

Impact of Climate and Rapid Land Use Changes on Runoff Quantities in Lower-Lampao River Basin

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Abstract. *The trends of climate change can be shown that the temperature increase or decrease of precipitation. Rapid land use change from forest area to agriculture and urban areas, are reasons for the changes in runoff caused to flooding and drought in many areas. Predicting future climate and land use changes can contribute to the planning, management and development of water resource in the basin properly. The objective of this study aims to examine the impact of climate and land use changes on future runoff quantities during periods 2016-2065 in the Lower-Lampao River Basin, Northeast of Thailand. The procedure comprises of 2 models: 1) PRECIS for projecting future climate change; 2) SWAT for projecting land use change patterns and develop future runoff quantities. The results showed that an average rainfall was increased to 14.5 mm, average daily maximum and minimum temperature increase to 2.6 and 1.8 degrees Celsius, respectively, along 50 years in future. In case of changed land use patterns from paddy fields to crops and urban area from 20, 40, 60, 80 and 100 percent increased, the average annual runoff were lower than the baseline year is between 16.6 to 35 percent, with the exception of the years 2012-2021. The long-term average runoff is higher than baseline year 13.4 percent. In conclusion, climate and land use changes has a direct impact on runoff, which has shown a declining trend in the future. The methodology and results of this study can be applied to analyze the runoff in other watershed areas with topography and hydrological conditions similar to this study area.*

Keywords:

Climate Change, Land Use Change, PRECIS, Runoff, SWAT

1. Introduction

In the past, Thailand is considered one of the most abundant agricultural areas of the world due to the location of the country is in monsoon area. Meanwhile in Thailand each year to meet the escalating issue of water resources, for example, increased flooding during the rainy season that

caused severe damage in several sectors, water shortage during the dry season due to the expansion of urban areas, increase of agriculture areas, high demand from industrial sectors, etc. In this context, the important factors that affect water resources is global climate change, which is generally understood to affect the climate elements such as precipitation, temperatures, relative humidity, wind speed [1]. Therefore, the dynamics of these factors is expected to affect mainly agricultural area of Thailand, especially in the rainfed cultivated [2], including the impact on the runoff cause a decrease in the dry season or a rapid increase in the rainy season [3]. Study on climate change in Thailand, especially in the Northeast, which is a major agricultural crops found that average temperatures are likely to increased, drought period is longer, which caused a shortage of water for irrigation and cultivation. In contrast, during the rainy season found a short time, but the intensity of the precipitation is very high, which caused flash floods in many areas. Changing patterns of land use that are caused by the rapid increase of the population is another important factor to consider along with climate change [4]. Change in agricultural areas into residential or industrial areas in order to support the expansion of economic and social policies in the future, including the invasion of forest to serve as farmland. Therefore, when the precipitation falls in the area with this changed. It is expected to be one of the reasons the flow behavior of the surface runoff has changed from the original [5].

An analysis of the runoff variation depends on the variables of hydrology process such as the area and the river slope, precipitation, temperature, humidity, soil type, and land use, etc. The study of annual runoff in the basin from the past to the present, find a declining trend continued as the area between the upper reaches of the river, including the temperature in the area is likely to rise and rainfall changes from the original [6]. Meanwhile water demand in the urban around the downstream has increased. Predictions of climate and land use changes to make the trends in precipitation, patterns of land use and future runoff in small basin can lead to manage and develop of water resources properly. Using a mathematical model to analyze the problem is another approach that can be used to make a quick answer or trends to forecast the events are

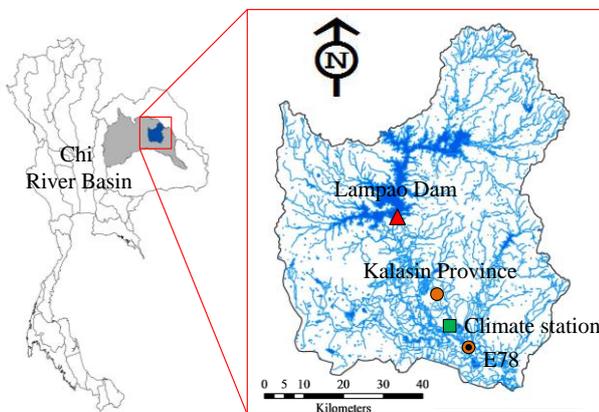
expected to occur in the future and the obtained results from the model to solve the problem as well.

