Assessment of Landuse Change and Climate Change on Runoff in Mae Chaem Watershed

การประเมินผลกระทบจากการเปลี่ยนแปลงการใช้ประโยชน์ที่ดินภายใต้การเปลี่ยนแปลงสภาพภูมิอากาศต่อปริมาณน้ำท่า ในลุ่มน้ำแม่แจ่ม

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ABSTRACT

The purpose of this study is to study the effect on runoff from the chang of landuse under A2 and B2 climate scenario in Mae Chaem watershed by using SWAT model. To run SWAT various input data are required, Digital Elevation Model: DEM, climatology data, soil data, and landuse/land cover. The reliability of a simulated value shall be compared with an observed value via Coefficient of determination (R^2) and Nash-sutcliffe efficiency (E_{ns}). This study is divided into 3 cases which are a. Present landuse, b. A huge agriculture expansion and c. Reforestation. The result shows that among these 3 cases the most area cover with agriculture area provides the most runoff in Mae Chaem watershed.

บทคัดย่อ

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อประเมินปริมาณน้ำท่าต่อการเปลี่ยนแปลงการใช้ประโยชน์ที่ดินภายใต้การเปลี่ยนแปลงสภาพภูมิอากาศแบบ A2 และ B2 ต่อปริมาณน้ำท่าบริเวณลุ่มน้ำแม่แจ่ม โดยการใช้แบบจำลอง SWAT model ซึ่งเป็นแบบจำลองนี้จะประมวลผลปริมาณน้ำท่าจากข้อมูลนำเข้าได้แก่ แบบจำลองระดับสูงเชิงเลข (Digital Elevation Model : DEM) ข้อมูลอุตุนิยมวิทยา ข้อมูลปฐพีวิทยา และข้อมูลการใช้ประโยชน์ที่ดิน บริเวณลุ่มน้ำแม่แจ่ม ทำการวิเคราะห์ผลของความน่าเชื่อถือของแบบจำลองโดยเปรียบผลของปริมาณน้ำท่าที่ได้จะการจำลองและปริมาณน้ำท่าที่ได้จากการตรวจวัดจริงจากวิธีการ ซึ่งการศึกษาจะถูกแบ่งออกเป็น 3 กรณี ได้แก่ กรณีที่ไม่มีการเปลี่ยนแปลงการใช้ประโยชน์ที่ดิน กรณีที่การใช้ประโยชน์ที่ดินที่เป็นพื้นที่การเกษตรกรรมทั้งหมดถูกเปลี่ยนเป็นพื้นที่ป่า และกรณีที่การใช้ประโยชน์ที่ดินที่เป็นพื้นที่ป่าทั้งหมดถูกเปลี่ยนเป็นพื้นที่เกษตรกรรม จากผลการศึกษาพบว่าการเปลี่ยนแปลงการใช้ประโยชน์ที่ดินจากพื้นที่ป่ามาเป็นพื้นที่เกษตรกรรมส่งผลให้ปริมาณน้ำไหลบ่าหน้าดินบริเวณลุ่มน้ำแม่แจ่มเพิ่มขึ้น

Keywords: Runoff, SWAT
คำสำคัญ: น้ำท่า SWAT

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Introduction

Thailand is an agricultural - based country. Since the habits of Thai's farmers have changed due to the highly competition in the present, from a Simultaneous Cropping System to a Single Crop Yields (The Organic Agriculture Development Center, 2010). An expansion of hill agriculture has led to more and more deforestation. This impact shall lead to erosion that can cause sedimentation in low land river. A high sedimentation in a particular spot shall lead to a shallow and direction changes. Hence, either drought or flood may occur.

To prevent the above threat, a good stimulation is required in order to understand the consequences from hill agriculture in each scenario. Runoff, nutrient, and sediment are keys component of these impact. Considering the agriculture activities, there are other factors that can drift the natural behavior of water such as climate changes, land use, specific management, and etc. which lead to various situations and managerial ways.

The Soil and Water Assessment Tool SWAT is widely used in assessing soil erosion prevention and control, non-point source pollution control and regional management in watersheds SWAT model has been used to simulate from a small watershed to a huge watershed scale in both quality and quantity of surface water and groundwater and also simulate the impact from landuse change, and climate change (SWAT, 2017).

