Evaluation of future water availability in Klongyai basin under various climate scenarios

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Abstract:
In this study, the water availability scenario assumes that average surface temperature and precipitation will change in the future because of climate change. To estimate future water use, scenarios including assumptions are simulated, for sustainable water resources management satisfying demands under these scenarios. By keeping the values of important parameters, which were obtained in the calibration process, it was found that SWAT has the ability to predict runoff in the watershed with acceptable accuracy (R^2=0.76, Nash=0.55 and IA=0.84). The computational result of these 3 scenarios can be utilized to advice the government to produce policy for water resources management. Since, forest area is major affect to increase the rainfall and runoff in the basin. To prevent the drought situation, the government should increase the forest area in the basin.

Keywords: *Climate scenario; water consumption; spatial analysis; land use change; Klongyai basin*

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1. Introduction
The effects of global warming are the change in local and regional water availability, since the climate system is part of the hydrologic cycle. These effects include the magnitude and runoff timing, the frequency and intensity of floods droughts, rainfall patterns, extreme weather events and the quality and quantity of water availability (Tao et al., 2007). Land use has important roles which induce different hydrologic watershed systems for each area (Heuvelmans et al., 2005). It affects the vanished quantity of the surface water due to the confinement on the surface, evaporation emission and permeability. Moreover, land use for agriculture and the pasture land or empty land has small impact on the surface water quantity (Huisman et al., 2004). However, it is important to have regulations for soil and water preservation, in order to provide watershed management and to preserve the water balance as well (Behara and Panda, 2006).

In 2005, there were drought problems in Rayong province. These problems caused major difficulties for the industrial sector, which had to be supplied with water from outside the province. The high priority of water resource management is for domestic use, agriculture and industry. An understanding of the relationship between hydrological processes, physical characteristics such as land use and soil and climate change is important for watershed management design. At this point, the aim of this research is to investigate the hydrological processes interacting with the physical characteristics. The selected area covered by this study is the Klongyai Basin, which is located in Rayong Province. Although the majority of water demanded in Thailand is for use in agriculture, Rayong is an area where water is used also for industrial development. The objectives of the study are: 1) To investigate how much runoff change with selected scenarios of land use and climate changes, and 2) to estimate future water use by using scenarios including assumptions, for sustainable water resources management satisfying demands under these scenarios.

2. Material and methods
2.1 Study area
Klongyai basin is located in Rayong and Chonburi provinces, on the east coast and northern shoreline of the Gulf of Thailand. This basin area is about 1,704 km^2. The climate is tropical,

generally warm and humid with abundant rainfall. Water from Nhongplalai and Dokkrai reservoirs has been used for consumption, industry and agriculture. The upper watershed areas of these reservoirs have been specified as the core area of the master plan of the land use and community in the eastern coastal areas, which remain semi-agricultural countryside. The special characteristic of these areas is that there is potential to set up new cities. There are many industrial estates in the southern area including convenient transportation networks, which means that this area has the potential for industrial investment. However, these areas are the upper watershed and nearby are the preservation areas. It is an area sensitive to change. They will be expanded for area development, in preparation for industry and a city community in the future, which will impact the quantity and quality of the surface runoff.

2.2 Description of SWAT Model

SWAT is a watershed-scale model. The model works well on large basins without the detailed data which are required for a standard calibration and validation effort (Arnold et al., 1998). An interface for large GIS data sets and efficient computations for long-term, continuous simulation at daily time steps, are required. This uses daily values for maximum and minimum temperatures, precipitation, relative humidity and wind speed.

The hydrologic cycle simulated by SWAT is based on the water balance equation as in (1)

$$SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \qquad (1)$$

where SW_t is the final soil water content (mm H_2O), SW_0 is the initial soil water content on day i (mm H_2O), t is the time (day), R_{day} is the amount of precipitation on day i (mm H_2O), Q_{surf} is the amount of surface runoff on day i (mm H_2O), W_{seep} is the amount of water entering the vadose zone from the soil profile on day i (mm H_2O), Q_{gw} is the amount of return flow on day i (mm H_2O).

The SWAT simulation methodology consisted of an initial calibration and validation phase followed by a second phase in which the impact of variations in climatic inputs was assessed for the hydrology. The following model options were used for all of the simulations performed in both phases. Manual calibration was conducted to bring the optimized values to better estimated ones that allow the model to represent the real conditions of the area.

