Impact of Climate Change on Hydrological Regime of Khlong Krabi Yai Watershed, Krabi Province, Thailand

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Abstract

Khlong Krabi Yai watershed in Krabi Province, the western coastal province in the southern region of Thailand. The watershed provides water to support agricultural, consumptive, tourismas well as maintain integrity of Ramsar site wetland in the catchment. Change in water demand, especially from increasing oil palm plantation has raised concern on water balance of the catchment in longer term which climate change may also affect the hydrological regime of the catchment. This study evaluates the impact of climate change on future water resources of Klong Krabi Yai catchment using SWAT model. Future climate data, precipitation and temperature data from 5 Global Circulation Models, over the period of 2045-2064 show that annual rainfall will increase in range of 3% to 20% and mean annual maximum temperature will increase in range of 1.6 – 3.8 Degree Celsius while increasing of minimum temperature will be higher than maximum temperature. Under multiple climate change conditions, based on 5 projections, analysis result shows trend of increasing annual discharge of the watershed, however, the increase of discharge only occurs during the southwest monsoon season, from the month of May to October, while discharge level during the rest of the year would remain in the same range as present. This raised concern on imbalance in water supply and increasing water demand for agriculture and other sectors during the period of off-southwest monsoon season and strategy on water resource management should be formulated as adaptation plan to cope with this impact of climate change.

Key words: Klong Krabi Yai Watershed, SWAT, climate change, discharge

1. Introduction

Khlong Krabi Yai is the watershed in southern coast of Thailand in Krabi province. The key role of the watershed is supplying water primarily to support agricultural and tourism sectors in Krabi Province as well as to maintain integrity of a wetland Ramsar site, Krabi estuary. Agricultural in this area mainly comprise of rubber tree and oil palm plantation, which require substantial amount of water. Even though, rubber tree plantation may have low water demand in a dry season, however, Oil palm plantation, which has been expanding over the years from the national policy on renewable energy from bio-fuel, requires substantial amount of water throughout the year. Lastly, the tourism sectors, which its peak season is during December and May, has also been expanding from the government tourism promotion policy over the years, would substantially increase water demand. As mentioned, the changes in economic condition and its trend in the future indicate increasing in water demand during dry season, after the end of southwest monsoon season.

While change in social and economic development would drive change in water demand, the global warming and climate change may drive change in water supply of the watershed. This study will analyze impact of climate change on hydrological regime of the watershed in order to point out whether the change in water demand and water supply of the Klong Krabi Yai watershed would be of concern in the future or not.

2. Study area

Khlong Krabi Yai begins at Khao Phanom Banja mountain range, which lies from North to South along with the coastline. Its watershed in Krabi Province, is the catchment with size of 198 sq.km. (Figure 1) and about 132 meter high by average. It is the larger sub watershed of the two sub-watersheds that provide fresh water into Krabi River which is flows through the Krabi town into the Andaman Sea at Pak Mae Nam Krabi. The wetland area of 21.3 Sq.Km around Pak Mae Nam Krabi, Krabi estuary, is registered as Ramsar Site in 2001 year (Ramsar, 2007).

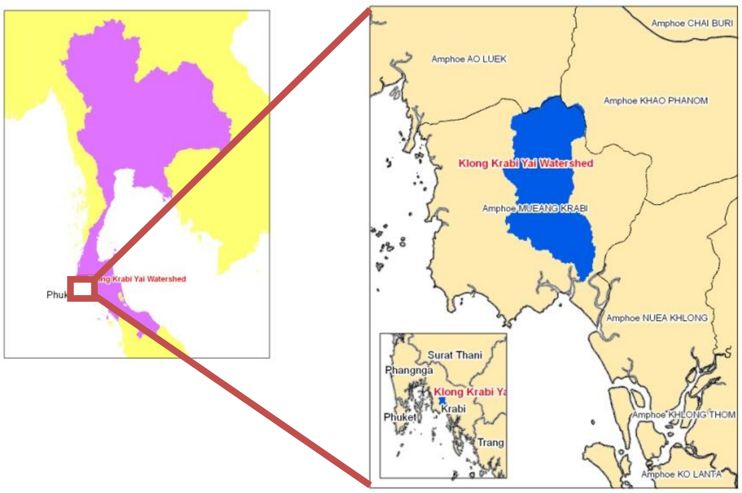


Figure1. Khlong Krabi Yai watershed (blue)

3. Methodology

This study assesses impact of climate change on hydrological regime of the Klong Krabi Yai watershed by analyzing change in monthly discharge of the river basin over the year in the future. The analysis based on hydrological modeling technique using Soil Water Assessment Tool (SWAT), to evaluate the stream flow at outlet of the watershed. Future flow would be simulated based on 5 climate scenarios using future climate data from projection of 5 global circulation models (GCMs) which is in the database of Climate Change Explorer Tool (CCE) by Stockholm Environmental Institute (SEI). Future discharge of the watershed from simulation result will be compared with the observed data in order to determine change and concerns from the change in hydrological regime of the watershed.