Objectives of the study

The aim of this study is to assessing the amount of runoff in Mae Chaem watershed in accordance with landuse change scenarios under A2 and B2 climate scenario.

Material and Methodology

Data preparation

To simulate runoff, SWAT model required a data to process. The input data collect in this study are Base map and Climatology data. The data were requested from Land Development Department and Northern Meteorological Center Meteorological Department as listed in table 1

Table 1 Input data for SWAT model

Type of data	Details	Source of data	Step
Base map			
• Dem 30	- A projected Grid shows the elevation in Mae Chaem.	- Land Development Department	- Project setup
• Mae Chaem Boundary	- A projected Grid shows the boundary of Mae Chaem.	- Land Development Department	- Water delination
• River line	- A projected Grid shows the river line in Mae Chaem.	- Land Development Department	- Water delination
• Land use	- A projected Grid shows the	- Land Development Department	- HRU analysis

Table 1 Input data for SWAT model (Cont.)

Type of data	Details	Source of data	Step
• Soil type	- A projected Grid shows the soil characteristics in Mae Chaem.	- Land Development Department	- HRU analysis
Weather data			
• Temperature	- The temperature collected from Mae Chaem weather stations, recorded from (1/1/1979) to (31/12 /2016)	- Meteorological department	- Weather station
• Precipitation	- The precipitation collected from Mae Chaem weather stations, recorded from (1/1/1979) to (31/12 /2016)	- Meteorological department	- Weather station
• A2 B2 climate scenario	The daily temperature and precipitation from (1/1/2016) to (31/12/2031)	- SEASTART	- Weather station
Observed data			
• Runoff	- The daily runoff at hydrology station P14A recorded from (1/1/2010) to (31/12/2016)	-Upper Northern Region Irrigation Hydrology Center	- Calibration & Validation

Landuse changes scenarios

Landuse changes in this study shall be divided into 3 scenarios, where each scenario is an assumption as follow.

Present landuse

The first scenario is the base year of a present landuse (2015) which shall be simulated base on landuse map in Mae Chaem watershed.

A huge agriculture expansion

In this scenario the researcher assumed that there is an increasing in agriculture in Mae Chaem watershed. The total amount of agricultural area increase is equal to the amount of forest area left at present, meaning that all available forest area shall be converted to an agricultural area.

Reforestation

In this scenario the researcher assumed that there is an increasing in forest conservation in Mae Chaem watershed. The total amount of forest area increase is equal to the amount of agricultural area left at present, meaning that all available agricultural area shall be converted to forest area.

Climate change scenarios

The titles of the storylines have been kept simple: A2 and B2 described by Sangmanee et al. (2010) as follow:

A2 Climate scenario

A2 climate scenario was selected to represent an upcoming monthly weather forecast. To illustrate the underlying theme is self-reliance and preservation of local identities, where economic growth and technology are gradually developed. Values of A2 climate change consist of precipitation (rainfall in mm.) and temperature (degree celcius).

B2 Climate scenario

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

Applying SWAT model for runoff simulation

Before simulate runoff from SWAT model. SWAT model require a calibration, in order to get the closet and harmonize with the observed data in both runoff and sediment. Parameters in SWAT model shall be adjusted by SWAT-CUP, then the best parameters shall be readjusted to SWAT model. After the calibration is done, validation is required. When calibration and validation are done, SWAT model is applicable.

Calibrate and Validation

The monthly observed runoff for calibration and validation are retrieved from hydrology station P14A which locate at Hot district Chaing Mai. Coefficient of determination (R^2) and Nash-sutcliffe efficiency (E_{ns}) shall be evaluate.

Results

SWAT parameters are calibrated via SWAT – CUP as show in table 2. These streamflow-related parameters are frequently used for SWAT model calibration, summarized by (Douglas-Mankin et al., 2010).

