonable flow and water quality management.

Netnapa [2] applied the Soil and Water Assessment Tool (SWAT) model for evaluations streamflow, sediment, nutrient loading simulations in the Lam Takong River basin. That author demonstrated that the SWAT model could be a useful tool for water resources management in the Lam Takong River basin.

The water flow change at the outlet of the Kosynthos river watershed affected the nutrient loads [3]. Previous studies in the Lam Takong basin have not estimated the relationship between flow and nitrate in LTW.

In this study, ArcGIS integrated with the SWAT model, which can realistically represent the spatial variability of watershed characteristics, will be used to study upstream and downstream areas in the Lam Takong River basin. SWAT model is selected for this study because it is included channel degradation routine with detail appropriate for watershed management [4]. The results could be a useful tool for water resources planning in LTW.

2. MATERIALS AND METHODOLOGY

2.1. Study Area

Lam Takong River basin is a part of the Mun watershed in the Northeastern region of Thailand, is also a sub-basin of the great Mekong river. The length of the river is around 220 km, originated from Khao Yai National Park to Mun river, has an area of 3,518 km^2 covering six districts in Nakhon Ratchasima province and more 880,000 population reside [5] (Fig. 1).

LTW is under the influence of southwest and northeast monsoon. From May to October, the southwest monsoon brings moisture from the Indian Ocean causing rain, peaking in August and

September. The average amount of rainfall is 1,454 mm (2010).

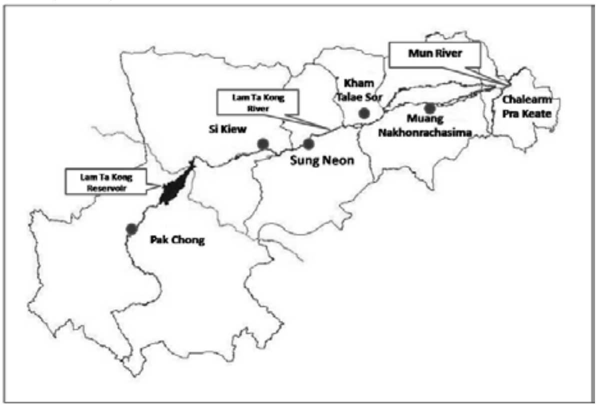

Fig.1 Lam Takong watershed.
(Wijitkosum, 2010)

2.2 Model Description

ArcGIS 10.1 software is integrated the SWAT2012 (Soil and Water Assessment Tool) model to calculate the flow in Lam Takong watershed. SWAT model was selected for this study due to a wide variety and with proper testing [6].

The subwatershed discretization of SWAT divides the watershed into 29 subbasins. Then, subbasins continue to be partitioned into 309 multiple hydrologic response units (HRUs) based on soil and land use distribution of the watershed. For each HRU, the land phase of the hydrological cycle is modeled, and the flow from each HRU are calculated. Then flow from HRUs within a subbasin are summed to get flow from this subbasin.

For a subbasin located downstream of another subbasin, flow from land phase are added at the outlet of the upstream subbasin and then continue to be routed through the channel.

The necessary data is collected for the simulation of flow in the Lam Takong river. The main input data for simulating the hydrological processes in Arc SWAT are the base map data, meteorological data and observed flow data.

The ArcSWAT2012 interface is used to delineate the Lam Takong basin based on an automatic procedure using the Digital Elevation Model (DEM) data. A DEM grid map with a 30m spatial resolution was available [7]. Moreover, a mask map which identifies the focused area for delineation to reduce the processing time and a burn-in river map which helps to accurately predict the location of the stream network was also input.

Calibration is used autocalibration tools in SWAT-CUP. Automatic calibration and uncertainty analysis capability are directly incorporated in SWAT2012 via the SWAT-CUP software developed by Swiss Federal Institute of Aquatic Science and Technology [8] and R^2 [9] will be selected as the efficiency criterion. SWAT-CUP includes automated as well as the semi-automated program SUFI2 for model calibration.

The sensitive parameters from the sensitivity analysis results will be considered in the calibration process. The following parameters will be included in the calibration CN2, ALPHA_BF, GW_DELAY, GWQMN.

2.3 Input Data

The main input data for simulating the hydrological processes in ArcSWAT are the base map data, meteorological data and observed data. The necessary data is shown in Table 1.

