Hydrological Responses to Climate Change in Stung Sreng River Basin

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Introduction

Climate change introduces a great concern on water resource management in Cambodia, particularly in the Tonle Sap River System, due to high variability in rainfall, uncertain duration of the dry seasons and sporadic drought spells during the wet season. Floods and droughts are related to climate change and they are critical in the Country. It is estimated that floods kill about 100 people annually and cause agricultural losses of USD 100-170 million each year. Therefore, flood and droughts are recognized by the government as one of the main drivers of poverty. In order to address some of these problems, regarding extreme disaster risks and climate change, it is necessary to understand hydrologic conditions. Nowadays, hydrological model is a useful tool to analyse runoff process for better understanding of hydrological processes and streamflow generation mechanisms of a catchment. The reliable prediction streamflow from the hydrological model is essential for evaluating climate change scenario in the future. Therefore, this research is to quantify the hydrological responses to climate change with a case study in Stung Sreng River Basin, Cambodia. It consists of two main objectives (1) to calibrate and validate Soil and Water Assessment Tool (SWAT) in predicting daily streamflow and (2) to analyze the hydrological components responding to climate change effects in the future.

Material and Methods

This study was conducted in Stung Sreng River Basin which is located in the northwest of Cambodia. It is one of 39 basins in the country and the third largest river basin that discharges into the Tonle Sap Great Lake (Figure 1). The catchment area of Stung Sreng is around 9,931 km^2. The SWAT model was employed in this research. It is an integrated semi-distributed hydrological model which includes a plant growth module. Procedures to describe the effect of CO_2 concentration, precipitation, temperature and humidity on plant growth evapotranspiration and runoff generation make the model a valuable tool for the investigation of climate change impacts (Eckhardt and Ulbrich, 2003). SWAT uses hydrological response units (HRUs) that consist of specific land use, soil and slope characteristics.

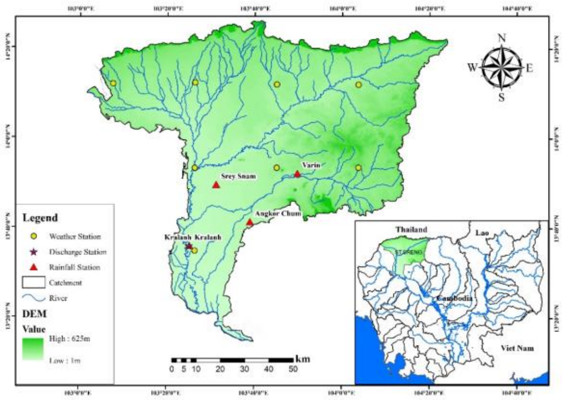

Figure 1 Map of Stung Sreng River Basin

The HRUs are spatial heterogeneity in terms of land cover, soil type and slope class within a watershed. The model estimates relevant hydrological components such as evapotranspiration, surface runoff and peak rate of runoff and groundwater flow for each HRU.

In order to setup SWAT for a particular river catchment, it is required to have geospatial data which includes Digital Elevation Model (DEM), land-use, soil type and hydrometeorological data such as rainfall, streamflow and other climate data (Table 1). The observed daily data of 15 years (1997-2011) was used to warm-up the model (2 years, 1997-1998), to calibrate the model (9 years, 1999-2007) and to validate the model (4 years, 2008-2011). The model performance was measured by three popularly used indicators: Nash-Sutcliffe efficiency (NSE), percent bias (PBIAS) and ratio of the root mean square error to the standard deviation of observed data (RSR) (Moriasi *et al.*, 2007). Climate change scenario data is required to quantify the relative change of climatic variables between the current and future conditions, which in turn are used as input to hydrological model for assessment of hydrological impact of climate changes. The climate change scenario data was dynamically downscaled from SEA START by PRECIS method. PRECIS is a regional climate model, based on the development of ECHAM4. The data recorded during 1997-2011 was used as the baseline and those from 2021, 2031 and 2041 were considered as the future scenario. The PRECIS data was downscaled to reduce the possible deviation (Minville *et al.*, 2010).