Table 2 Parameters adjusted in SWAT-CUP

Parameters	Detail	Old Value	New Value	Changes %
CN2	CN2 or runoff curve number is a value which identify an efficiency of runoff flow in accordance with land cover. Range from 35 - 98.	77	85.316	+10.8%

Table 2 Parameters adjusted in SWAT-CUP (Cont.)

Parameters	Detail	Old Value	New Value	Changes %
ALPHA BF	A constant value which direct variation to groundwater recharge. Range from 0.1 - 0.3	0.48	0.006	-98.5%
GW DELAY	The delay time consume in permeability process. Range from 0 - 500	31	500	+1512%
GWQMN	The initial value of water in aquifer. (Groundwater will reach surface water when a water level is greater or equal to GWQMN). Range from 1 - 1000.	1000	1.95	-99.8%

The calibration data is a monthly observed runoff from hydrology station P14A during January – December 2014 as shows in table 3. The satisfactory of (R^2) and (E_{ns}) are greater or equal to 0.6 and greater or equal to 0.5 (Arnold et al., 2012) respectively.

Table 3 Monthly comparisons between observed runoff and simulated runoff at hydrology station P14A

Year 2014	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Obs	47.28	29.69	24.22	9.37	44.53	44.41	50.47	94.13	146.81	73.78	37.26	26.51
Sim	31.47	30.73	26.78	23.64	27.97	40	45.81	59.79	124.2	127.4	46.2	29.27

Calibration result

After compare a simulated runoff with an observed runoff as shows in figure 1 during January - December 2014 (via SWAT - CUP), the analysis reveals that Coefficient of determination (R^2) and Nash-sutcliffe efficiency (E_{ns}) are 0.67 and 0.65 respectively.

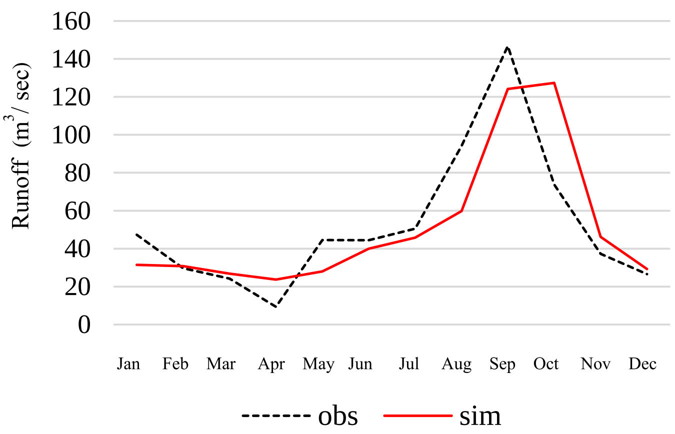

Figure 1 A graph shows observed runoff and simulated runoff (Calibration)

Validation result

In validation process observed runoff and simulated runoff are compared as shows in figure 2 by which the period of observed runoff is January - December 2016 (via SWAT - CUP), the analysis reveals that Coefficient of determination (R^2) and Nash-sutcliffe efficiency (E_{ns}) are 0.86 and 0.62 respectively.

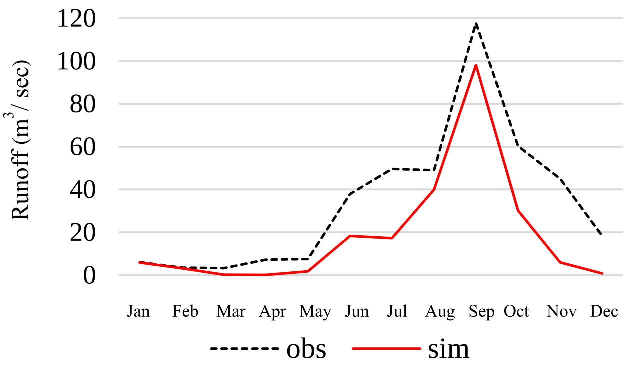

Figure 2 A graph shows observed runoff and simulated runoff (Validation)

Therefore, both calibration and validation were satisfied. SWAT is applicable for estimate both runoff and sediment in accordance with landuse changes in Mae Chaem watershed under climate change scenarios.

