Conference Paper, Published Version

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ABSTRACT: The objective of this study is to evaluate the applicability of SWAT model for the simulation of daily runoff in the coastal watersheds of Southeast China. Jinjiang watershed, which is located in south-eastern Fujian Province of China, was taken as a study area. Three hydrological gauging stations, Shilong, Shanmei and Anxi, were used to calibrate and validate the SWAT model at multiple time scales. Based on the measured daily runoff data of the three stations, the model was calibrated from 2002 to 2007, and validated from 2008 to 2010. The calibration and validation results were evaluated by Ens, R^2 and PBIAS. Through parameters sensitive analysis, seven sensitive parameters were identified, and all the parameters were manually estimated. The results shows that Ens and R^2 were both greater than 0.9 for annual and monthly runoff in all three locations. All PBIAS values were less than 7%. As for daily scale, the Ens and R^2 were both greater than 0.75, and PBIAS was less than 6.5% for all locations and periods. It indicates that SWAT model performs well for the coastal watershed of Southeast China.

Keywords: Daily runoff, Simulation, Calibration, Sensitive parameters, SWAT, Jinjiang watershed, China

1 INTRODUCTION

Water quantity and quality is crucial for the socio-economic development and environmental stability, especially for the region of coastal watershed of Southeast China. The global climate changes and human activity have impacted the temporal-spatial distribution of precipitation, interception, evapotranspiration and soil infiltration, and eventually may cause water resources shortage, flood-drought disasters and ecological problems such as land erosions (Wei et al. 2010; Wang et al. 2008; Blair et al. 2014; Saghafian. et al 2008; Wu et al. 2012). It is meaningful to strengthen the research of simulation of hydrological processes, which is essential for revealed the interrelationship of climate change and human activity (e.g. land use change, hydraulic engineering construction, etc.) with hydrological cycle. As a distributed physically-based model, SWAT is capable of simulating temporal-spatial variations in hydrological processes and assisting in understanding the influence mechanisms behind the human activity and climate changes. It is one of the most popular models for simulating hydrological processes (Behera and Panda, 2006). Among of them, Nie et al. (2011) and Baker et al. (2013) used SWAT model to examine the land-use change effects on yearly runoff. Guo et al. (2008) studied the effects of climate and land-cover changes on annual and seasonal streamflow by SWAT model in the Poyang Lake Basin in Southern China. Dixon et al. (2012) simulated the monthly runoff response to urbanization. These previous applications mainly focused on annual, seasonal or monthly time scales, but there are fewer studies on the daily scale. In this study, the SWAT model was applied to simulate the runoff in Jinjiang Watershed which is located in the south-eastern coastal of China, and the efficiency of simulation for annual, monthly, and daily scales was evaluated.

2 STUDY AREA AND DATA

2.1 *Study area*

Jinjiang watershed (from 117° 40′ 32″ E to 118° 12′ 52″ E and from 24° 49′ 57″ N to 25° 34′ 22″ N) is located in south-eastern China and covers an area of 5629km^2。It`s total length is approximate 302 km (main section is 182 km) and is the third largest river in Fujian, one province of China. There are two major river branches within the catchment-the east branch goes through Shanmei gauging station and the west branch goes through Anxi gauging station, merging 2.5 km upstream of the Shilong gauging station. The drainage area upstream of Shilong was selected as study area (5042 km^2, Figure 1). Forest is the dominant type of land use, followed by orchard, cropland and urbanized area. The watershed is characterized by a subtropical climate, with an average annual temperature and precipitation of 20℃ and 1686mm. More than 60% of the annual precipitation falls between May to August with both convective storms and typhoons.

2.2 *Input data*

The datasets for the SWAT model required are topography, land use, soil and hydro-meteorological data, which are described as follows.

(1) Topography. The topographical information came from DEM (Digital Elevation Model) with a resolution of 30 m 30 m obtained from the International Scientific Data Platform of the Chinese Academy of Sciences (http://datamiffor.csdb.cn/admin/datademMain/jsp).