The objective of this study was to determine the impacts of climate and land use changes on the runoff quantities between periods of 2006-2065 in the Lower-Lampao River Basin by using mathematical models are, PRECIS; for predicting future climate change, and SWAT; a model was developed for use in assessment of hydrology and runoff in both the current conditions and future expectations. The results obtained from this study can be applied in the planning and troubleshooting the floods and droughts events that are expected to occur in the most efficient way.

2. Methodology

2.1 Study Area

The study area, Lower-Lampao River Basin is the branch of the Chi River Basin located in the Northeast of Thailand (Figure 1). An area of approximately 4,264 km², total annual rainfall 1,290 mm and cumulative annual runoff of about 661 MCM, water resource problems in the watershed has several aspects: insufficient water for agriculture; soil is not absorb water; natural river is narrow and shallow intrusion; upstream forests were destroyed; area is very sloped and the water flow strength and faster; and people use agricultural areas unsuitable.



Thailand 25 main basins Lower-Lampao River basin

Fig. 1 Lower-Lampao River Basin.

2.2 Climate Change Scenario Data

PRECIS (Providing Regional Climates for Impacts Studies) is a regional climate model (RCM) that was developed by Hadley Centre for Climate Prediction and Research. It was developed in order to help generate high resolution climate change scenario information for as many regions of the world as possible [7], with the spatial resolution of 0.22 degrees or approximate 25 km and re-scale to 20x20 km² [8]. In Thailand, for the climate data

from PRECIS has been downloaded from the Southeast Asia START Regional Center (<http://www.start.or.th>). For this study, selected predictions from simulations of future global greenhouse effect case B2 (Emission Scenarios) by IPCC SRES [9]. Climate scenario data from PRECIS can be downloaded by selecting the scope of the data as coordinates, which the position of Lower-Lampao River Basin was located at coordinates between latitudes 17.2 N, 16.2 N, and longitudes 103 E, 104 E. Required data from PRECIS are: 1) precipitation, 2) maximum and minimum temperatures, 3) relative humidity, 4) solar radiation, and 5) wind speed, which simulate future climate data are daily from 2016-2065 (50 years).

2.3 Runoff Quantity Analysis

SWAT (Soil and Water Assessment Tool) has been developed for use in assessing the hydrological conditions, the runoff in the past present and forecast the future. The model is able to analyze the impact of changes in the volume of runoff from the large-complex watershed due to changes in soil conditions, land use, climate change, increasing of water demand and floods protection. Simulation of hydrology of a basin can be separated into two major divisions, land phase and routing phase of hydrological cycle base on water balance [10]. SWAT requires spatial data, including topography, land use, soil parameter in relation to hydrology, climate and hydrological data into daily time-step [11]. The database for SWAT will be 2 types of GIS spatial data and map data, which include 1) soil characteristics, and 2) the land use map. The topographic map or DEM about 30x30 m resolution, soil and land use database were extracted from the provincial soil survey map of the Land Development Department (LDD) [12] in year 2013. For the model calibration, selected baseline year with simulated future runoff were based on the observed data during periods 2006-2014, which comprise: 1) the daily climate data from Thai Meteorological Department (TMD) and 2) the runoff quantities data from Royal Irrigation Department (RID).

2.4 Model Calibration

The calculation of runoff from the hydrological model requires a comparison between the observed data from the gauging station. In this study, the E78 gauge station (Figure 2) has been used to assess the accuracy of the model results with the daily runoff during the years 2006-2015 (10 years). For verification the accuracy of the model results and the observed data, in this study, the coefficient of determination (R^2) was used as indicator. In terms of methods to customize model to calculate the runoff are similar to the observed data, SWAT will use the configuration hydrological parameters for the model calibration called 'model sensitivity parameters', in this study, 6 sensitivity parameters were used including SOL_AWC, CH_N2, QW_QMN, GW_DELAY, ALPHA_BF, and ESCO.

Adjusting the parameters is performed until the comparison of the results from the model and the observed data are similar in level of satisfaction, which show the R^2 close to 1 as possible. Figure 2 shows a simulation of the river, the climate station, inflow gauge station and the basin delineate from SWAT based on DEM.