Landuse changes and runoff

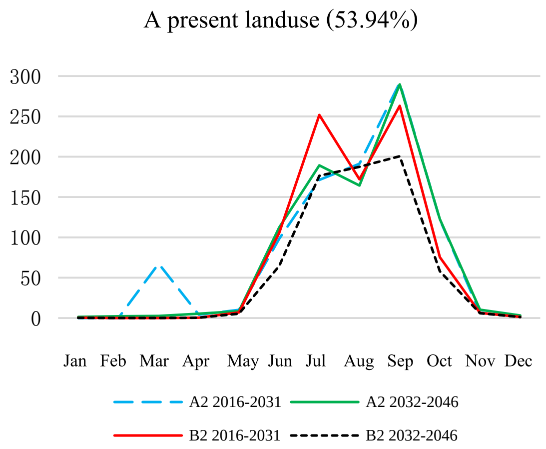

Figure 3 Simulated runoff in present landuse under A2 and B2 climate changes

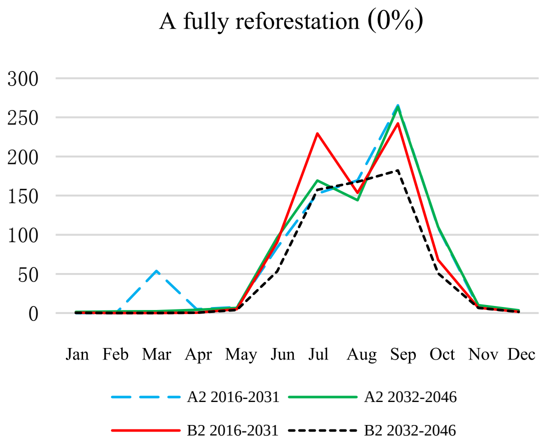

Figure 4 Simulated runoff in fully reforestation under A2 and B2 climate changes

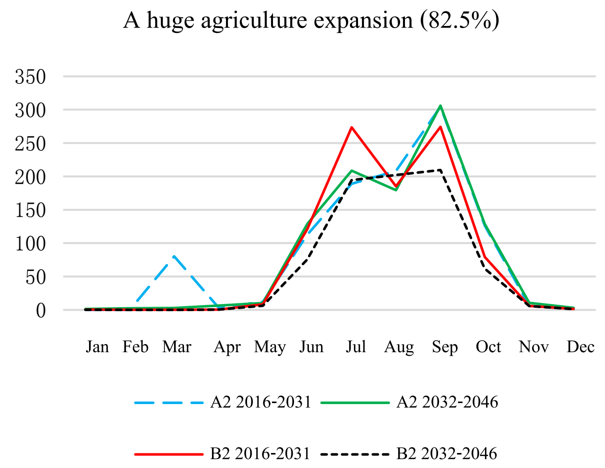

Figure 5 Simulated runoff in huge agriculture expansion under A2 and B2 climate changes scenarios

Table 4 Simulated runoff in accordance with landuse changes in Mea Chaem watershed under climate change scenarios

Climate Scenario	Landuse	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (m^3/year)
A2 2016-2031	Present landuse (53.94%)	0.06	0.05	67.45	4.17	10.09	98.14	171.20	191.20	291.50	122.00	6.63	1.63	964.12
	Reforestation (0%)	0.07	0.06	53.76	4.88	7.69	83.62	152.60	169.60	265.40	109.10	7.70	1.91	856.39
	Agriculture expand (82.5%)	0.05	0.05	80.16	3.52	12.00	112.80	189.00	208.10	304.40	126.30	5.93	1.46	**1043.78**
A2 2032-2046	Present landuse (53.94%)	1.46	2.26	2.58	5.46	8.69	112.40	189.30	164.20	289.70	122.60	10.41	3.19	912.25
	Reforestation (0%)	1.52	2.16	2.33	4.16	6.70	96.43	169.30	144.20	263.30	110.00	10.02	3.45	813.57
	Agriculture expand (82.5%)	1.43	2.33	2.73	6.33	10.22	128.70	208.60	179.30	**306.1**	128.60	10.49	3.00	987.82
B2 2016-2031	Present landuse (53.94%)	0.49	0.12	0.15	0.44	6.98	105.60	251.70	172.10	263.10	75.52	6.37	1.46	884.04
	Reforestation (0%)	0.56	0.14	0.16	0.46	5.06	90.46	229.30	153.60	242.20	67.96	6.91	1.69	798.51
	Agriculture expand (82.5%)	0.44	0.11	0.14	0.44	8.37	121.20	273.40	185.20	274.10	79.27	5.94	1.30	949.91
B2 2032-2046	Present landuse (53.94%)	0.18	0.04	**0.02**	0.39	5.39	64.50	176.30	187.50	200.50	58.00	6.11	1.33	700.26
	Reforestation (0%)	0.22	0.05	0.03	0.41	4.05	53.24	157.50	167.70	182.20	50.81	6.55	1.54	**624.29**
	Agriculture expand (82.5%)	0.15	0.03	**0.02**	0.39	6.27	75.65	194.50	202.20	209.50	61.85	5.71	1.18	757.45

