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Comparative Study Using the 2-Hydrological Models with the Global Weather in a Small Watershed, a Case Study in the Upper Tha Chin River Basin, Thailand

Sombat Chuenchooklin[1*], Udomporn Pangnakorn[2], Puripus Soonthornnonda[3]

[1]Department of Civil Engineering, Water Resources Research Center, Faculty of Engineering, Naresuan University, Phitsanulok, Thailand
[2]Department of Agricultural Science, Faculty of Agriculture Natural Resources and Environment, Naresuan University, Phitsanulok, Thailand
[3]Department of Civil Engineering, Faculty of Engineering, Naresuan University, Phitsanulok, Thailand
Email: *sombatc@nu.ac.th, upangnakorn@gmail.com, puripus@gmail.com

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Abstract

The hydrological study in the upstream of the Huai Khot Wang Man diversion canal in Huai Khun Kaew watershed of the Upper Tha Chin River Basin in Uthai Thani Province, Thailand was studied. The soil and water assessment tool (SWAT) and the integrated flood analysis systems (IFAS) applied to the analysis of flow at the outlet. The global weather data provided automatically by the models including land use covers and soil types. The climate forecast system reanalysis (CFSR) and the near real-time precipitation (GSMaP_NRT) used in SWAT and IFAS, respectively. The model sensitivity with Nash and Sutcliffe efficiency (NSE), correlation (R^2), and root mean square error (RSME) were applied. The monthly calibrated results from SWAT fitted to the observed data in 2007-2010 with 0.77, 0.88, and 9.08 m^3/s, and verified in 2011 with 0.25, 0.61, and 14.30 m^3/s, respectively. The daily results from IFAS during a flood period in 2011 fitted to the observed data with 0.21, 0.39, and 34.32 m^3/s. Both models showed applicable for efficient gate operation of the diversion canal from this watershed to the Nong Mamong District in Chai Nat Province.

Keywords

Hydrological Model, SWAT, CFSR, IFAS, PUB

1. Introduction

The ungauged small or medium basin is generally difficult in flood estimation as

Prediction in Ungauged Basin (PUB) [1]. Accurate estimates of stream runoff and other hydrologic quantities are needed for numerous purposes of water resources planning and management. The way of obtaining such estimates by modeling methods e.g. the rational and index-flood method, which can be found such as the Hydrologic Modeling System (HMS) [2]. The Soil and Water Assessment Tool (SWAT) [3], is a river basin scale model developed to quantify the impact of land management practices on water, sediment and agricultural chemical yields in large, complex watersheds with various soil, land use and management conditions over long periods of time. SWAT main components include weather, surface runoff, return flow, percolation, evapotranspiration, transmission losses, pond, and reservoir storage, crop growth, and irrigation, groundwater flow, reach routing, nutrient and pesticide loading, and water transfer. It has proven to be an effective tool for assessing water resource and non-point source pollution problems for a wide range of scales and environmental conditions across the globe with a wide range of other water use and water quality applications through the standalone or any geographic information system (GIS) including QGIS as QSWAT [4]. Moreover, an open source distributed rainfall-runoff hydrological model as the Integrated Flood Analysis System (IFAS) developed by the Public Works Research Institute of Japan (PWRI) [5] which can be applied to the very large watershed, e.g. the Chao Phraya Basin, the Indus River Basin, the SEA countries [6], Pakistan [7], Taiwan [8], Japan, and others. Since the proper selection of grid sizing in the IFAS should be undertaken otherwise the longer computation time will occur [9].

Poor water management of existing diversion structures without any storage dam as a head-water source in the central plain of Thailand, including the Tha Chin and Sakae Krang River Basins was reported that it is not realized in the estimation of the upstream discharges to those diversion structures as difficulty in gate management with full potential [10] [11]. Thus, this study aimed to analyze the stream flow discharge by using the QSWAT and IFAS to the Huai Khun Kaew Watershed at the upstream of the Huai Khot-Wang Man diversion point in the Nong Mamong District, Chai Nat Province. The study was a part of the overall research on the Development of Supporting Mechanisms for Budget Planning of Water Resources and Agriculture based on the Application of Information Technological Linkages in the Chai Nat Province which was sponsored by the Thailand Research Fund (TRF) in 2016 [12].

2. Methodology

2.1. Modeling Setting in the Study Area

The study area, Huai Khun Kaew watershed, with a drainage area of 1066 km^2 locates in the Upper Tha Chin River Basin in Uthai Thani and Chai Nat Provinces, Thailand. The Huai Khun Kaew is a major stream and contains with the largest tributary: Huai Khot with the flow direction from east to west. The hydrological observation station, C.51, has been installed at the outlet by the Royal

Irrigation Department (RID). The Huai Khot-Wang Man diversion canal was built to convey some part of a flood from existing watershed to the Nong Mamong District in Chai Nat Province.

This study applied the two different hydrological models as for the comparative study in hydrography products throughout the outlet of the study area base on daily and monthly computation. The models were SWAT via QGIS platform as QSWAT [4] and IFAS [5] which applied to the Huai Khun Kaew Watershed in the Upper Tha Chin River Basin as shown in **Figure 1**.

Firstly, the IFAS model set applied with the 2-layers and 3-tanks with surface water, groundwater and river course tanks [13]. The sub-basins, river networks, and other components were applied by using the square grid-cell size of 300 m based on direct access to the global data sets e.g. digital elevation model (DEM): GTOPO30, land use covers: GLCC, and near real-time satellite mapping of precipitation: GSMap_NRT [14] [15].