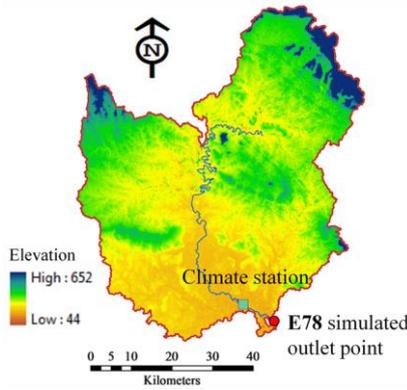


Fig. 2 Runoff observed station and sub-basin delineated by SWAT based on DEM.

2.5 Runoff Scenario

Future runoff during 2016-2065 can be calculated from the SWAT model by importing daily climate data from PRECIS. Meanwhile, SWAT has a module that can modify the land use map data from the baseline map, for example, rice paddy to agriculture and urban area, which adjust the amount of area as a percentage. In order to represent a change from past years, 2006-2015 (as baseline) to the future periods 2016-2065 (as projected) between climatic, land use and runoff. This study has been divided into five ranges, with each period of 10 years, including 2016-2025, 2026-2035, 2036-2045, 2046-2055, and 2056-2065. Each ranges is assigned a change of land use from paddy field into agricultural and urban with intervals of 20 percentages, as shown in Table 1, the analysis of the SWAT runoff compared to baseline year.

Scenarios	Year	Paddy (%)	Agriculture (%)	Urban (%)
BL	2006-2015	100	0	0
SN1	2016-2025	80	10	10
SN2	2026-2035	60	20	20
SN3	2036-2045	40	30	30
SN4	2046-2055	20	40	40
SN5	2056-2065	0	50	50

Table 1 Simulation of land use changes during 2006-2061.

3. Results and Discussions

3.1 Future Climate Trend from PRECIS

Results of projected future climate during the year 2016-2065 compared to the baseline year (2006-2015) in each range 10 years, found that the average precipitation increased of 3.6 mm per range. The maximum and

minimum temperature increased of 2.3 and 1.8 degrees Celsius per range, respectively. Figure 3 and 4 shows the trends of increasing precipitation, maximum and minimum temperatures over the long-term during 2016-2065 that were simulated by the PRECIS model, for the B2 scenarios. For this reason, it may be a direct impact on surface runoff, evapotranspiration and soil moisture [13].

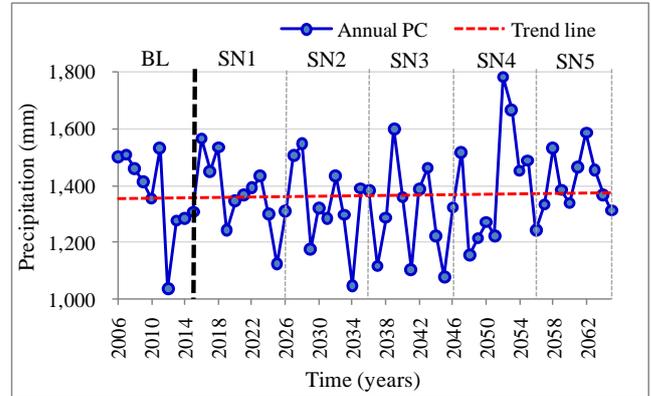


Fig. 3 Trend of annual precipitation.

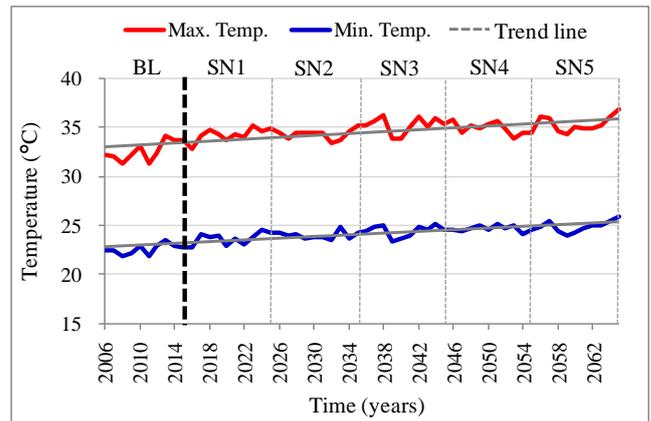


Fig. 4 Trends of maximum and minimum temperatures.