Figure 3 - 5 the simulation runoff in each landuse change scenario under A2 and B2 by which the period of A2 and B2 climate scenarios were split into two periods (2016 - 2031 and 2032 - 2046). From table 3 the result reveals that, the highest runoff occurs in September (306.1 m^3/sec) under A huge agriculture expansion landuse under A2 2016-2032 climate change. The lowest runoff occurs in March (0.02 m^3/sec) in accordance with both Present landuse and A huge agriculture expansion landuse under B2 2032-2046 climate change.

Table 4 shows that the second scenario (Reforestation under A2 and B2 climate scenario) gives the lowest runoff which are 856.39, 813.57, 798.51 and 624.29 m^3 / sec. For the first scenario (Present landuse under A2 and B2 climate scenario) gives a moderate runoff which are 964.12, 912.25, 884.04 and 700.26 m^3 / sec. For the third scenario (Huge agriculture expand under A2 and B2 climate scenario) gives the highest runoff which are 1043.78, 987.82, 949.91 and 757.45 m^3 / sec .

Discussion

As the result shows that, in a situation with an increasing in agriculture area cause an increasing in runoff. This result relates to a study of Wuttichaikitcharoen (2013) when forest is converted to an agriculture area, the ability of plant uptake decrease. Water yield has a decrease of 1.8 percent in the forest landscape scenario and an increase of 4.2 percent in the agriculture-rich scenario (Sun et al, 2015). It also proofs that a forest cover loss is accompanied by an increased stream discharges and surface runoff (Guzha et al, 2018). Water demand from maize crop is less than tree's demand which lead to a higher runoff in a scenario with a more agriculture area. The impacts of climate change under A2 scenario and landuse change is prior to (Pervez & Henebry, 2015) that runoff is projected to increased by 10% annually when the area of forest is reduced under A2 climate.

It is obvious that, the total runoff shall response differently among landuse. These responses are determined by a hydrological process of interception, infiltration, evapotranspiration, and groundwater (Lin et al, 2015). Conversion from agriculture (except orchard) to forest usually increases evapotranspiration rate and soil infiltration capacity, which lead to a reduction in total runoff (Lin et al, 2012).

Conclusions

The impact on runoff from landuse change under A2 climate scenario was estimated, while landuse change scenarios were assumed by changing from an agriculture area to a forest area and vice versa. The assumption of landuse changes were defined as a. 0% of agriculture area (all agriculture area was converted into forest area) b. 53.94% of agriculture area (forest area remained at 28.56%) and c. 82.5% of agriculture area (all forest area was converted into agriculture area)

Before using SWAT model to simulate runoff, calibration and validation are required. The result shown that both coefficient of determination (R^2) and nash-sutcliffe efficiency (E_{ns}) have reached the satisfactory standard at 0.67 and 0.65 for calibration, and 0.86 and 0.62 for validation, while calibration period is January-December 2014 and January-December 2016 for validation.

The evaluation on the impact from each landuse change scenario reveals that, a huge agriculture expansion scenario (82.5% of agriculture: no forest area) generate the most annual runoff (1043.78) while a reforestation scenario (82.5% of forest: no agriculture area) generate the least annual runoff (856.39)

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