2.3 Model Performance

In these models, the Nash-Sutcliffe coefficient (Nash, 1970) is used as the error criterion to assess the goodness of fit of the flow and head hydrographs. It is used to assess the predictive power of hydrological models. This criterion is always less than unity. A value equal to unity represents perfect agreement between the observed and simulated streamflows. According to the guidelines, the model output is considered satisfactory if Nash> 0.5. In addition, the closer the Coefficient of Determination (R^2) and Index Agreement (IA) to 1, the better is the goodness of fit between the observed and simulated parameters. If the Nash values are are less than or close to zero, then the model prediction is unacceptable. If the values equal one, the model predictions are considered perfect.

2.4 Methodology

The climate change impact assessment on water resources can be best handled through simulation of the hydrological conditions in this area. The interface is used for pre- and post-processing of the data and outputs (see Fig.1).

Model inputs required to run SWAT include DEM, land use map, soil map and weather data (Fig. 2). The 90 m resolution topography data used for this study were extracted from the Shuttle Radar Topography Mission (SRTM, 2010). This watershed area was delineated into sub-basins and Hydrological Response Units (HRU) (each with unique combination of land use, slope and soil).

Main land use in Klongyai is agriculture (89%) such as cassava, mixed crop pineapple and para rubber. However, main water is used for industries.

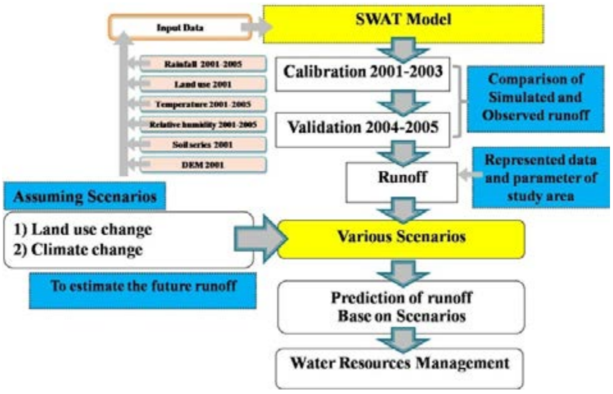

Fig. 1 Flow chart of research methodology.

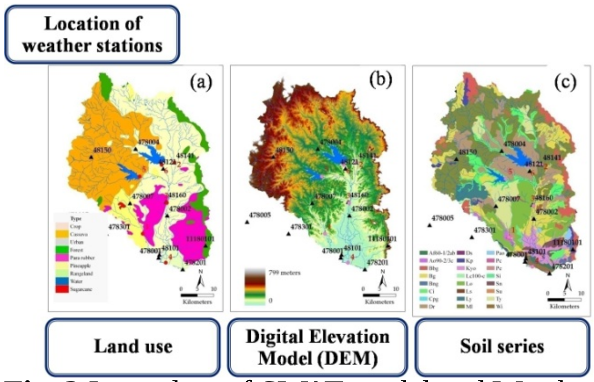

Fig. 2 Input data of SWAT model and Weather and runoff stations (a) Land use (b) DEM (c) Soil series.

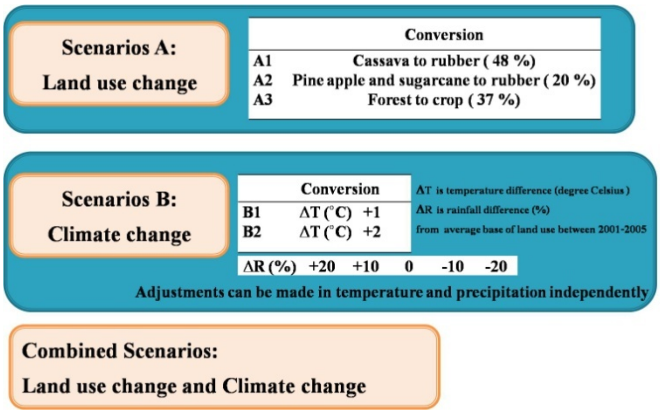

Fig. 3 Three scenarios of land use and climate change.

2.5 Climate and land use scenarios

In this study, the water availability scenario assumes that average surface temperature and precipitation will change in the future because of climate change. To estimate the future water use, the water use scenarios including assumptions about the trend in the driving forces of water use in the domestic, industrial and agricultural sectors. These conditions were adapted from the IPCC criterion (IPCC, 2007), and obtained using a variety of scenarios that are likely to influence future climate (Babel et al., 2011). The land use of year 2001 was used as the base case scenario for the study. Scenario A1, which refers to an increase in the para rubber area from 14 to 48% is motivated by economic and benefit condition through cassava conversion. Scenario A2, which refers to an increase of the para rubber area from 14 to 20% is motivated by economic and benefit condition through pineapple and sugarcane conversion. Scenario A3, which refers to an increase in the crop area from 30 to 37% is motivated by economic and benefit condition through forest conversion. Scenario B, the evaluated climate change scenarios, comparison of hydrological impacts of climate change simulated (Fig. 3). Adjustments can be made in temperature and precipitation independently. In order to cover a wide range of climate variability, 10 hypothetical climate change scenarios were derived from combinations of 2 temperature increases and 5 precipitation changes.