(2) Land use. The land use map in 2006 was obtained from Landsat TM by manual interpretation after radiometric and geometric correction, and was divided into seven types: forest, cropland, grassland, orchard, water, urban, and bare land (Figure 2). The dominate land use type is forest, which accounts for 55.65% of the study area, flowed by orchard, cropland and urban, which account for 20.97%, 12.25%, and 7.77%, respectively.

(3) Soil. The digital soil type map with the resolution of 1:500,000 was obtained from the Soil Fertilizer Laboratory of Fujian Province, and reclassified into eleven soil types for the study area. Their hydrological features were obtained by using the SPAW software developed by USDA (Saxton and Rawls, 2006).

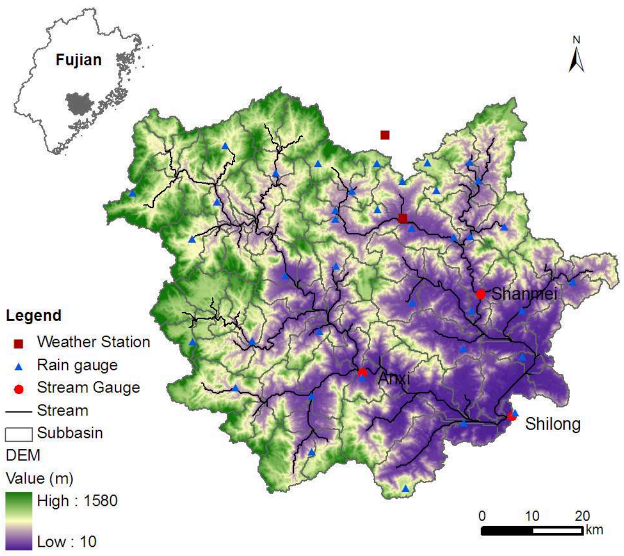

Figure 1. Location map and observed sites of the study area

(4) Hydro-meteorological data. The study selected years 2001-2010 as the study period. The daily river discharge data from 2001-2010 at Anxi , Shanmei and Shilong gauging station were obtained from the Water Conservation Agency of Fujian Province. Meteorology data including daily rainfall, maximum temperature, minimum temperature, wind speed and relative humidity from 2001 to 2010 at two meteorological stations, and 32 rain gauges in the catchment were obtained from Meteorology Agency of Fujian Province. All the hydro-meteorological sites show in Figure 1.