Table 1 Model input data sources for the Lam Takong watershed

Data type	Source	Detail
Topography (DEM) 30mx30m	Land Development Department	Elevation, slope
Soil	Land Development Department	Spatial soil variability Soil types and properties
Land use	Land Development Department	Land cover classification and spatial representation
Weather stations	Thai Meteorological Department	Daily precipitation Temperature (maximum and minimum) Relative humidity Wind speed Solar radiation
Flow of water	Lam TaKong Water Supply &Maintenance Project	M89, M183, M177, M191, M164 stations (m^3day^{-1})
Water quality	Regional Environment Office 11	Sediment (mgl^{-1}) Nitrate nitrogen (mgl^{-1})

The base map data is overlayed by land use and soil data. Climate data input consists of temperature, relative humidity, wind speed, solar radiation; the weather data and the rainfall data. Observed data consists of the concentration of sediment and nitrate nitrogen.SWAT simulates the different land use in each sub-basin. The land use in Lam Takong watershed is divided into nine land use types and they were used for the flow and water quality simulation in this study (Table 2).

Table 2 Land use data (Land Development Department, 2015)

Land use types		% of total area
Urban and Built-up land	(UBL)	6.62
Rice farm	(RF)	32.92
Corn farm	(CF)	3.55
Sugarcane farm	(SF)	7.33
Cassava farm	(CF)	19.09
Other agriculture	(OF)	6.44
Forest land	(FL)	17.70
Water Body	(WB)	2.27
Miscellaneous land	(ML)	4.07

3. RESULT AND DISCUSSION

The Lam Takong watershed is delineated into sub-basins using the digital elevation map (30m) and it is divided into 29 subbasins outlet of Lam Takong River (Fig 2).

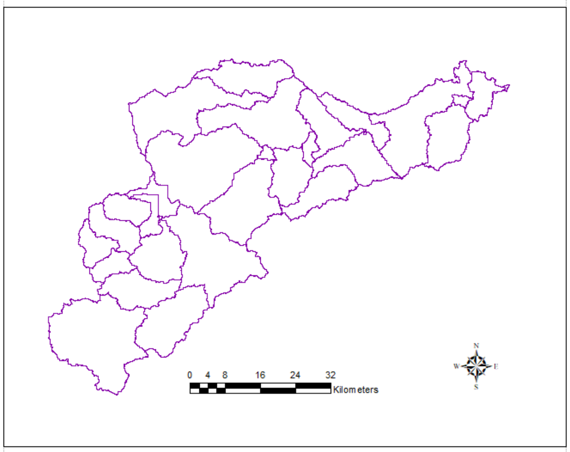

Fig.2 Subbasins of Lam Takong watershed.

Land use data are required for pollution assessment because of activities that we do on land can affect on generate the pollutants. The digital land use data were obtained from the Land Development Department (LDD) in the year 2011.

The U.S. Natural Resource Conservation Service (NRCS) classifies soils into 4 hydrologic groups based on infiltration characteristics of the soils including group A (high infiltration rate), group B (moderate infiltration rate), group C (slow infiltration rate) and group D (very slow infiltration rate). Soil data was obtained from LDD including fourteen soil series with soil texture class and quantitative particle size distribution analysis by LDD were transformed to hydrologic soil group.

The delineated sub-basin map, land use, and soil map will be overlaid. SWAT simulate different land use in each sub-basin. Lam Takong River watershed's DEM, land use and soil data are integrated to accumulate flow direction, and stream network in Lam Takong River (Fig 3).

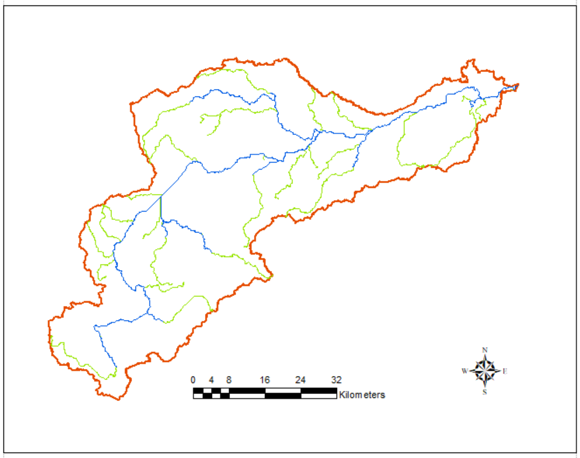

Fig.3 Stream network of Lam Takong watershed

3.1 Simulated Monthly Flow in Lam Takong Watershed

Calibration is conducted in lower LTW by adjusting input four parameter values CN2 (-0.1516), ALPHA_BF (0.287), GW_DELAY (51.42), GWQMN (1.89) from initial default conditions.