3.1 Climate Scenario Data: Key input for hydrology model

The Climate Change Explorer (CCE) is a tool that aims to facilitate the gathering of climatological information and its application to adaptation strategies and actions. The CCE packages data access routines with guidance and customized analytical and visualization procedures. It is designed to simplify the tasks associated with the extraction, query and analysis of climate information, thereby enabling users to address issues of uncertainty when devising policies and strategies, and also when implementing actions (SEI, 2009). Data from Climate Change Explorer (CCE)[1] developed by Stockholm Environmental Institute (SEI) and Climate System Analysis Group (CSAG), University of Cape Town which is point location information downscaled from 8 Global Circulation Models (GCMs) under A1B SRES greenhouse gas scenario provide the local (station-scale) response to the large scale forcing as

[1] Climate Change Explorer tool can be accessed at
http://wikiadapt.org/index.php?title=The_Climate_Change_Explorer_Tool

shown on the GCMs,that aims to facilitate the gathering of climatologically information and its application to adaptation strategies and actions. The CCE is designed to simplify the tasks associated with the extraction, query and analysis of climate information, thereby enabling users to address issues of uncertainty when devising policies and strategies, and also when implementing actions.

Because the future climate data at Krabi province, which is study area of this research, is not available in CCE database, therefore the future climate data for the study site needs to be prepared based on the analysis of relative change between future climate projections and baseline period of climate variables at Phuket Province, which is approximately 60 kilometer away and is in the same geographic zone and assumed to have the same influence of global warning in the same way as Krabi Province and also monthly rain distribution like Krbi province (see figure 3). The different in the simulated climate data between baseline period and future at Phuket province is applied to the baseline climate data at Krabi Province, which is actual observed data, in order to obtain future climate for the analysis on climate change impact on hydrology regime at the study watershed in Krabi Province, the stages of preparing climate scenario data is shown in figure 2. The analysis was based on relative change in climate variables, including precipitation, maximum temperature and minimum temperature, between baseline (1961 - 1980) and future (2045 - 2064) period from 5 climate models (see Table1) and used for adjusting observed data at the weather station in Krabi Province to represent future climate for the studied watershed.