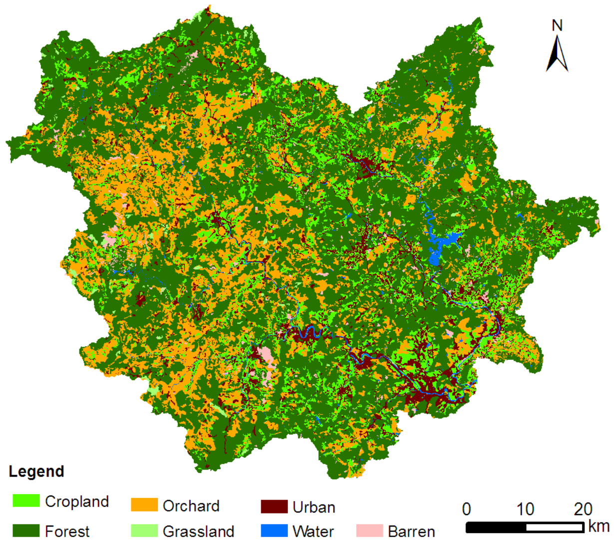

Figure 2. Land use for 2006 in the study area

3 METHODS

3.1 *SWAT model*

SWAT model divides a basin into sub-basins based on DEM, and further into hydrological response units (HRU) with a homogenous land use, soil type and slope. With each HRU, daily balance is calculated by considering the processes of rainfall, infiltration, evapotranspiration, surface runoff, lateral flow and groundwater flow. Then outflows from individual HRUs are routed along the river system to give total river runoff. In this study area, the basin was delineated into 99 sub-basins with a threshold area of 3000 ha based on the DEM, and three gauging stations. The land use, soil and topography maps were overlaid to create a total number of 886 HRUs over the study area. The HRUs were selected by ignoring the land use, soil and slop areas covering less than 5%, 20% and 20% of the total sub-basin area, respectively. Surface runoff was calculated from daily rainfall by the Soil Conservation Services (SCS) curve number method, the Penman-Monteith method was selected to calculated potential evapotranspiration, the storage-pool method for infiltration and lateral flows, and the kinematic storage method for groundwater flows. Channel flow routing was achieved by the Muskingum method.

3.2 *Model calibration and validation*

A sensitivity analysis was done to identify the most sensitive parameters of SWAT, which would improve the efficiency of SWAT calibration. In this study, latin-hypercube one factor at a time (LH-OAT) algorithm was used to identify the most sensitive parameters. The use of multi-site method can improve SWAT model calibration and validation (Cao et al, 2006). Therefore, the study used the observed runoff of three gauging stations to calibrate the model. The year 2001 was selected as warm-up period. Next, the most sensitive parameters were calibrated manually against the observed daily runoff from 2002 to 2007. The model validation was done by running the same model parameters for different simulation periods using the daily rainfall data (2008-2010) as input. The model performance for the runoff was evaluated using statistical methods, such as the Nash-Suttcliffe coefficient of efficiency (Ens), coefficient of determination (R^2), and Percent Bias (PBIAS). Model performance is accepted as satisfactory if Ens>0.5, R2>0.7, and PBIAS<±25% for runoff (Moriasi et al., 2007).

4 RESULTS

4.1 *Sensitive parameters analysis and calibration*

Through parameters sensitivity analysis procedure, the seven most sensitive parameters of the model were identified including SOL_AWC (available water capacity of the soil layer), RCHRG_DP (deep aquifer percolation fraction), CN2 (initial SCS curve number for moisture condition), GWQMN (threshold depth of water in the shallow aquifer acquired for return flow to occur), ESCO (soil evaporation compensation factor), SOL_K (saturated hydraulic conductivity), and CANMX (maximum canopy storage). Next, all the sensitive parameters were manually estimated followed the rules that firstly calibrate long time scales (yearly and monthly runoff) to short time scale (daily runoff), and firstly calibrate upstream (Anxi and Shanmei gauging stations) to downstream (Shilong gauging stations). The adjusted value range or optimal values of these parameters were listed in Table 1.

Table 1. Sensitive parameters and optimal values in study area

No	Name	Rang	optimal value
1	SOL_AWC	0-1	0.11-0.34
2	RCHRG_DP	0-1	0.3
3	CN2	35-98	44-94
4	GWQMN	0-500	30
5	ESCO	0-1	0.5-0.8
6	SOL_K	0-2000	0.2-79.2
7	CANMX	0-100	4

4.2 *Runoff calibration results*

4.2.1 *Yearly runoff*

The Shilong sub-watershed simulation results of yearly runoff for the period 2002-2010 are given in Figure 3a, which shows that most of the year simulated runoffs were consistent with the observed runoffs in addition to the dry years. In the yearly calibration period for three gauging stations, all Ens and R^2 are above 0.94, and PBIAS are less than 4%. For the validation period of 2008-2010, all Ens are above 0.96, R^2 are above 0.99, and PBIAS are less than 6.7%, which suggest very good model performance.

4.2.2 *Monthly runoff*

Figure 3b shows the simulation results of monthly runoff for Shilong gauging stations. The model captured the monthly runoff hydrographs both for the low and high flows. Model performance for calibration period was Ens>0.94, R^2>0.95 and PBIAS<4.1%, and for the validation period Ens>0.91, R^2>0.94 and PBIAS<6.2%, suggesting SWAT model is well performance for monthly runoff simulation.