The sensitive parameters were replaced SWAT model to simulate flow and nitrate loading. The simulated flow was compared to observed flow in upstream LTW.

SWAT has simulated during a time period when the average daily precipitation is input date. The model was validated for an average time period from January 2007 to December 2017.

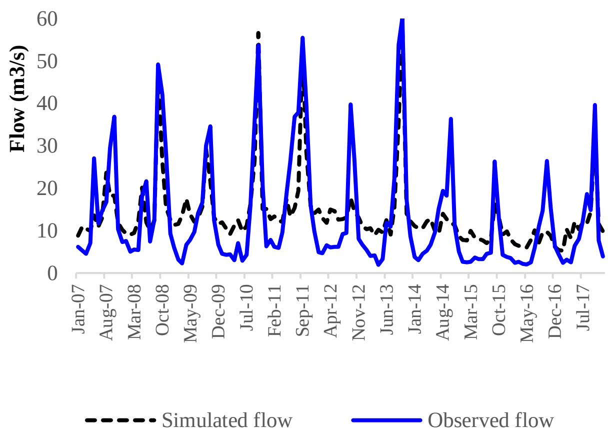

Fig.4 Simulated monthly flow and observed monthly flow at upstream of LTW

Calibration of the model gave results that the modified values for the model SWAT, the Nash-Sutcliffe R^2 for monthly total flows in upper Lam Takong river was 0.69. The simulated flow values are compatible with observed flow values in upper LTW. The peak flow value in October 2013 both simulated and observed value are 58.9 và 60.2 m^3/s respectively (Fig. 4). Similarly, The minimum simulated and observed flow values in the upper LTW from 5.3 to 1.9 m^3/s. The average flow values are approximately equal to 13.9 and 13.2 m^3/s. The simulated flow at the subbasin outlet of LTK is shown Fig.5 from 2007 to 2017.

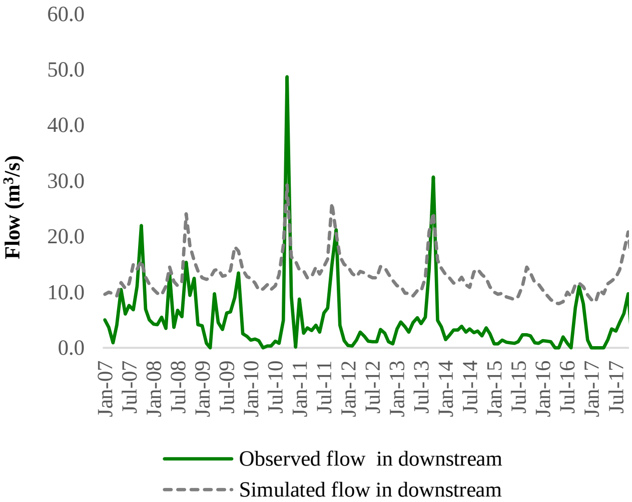

Fig.5 Simulated monthly flow and observed monthly flow at downstream of LTW

The average monthly observed and simulated flow from 2007 to 2017 for an outlet of LTW is presented in Fig.5. Results show that values of R^2 for monthly total flows in downstream of Lam Takong river was 0.64. The average simulated and observed flow values are roughly equal 12.9 and 11.5 m^3/s. However, maximum values are a relatively large difference.

Results obtained by using the model's modified values for simulating flow accentuate the critical need for model calibration in order to ensure that hydrologic processes are well represented on a watershed.

3.2 Nitrate Loading Simulation in Lam Takong Watershed

Sediment and nitrate were calibrated after flow calibration. Simulated nitrate values in downstream are higher upstream.

The annual nitrate loading in the Lam Takong river is shown in a general way following Fig 7. However, the upper area has a high nitrate loading from July to September and from March to June in the lower area. In contrast, both of the two areas had low nitrate loading is from December to January. This result is consistent with Netnapa's study [2] that September was the month with the highest NO_3-N while January and December had the lowest values.

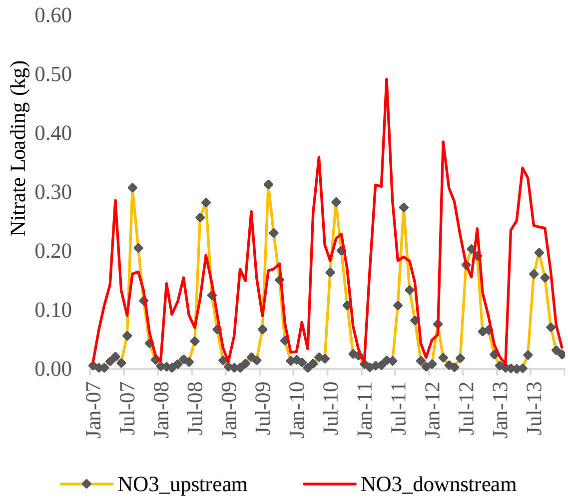

Fig.6 The monthly simulated nitrate loading in upstream and downstream of LTW.