3.2 SWAT Runoff Calibration

First simulated baseline runoff from SWAT (2006-2015) with non-adjustment sensitivity parameters compared with the observed runoff data from the E78 station showed that the R^2 was about 0.44. After adjusted the R^2 value increased to 0.72. The final adjusted of sensitivity parameters are show in Table 2. Figure 5 shown a comparison of SWAT runoff and the E78 observe station between periods 2006-2015.

Parameter	Definition	Adjusted value
SOL_AWC	Soil available water capacity	0.25
CH_N2	Manning's n coefficient	0.022
GW_QMN	Threshold water depth in the shallow aquifer for flow	50
GW_DELAY	Ground water delay time	105
ALPHA_BF	Base flow alpha factor	0.048
ESCO	Soil evaporation compensation factor	0.23

Table 2 Final sensitivity parameters for runoff calibration.

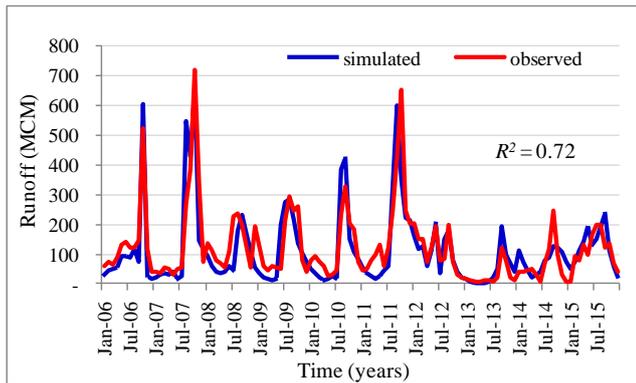


Fig. 5 Runoff comparisons between observe data and SWAT simulation during 2006-2014.

3.3 Runoff Scenario from SWAT

The calculation of future runoff during 2016-2065, provided climate change and changing patterns of land use, as detailed earlier. It was found that the average runoff during 10 years have shown lower than the average of the base year, which includes the SN2, SN3 and SN5 are between 21.4%, 32.8% and 16.6% respectively. Meanwhile, the SN1 and SN4 have shown higher than the baseline year of about 10% and 3.1%, respectively, as represented in Table 3. The results of this study are consistent with the research on the impact of land use change on runoff in China, which indicated that runoff decreases when changing patterns of cultivation of the paddy field to the urban and agricultural areas [14].

Considering the factors that affect the runoff is lower than the average observed runoff due to the precipitation in the SN2, SN3 and SN5 have shown lower than or close to the baseline, including a change of land use or land cover from rice paddy to agriculture and urban areas, which has become a obstacles to the surface runoff and water infiltration to the ground has changed. In contrast, in case of the precipitation is higher than the normal average, as indicated that in the SN1 and SN5 that will results in increased runoff as well.

Scenarios	Years	Runoff (MCM)	Difference (%)
BL	2006-2015	1,336.6	-
SN1	2012-2021	1,470.9	10.0
SN2	2022-2031	1,050.4	- 21.4
SN3	2032-2041	898.6	- 32.8
SN4	2042-2051	1,377.6	3.1
SN5	2052-2061	1,114.9	- 16.6

Table 3 Average 10-years runoff simulated from SWAT during 2012-2061 compared to the baseline.

4. Conclusion

The analysis of the impact of climate and land use changes on runoff quantities in the Lower-Lampao River Basin by using mathematical models to assist in the analysis

of projected patterns of climate, which results from PRECIS suggests that in 2006-2065 period, average precipitation, daily maximum and minimum temperatures have increased. From the use of SWAT to predict land use patterns change from paddy area into agricultural and urban areas during the period from 50 years (2016-2065), which results from the model indicate that the runoff during the 2016-2065 are lower ranged from 16.6%-32.8% and higher ranged from 3.1%-10% than average of the baseline years, respectively. In conclusion, the results of this study show that the effect of climate and land use changes are interrelated and expected to cause changes that may affect to the quantities of runoff, and the methodologies and the results obtained in these conditions are expected to be useful for decision making, planning, evaluating patterns of land use, environmental conservation to maximize the benefits of water resources management in this study area and the other watershed with the similar of topography and hydrological conditions. However, the results from PRECIS and SWAT need to be more in terms of calibration and validation results with historical data to improve performance and reliability, and the analysis of monthly runoff time to point out the differences at higher resolution and clarity.

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