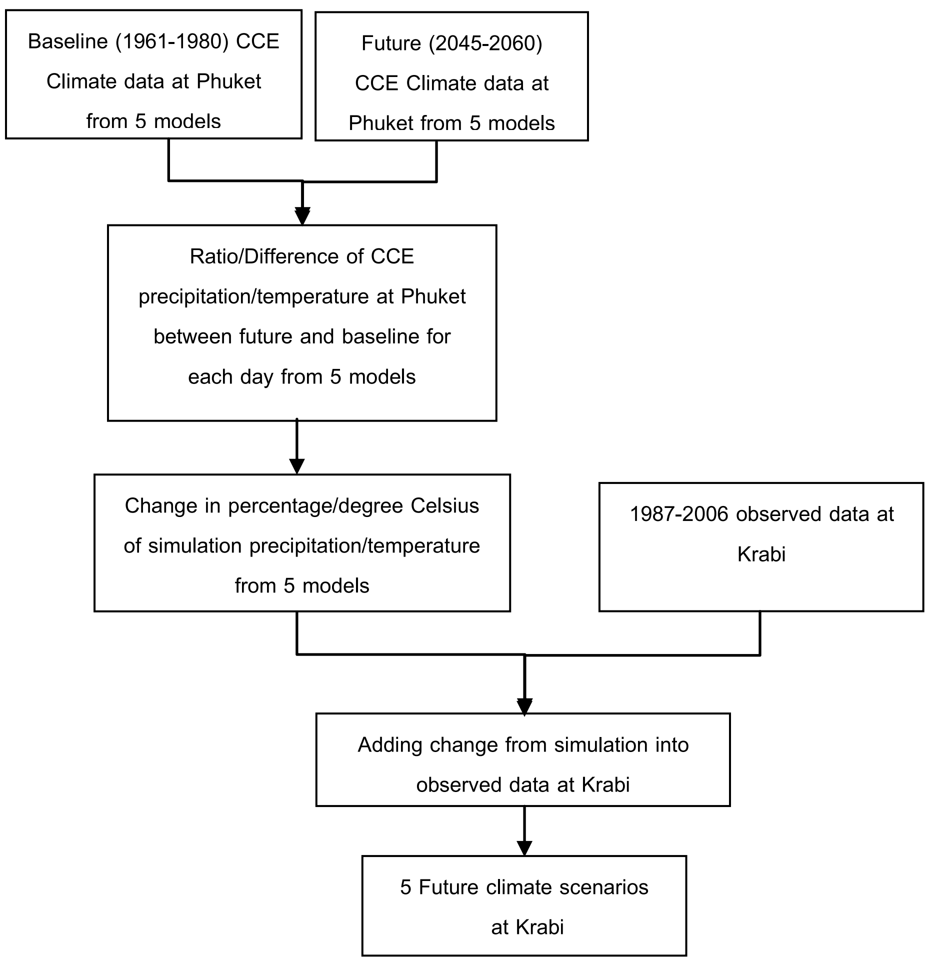


Figure 2. Diagram of preparing climate scenario data

Even though, baseline period of data in CCE tool does not match with available observed data in the study site, but the Phuket rainfall from the observation during the period of 1961-1980, which has mean annual rainfall of 2,512 mm., is closed to the rainfall during the period of 1987-2006, which has mean annual rainfall of 2,476 mm., so the data from 1987 to 2006 is assumed to be able for the use as reference in the study for the preparation of future climate data at the study site.

Table 1. 5 Climate Models were selected for the study

Model	Description
CCMA CGCM3 .1	Canadian Centre for Climate Modeling and Analysis, the third generatio n coupled global climate model (CGCM3.1 Model, T47).
MPI _ECHAM5	Max Planck Institute for Meteorology, Germany, ECHAM5 / MPI OM
CNRM_CM3	Meteo-France, Centre National de Recherches Meteorologiques, the thir d version of the ocean-atmosphere model (CM3 Model)
IPSL_CM4	IPSL/LMD/LSCE, France, CM4V1 Model
GFDL_CM2.0	NOAA Geophysical Fluid Dynamics Laboratory, CM2.0 coupled climate model

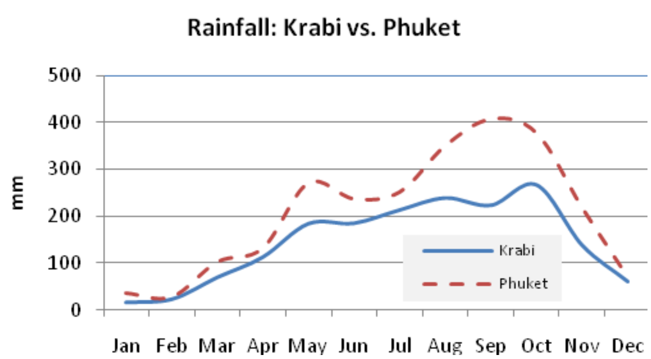


Figure 3. Mean monthly rainfall comparison between Krabi (Solid line) and Phuket (dash line) from 1987-2006

The future climate data is calculated by using difference technique for each variable. For temperature, difference between future climate (2045 - 2064), called CCE future from each climate model, and baseline climate (1961 - 1980), called CCE baseline, would be added into the mean daily temperature from observation data during 1987 to 2006 shown in eq. (1) while the preparation of future rainfall data for 2045 - 2064 would based on multiplying of mean daily rainfall during 1987 - 2006 with ratio of CCE future rainfall from each climate model to CCE baseline rainfall as shown in eq. (2).

$$T_{future}(i,j) = T_{Baseline}(i,j) + \left(T_{CCE\,Future}(i,j) - T_{CCE\,Baseline}(i,j)\right) \quad \text{------------------------- (1)}$$

When $T_{future}(i,j)$ is temperature in future at day i model j, $T_{Baseline}(i,j)$ is temperature in present at day i model j, $T_{CCE\,Future}(i,j)$ is temperature in CCE future at day i model j, $T_{CCE\,Baseline}(i,j)$ is temperature in CCE baseline at day i model j,

$$P_{future}(i,j) = P_{Baseline}(i,j) \times \frac{P_{CCE\,Future}(i,j)}{P_{CCE\,Baseline}(i,j)} \quad \text{------------------------- (2)}$$

When $P_{future}(i,j)$ is temperature in future at day i model j, $P_{Baseline}(i,j)$ is temperature in present at day i model j, $P_{CCE\,Future}(i,j)$ is temperature in CCE future at day i model j, $P_{CCE\,Baseline}(i,j)$ is temperature in CCE baseline at day i model j,

All models show trend of increasing rainfall during February to September which is divided as slightly increase during February to May and substantially increase in the southwest monsoon season from June to September, however the rainfall in the future during off-monsoon season from October to January does not change much as shown in Table 2. Figure 4 shows trend of increasing rainfall by comparison between baseline period and future using median value of the 5 climate models as well as range of future change from every models.