4.2.3 *Daily runoff*

The simulated and observed daily runoff in Shilong gauging stations for the simulation period (2002-2010) are compared in Figure 3c. The consistency of the simulated and observed values is clear. In addition to Anxi Ens=0.761 for calibration period, all the Ens and R^2 values for the daily calibration and validation are greater than 0.8, and PBIAS are less than 4.1%, PBIAS values are less than 6%. Model performance for the daily calibration and validation period were less favorable than yearly and monthly scales but still reasonable.

5 CONCLUSIONS AND DISCUSSION

1) The SWAT model was well calibrated for the coastal watershed of Southeast China, with satisfactory reproduction of annual, monthly and daily runoff processes over a nine year period at three gauging stations.
2) Compared with studies for other areas, the values of sensitive parameters were reasonable.
3) It is natural that the daily indices are worse than the annual or monthly index, as there are more variability and instability in daily runoff processes.

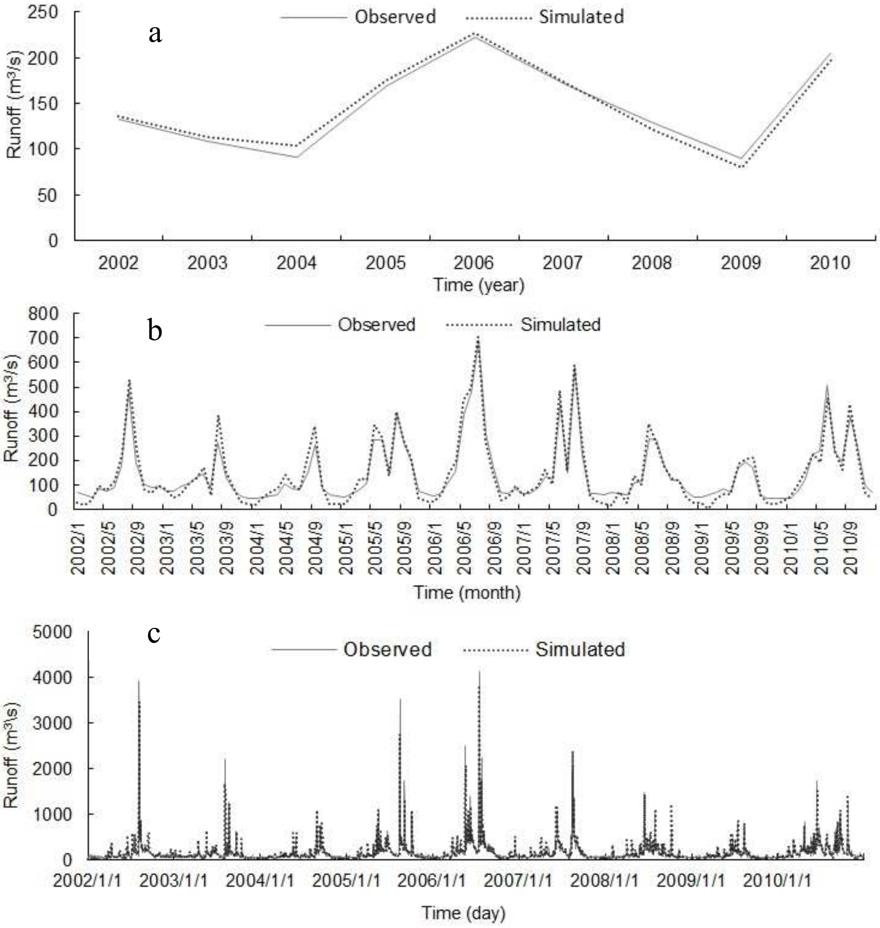

Figure 3. Comparison of simulated and observed runoff for yearly scale (a), monthly scale (b) and daily scale (c) in Silong gauge station

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