The annual nitrate loading in the Lam Takong river is shown in a general way following Fig 7.

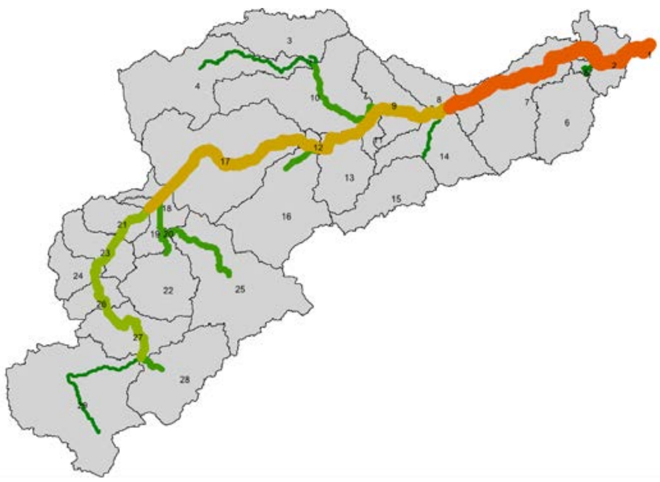

Fig.7 The annual nitrate loading distribution in Lam Takong river

The highest annual nitrate loading is in Muang Nakhon Ratchasima district area where is the center of province Nakhon Ratchasima such as reach 1, reach 2, reach 7 and reach 8 from 503770.5 kg/year to 569135.1 kg/year (Table 3). Besides, many reaches from upstream like reach 28 and reach 29 have the lowest annual nitrate concentration which is around 48987.5 kg/year and 26867.7 kg/year. The annual nitrate loading increases gradually from upstream to downstream (Fig. 7).

3.3 The Influence of the Flow on Nitrate-nitrogen Loading

The simulated results of flow and nitrate loading in upstream of LTW showed that they have a proportional relationship (Fig. 8).

Table 3 Total nitrate loading in Lam Takong river

Reach No.	NO3_(kg)	Reach No.	NO3_(kg)
1	569135.1	16	28759.8
2	568372.7	17	353162.1
3	17755.4	18	316349.3
4	23515.8	19	190436.3
5	23231.3	20	117691.2
6	22259.1	21	184188.9
7	536259.8	22	49463.3
8	503770.5	23	182896.9
9	471753.9	24	164197.5
10	64740.1	25	67915.8
11	397114.7	26	156211.3
12	355378.1	27	134385.0
13	393971.2	28	48987.5
14	21507.1	29	26867.7
15	10691.4		

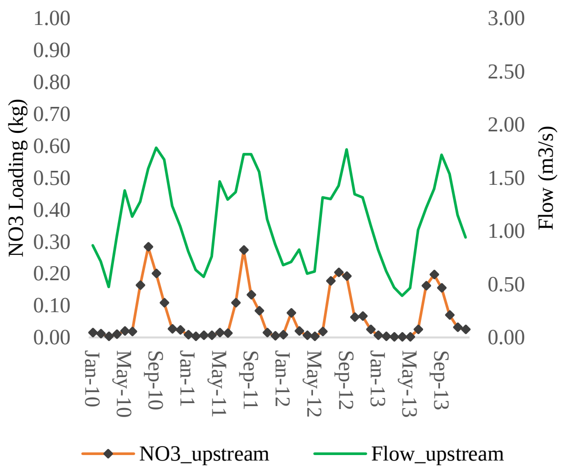

Fig. 8 Relationship of flow and nitrate loading in upstream of LTW

Both flow and nitrate loading value in Lam Takong river upstream has the lowest value in January and the highest in September. However, the value of nitrate load is low, lasting from January to April in every year. Besides, the maximum value of flow and nitrate loading is in September every year. In contrast to upstream, the flow values in downstream are inversely proportional to nitrate loading values and nitrate loading is highest from April to May. As upstream, the flow in downstream is also highest on September and gradually reduce to January. They are shown in Fig. 9.