Table 1 Model input data for Stung Sreng River Basin

Data type	Description	Resolution	Period	Source
Topography	DEM	30 m	-	ASTER GDEM 2
Land use	Land use classification	250 m	2002	MRC
Soil	Soil type	250 m	2002	MRC
Meteorology	Rainfall	Daily	1997-2011	MOWRAM
	Weather	Daily	1997-2011	SWAT Database
Hydrology	Streamflow	Daily	1997-2011	MOWRAM
Climate change project	Precipitation & temperature (Scenario A2)	20 km	1997-2011 2021-2041	Southeast Asia START Regional Center

Results and Conclusions

The statistics of calibration results showed an acceptable correlation between observed and simulated streamflow with NSE = 0.53, PBIAS = 0.38% and RSR = 0.68 (Figure 2). Validation proves the performance of the model for simulated flows in periods different from the calibration periods, without further adjustment in the calibrated parameters. In validation stage, the model performed well overall. The statistics at this stage for daily time step showed NSE = 0.51, RSR = 0.70, and PBIAS = -26.82 %. In conclusion, SWAT was successfully setup for Stung Sreng River Basin. The calibrated model was afterwards applied to forecast the future hydrological conditions in next 30 years under the A2 climate change scenario.

As a result, the evapotranspiration is predicted to increase from -11% to -4% and potential evapotranpiration is predicted to increase from +1% to +4% (Figure 3). The surface runoff changes by -1% in 2021, -61% in 2031 and +6% in 2041. For other hydrological components, climate change in the A2 scenarios causes a -47% to -89% decrease in groundwater discharge, -7% to -37% decrease in lateral flow, -26% to -61% decrease in percolation and -15% to -57% decrease in water yield. Regarding annual changes, the annual streamflow is expected to increase +7.67% in 2021 and +20.41% in 2041. However, the annual streamflow in 2031 is decreasing with a rate of 36%. For the seasonal changes, the predicted sreamflow decreases remarkably between 3% and 61.73% in dry season. It was found that in dry season the study area will meet the draught events, especially in 2031 and 2041. Additionally, in the rainy season, streamflow is predicted to increase +15.40% in 2021 and +61.81% in 2041. In 2031, streamflow will decline -18.22%. Extreme flood is expected to occur in the rainy season in 2041, while the occurrence of severe drought is expected in 2031. Hence, according to the impact of climate change in the future, to prevent disaster risk that will occur, proposing dam to store the water for domestic supply, irrigation and industrial in dry season and to convey flood in the rainy season should be constructed.

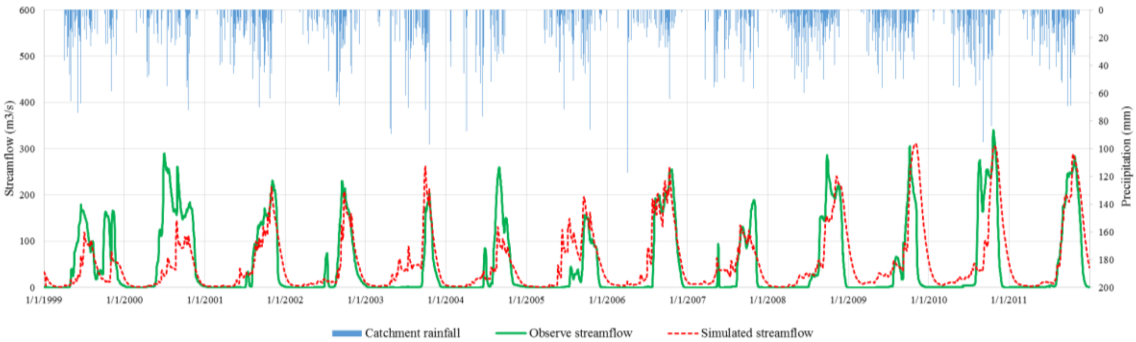

Figure 2 Time series comparison between observed and predicted streamflow

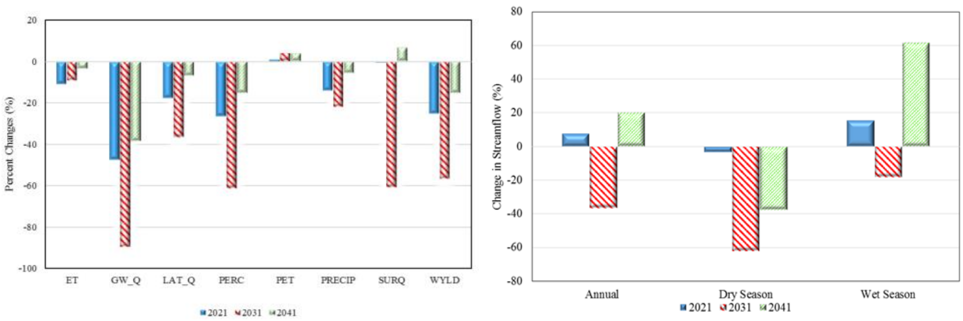

Figure 3 Hydrological responses to climate change

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