3. Results and discussion

In this process, calibration of the model involves calibrating the parameters to match closely the real spatial data.

3.1 Calibration and validation

The observed and simulated data for 2001–2003 are compared to assess the probability of calibration in this model. The most sensitive parameters were: the soil evaporation compensation factor (ESCO) of 0.77 and the initial SCS Curve Number II value (CN2) of 47. The statistical accuracy in this calibration with acceptable accuracy (R^2=0.76, Nash=0.55 and IA=0.84). The validation of the model requires comparison of the model results with an independent data set, without further adjustment. The observed and simulated data in 2004–2005 are compared to assess the probability of the validation of this model. The statistical accuracy in this validation with acceptable accuracy (R^2=0.69, Nash=0.47 and IA=0.89).

These results indicated that only a few parameters are sensitive to the runoff in the study area. The most important parameters are ESCO and CN2 which are closely connected to the climatic and hydrologic characteristics of the watershed. Otherwise, the climate scenario and land use factors are related to increasing and decreasing streamflow on surface water. Therefore, the result from the simulation has effect on water resource management for drought and flood situation in this area.

3.2 Effect of three scenarios set from land use change

Effect of three scenarios set from land use and climate changes. The water availability scenario assumes that average surface temperature and precipitation will change in the future because of climate change. The effect of three scenarios from land use is shown in Figs. 4 and 5. Runoff of scenario A1 is higher than other two scenarios and runoff in 2001 and 2004 higher than other years. The average annual runoff 2001 to 2005 which depend on three land use change scenarios and average runoff between 2001-2005 are shown in Fig. 5. Dry season starts from November to February in the next year and wet season starts from July to October.

3.3 Effect of three scenarios set from climate change

Average annual change in runoff is responsed to temperature increases for a given precipitation change. The slopes of the lines in each branch of lines reveal the changing rate of runoff in response to precipitation changes. The runoff changes are more sensitive to precipitation changes than to temperature. The study considered the impact assessment of water management related to the climate and hydrological changes, and an alternative adaptation scheme to reduce the impacts in Klongyai Basin. The result of various scenarios, in near and far future periods, shows that rainfall will be increased in September and October in wet season, according to decreasing rainfall in the dry season (November – April). These results agree with Chaowiwat and Koontanakulvong (2010) that the rainfall will be increased from August to October in the last wet season.

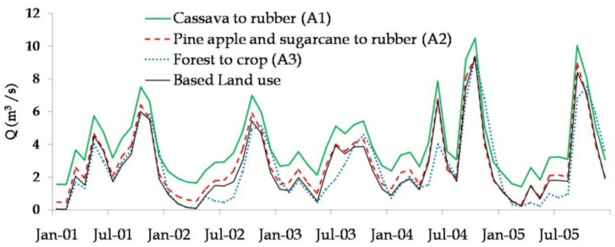

Fig. 4 Daily runoff of three scenarios.

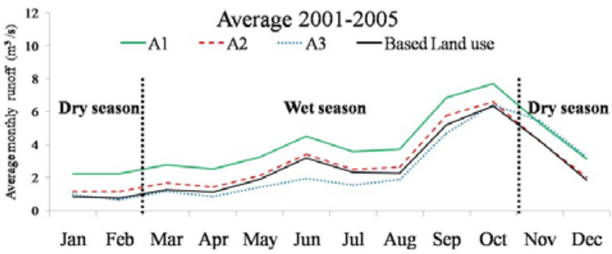

Fig. 5 Average monthly runoff of three scenarios.

4. Conclusion

Climate change scenarios are derived from combinations of two temperature increases and five precipitation changes. However, variable of climate change scenarios does not significant effect than parameter of land use change. The computational result of these scenarios can be utilized to advise the government to produce policy for water resources management. Since, forest and para rubber area is major effect on increasing of the rainfall and runoff in the basin which depend on economic and benefit conditions. According to analysis there are outstanding advantages of Para rubber, because of all part of the tree are useful for economic. To prevent the drought situation, the government should increase the forest and para rubber area in the basin. The existing water management will induce water deficit risk in dry season in the future. The greatest deficit sector is agricultural, domestic and industrial users. The spatial analysis leads to early warning and disaster management too. This can reduce the impact of disasters and help to develop a network of communities in risk areas for planning and building linkages between communities and government agencies, on issues such as the technical basis, to manage natural disasters.

5. Acknowledgement

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