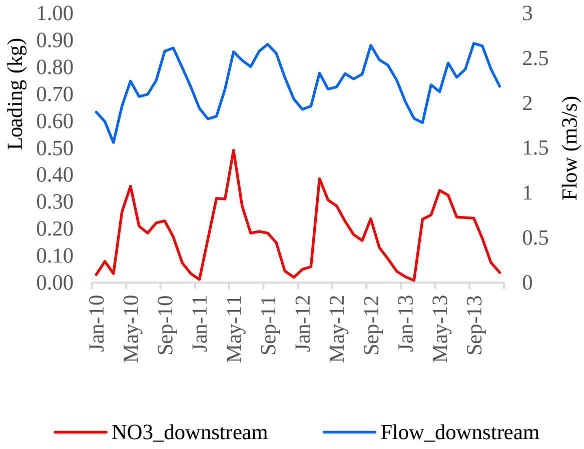

Fig.9 Relationship of flow and nitrate loading in downstream of LTW.

As the flow rate increases, nitrate loading values tend to decrease from May to October. However, from November to January flow and nitrate loading value have the same downtrend.

4. CONCLUSION

For this study, the calibration process was conducted with four parameters CN2, ALPHA_BF, GW_DELAY, GWQMN. The R^2 value 0.69 in upstream and 0.64 in downstream of Lam Takong river is compared to the results from Zhao et al [10] the regression coefficient of measured value and simulation value was 0.63 and it shows that the correlation between observed and simulated monthly runoff is good. This means that the SWAT model is suitable for the fluid flow and nitrate nitrogen. The determination of accurate parameters in calibration when modeling watersheds are vital for simulating streamflow data corresponding to measured values.

The simulated flow and nitrate loading values in LTW upstream have a proportional relationship, oppositely in downstream, they have an inverse ratio from May to October.

5. ACKOWLEDGMENTS

The author thanks anonymous reviews for their comments and suggestions; Dr. Chatpet for his huge contribution in improving the paper; the Land Development Department, Regional Environmental Office 11, the Royal Irrigation Department, the Thai Meteorology Department, Lam Ta Kong Water Supply and Maintenance Project for providing data and results from SWAT model; and the SUT-PhD scholarship for ASEAN countries for financial support in the Suranaree University of Technology in Thailand.

6. REFERENCES

[1] Wijitkosum S. and Sriburi T., "Evaluation of water resource management in lam ta kong watershed : the water scarcity area of Thailand," vol. 4, no. 4, pp. 1047–1057, 2010.

[2] Pongpetch N., Suwanwaree P., Yossapol C., Dasananda S., and Kongjun T., "Using SWAT to assess the critical areas and nonpoint source pollution reduction best management practices in Lam Takong river basin, Thailand," *EnvironmentAsia*, 2015.

[3] Pisinaras V., Petalas C., Gikas G. D., Gemitzi A., and Tsihrintzis V. A., "Hydrological and water quality modeling in a medium-sized basin using the Soil and Water Assessment Tool (SWAT)," *Desalination*, vol. 250, no. 1, pp. 274–286, 2010.

[4] Staley N. A., Wynn T., Benham B., Yagow G., and Tech V., "Modeling Channel Erosion at the Watershed Scale : Model Review and Case Study," no. March 2006.

[5] Pongpetch N., Suwanwaree P., Yossapol C., Dasananda S., and Kongjun T., "Sediment and Nutrient Load Environmental Factors of Lam Takong River Basin, Thailand," *Adv. Mater. Res.*, vol. 1030–1032, pp. 594–597, 2014.

[6] Arnold J. G., Kiniry J. R., Srinivasan R., Williams J. R., Haney E. B., and Neitsch S. L., "Soil & Water Assessment Tool: Input/output documentation. version 2012," *Texas Water Resour. Institute, TR-439*, pp. 207–208, 2013.

[7] Winchell M., Srinivasan R., Di Luzio M., and Arnold J. G., "ArcSWAT Interface for SWAT2012," *Texas AgriLife Res. United States Dep. Agric. Agric. Research Serv.*, 2013.

[8] Swiss Federal Institute of Aquatic Science and Technology (Eawag), *User manual SWAT-CUP*. 2015.

[9] Krause P., Boyle D. P., and Bäse F., "Comparison of different efficiency criteria for hydrological model assessment," *Adv. Geosci.*, vol. 5, pp. 89–97, 2005.

[10] Zhao W. J., Sun W., Li Z. L., Fan Y. W., Song J. S., and Wang L. R., "A Review on SWAT Model for Stream Flow Simulation," *Adv. Mater. Res.*, vol. 726–731, pp. 3792–3798, 2013.