Secondly, SWAT's water balance conceptual model, as well as all variables and parameters [16] [17], was applied in the study area based on the ASTER Global DEM (GDEM) with 30 m resolution [18]. The land use covers, soil data, and slope were generated to the 16-hydrologic response units (HRUs). The weather data were obtained from SWAT editor based on the Climate Forecast System Reanalysis (CFSR) [19].

2.2. Sensitivity of the Models

The Nash-Sutcliffe efficiency (NSE) is a normalized statistic that determines the relative magnitude of the residual variance as noise compared to the measured data variance as information. NSE is computed as shown in "Equation (1)" [20] where Y_i^{obs} is the i^{th} observation for the constituent being evaluated, Y_i^{sim} is the i^{th} simulated value for the constituent being evaluated, Y^{mean} is the mean of observed data for the constituent being evaluated, and n is the total number of observations.

$$NSE = 1 - \left[\frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim} \right)^2}{\sum_{i=1}^{n} \left(Y_i^{obs} - Y^{mean} \right)^2} \right] \tag{1}$$

The root mean square error (RSME) incorporates the benefits of error between simulated result and observed data is computed as shown in "Equation (2)".

$$RSME = \sqrt{\frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim} \right)^2}{n}} \tag{2}$$

3. Results and Discussions

The use of different DEM from each source e.g. GTOPO30 with grid sizing of 300 m and GDEM with the grid sizing of 30 m were applied in the IFAS and SWAT, respectively. The streamlines and sub-basins using the watershed delineation module produced by each model were close to existing GIS.

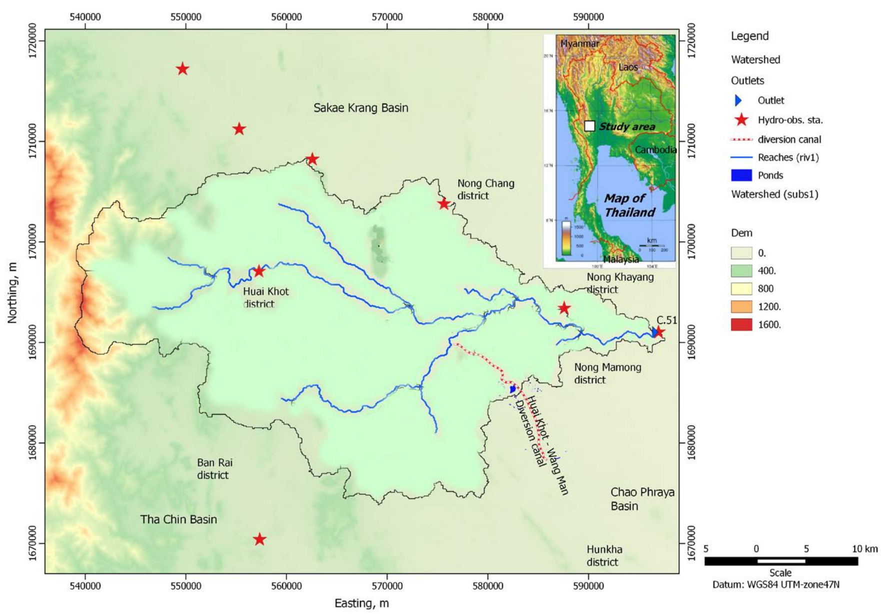

Figure 1. Map of the Huai Khun Kaew watershed and stream layouts the Huai Khot-Wang Man diversion canal, and stream gauging stations in the Upper Tha Chin River Basin, Chai Nat and Uthai Thani Provinces.

Table 1. The model sensitivity from SWAT during the calibration and verification.

No.	Monthly calibration and verification		
	Model sensitivity	Calibrated in 2007-2010	Verified in 2011
1	NSE	0.77	0.25
2	R^2	0.88	0.61
3	RMSE (m^3/s)	9.08	14.30

Table 2. Model sensitivity verfied of IFAS and SWAT based on daily during a flood period 2011.

No.	Verification of flood flow from 01 September to 10 November		
	Model sensitivity	IFAS	SWAT
1	NSE	0.21	0.71
2	R^2	0.39	0.76
3	RMSE (m^3/s)	34.32	9.73

The monthly calibration results from SWAT fitted to the observed in 2007-2010 with NSE of 0.77, R^2 of 0.88, and RMSE of 9.08 m^3/s, respectively as shown in **Table 1**. It had verified in 2011 with 0.25, 0.61, and 14.30 m^3/s, respectively.

Since IFAS was verified during a flood period in 2011 based on daily flow using the range of those parameters which depends on the classification of tank's characteristics [21] [22] fitted to the observed with NSE of 0.21, R^2 of 0.39, RMSE of 34.32 m^3/s, respectively. It was compared to SWAT result during the verification in 2011 as shown in **Table 2**.

4. Conclusion and Discussion

The calibrated and validated results from SWAT and IFAS fitted to the observed in 2007-2011. Both models showed applicable for further efficient gate operation of the diversion canal from this watershed to the Nong Mamong District in Chai Nat Province. The applicable of IFAS is better to simulate daily flows to any point in the basin with the short period e.g. during a flood. However, it takes longer computation time if the model applied with time series for more than 1 year. The SWAT model seems to be very applicable and results are realized to the observed data. However, the complication of the calibration parameters of SWAT is more difficult than IFAS with less parameter. The inspection on models sensitivity should be further carried out and compared to ground-based observation data.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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