Table 2. Change in future rainfall at Krabi Province according to projection from 5 climate models (mm.)

	Change in rainfall (mm.)					
	mpi_echam5	cccma_cgcm3_1	ipsl_cm4	cnrm_cm3	gfdl_cm2_0	**Median**
Jan	8.8	4.2	-8.0	-9.3	-1.1	**-1.1**
Feb	-1.2	9.8	11.5	-6.3	13.9	**9.8**
Mar	43.1	15.8	34.7	28.9	54.2	**34.7**
Apr	40.2	1.0	33.7	4.3	64.1	**33.7**
May	44.6	48.4	6.8	14.0	17.0	**17.0**
Jun	20.6	74.6	49.6	8.2	58.8	**49.6**
Jul	83.7	91.7	127.0	71.8	71.2	**83.7**
Aug	47.1	82.1	156.7	38.9	34.4	**47.1**
Sep	32.6	77.6	62.6	38.9	18.7	**38.9**
Oct	1.0	57.4	42.9	4.9	2.2	**4.9**
Nov	-5.4	-2.1	-22.5	-46.4	45.5	**-5.4**
Dec	6.0	6.8	-12.4	-19.7	10.7	**6.0**
Total	321.1	467.5	482.5	128.1	389.5	**389.5**

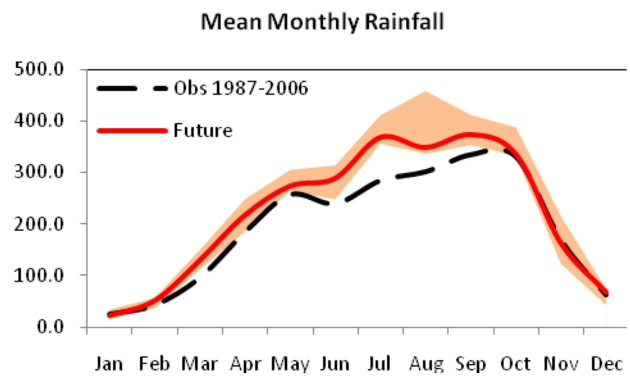
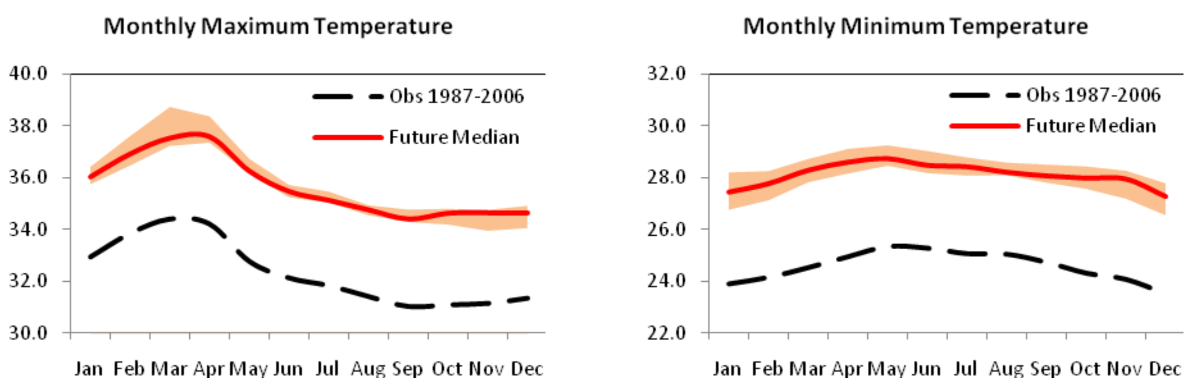


Figure 4. Comparison of mean monthly Rainfall on observation (dash line), median value from 5 climate models (solid line) and range of future rainfall from 5 climate models

Figure 5(a) shows comparison of maximum temperature in future and present including maximum and minimum range from every model (shown by shaded area). The maximum temperature trends to increase about 3.0-3.8 Degree Celsius. Figure 5(b) shows comparison of minimum temperature in future and present including maximum and minimum from every model (shown by shade area). The minimum temperature trends to increase about 3.1-4.0 Degree Celsius.



(a) (b)

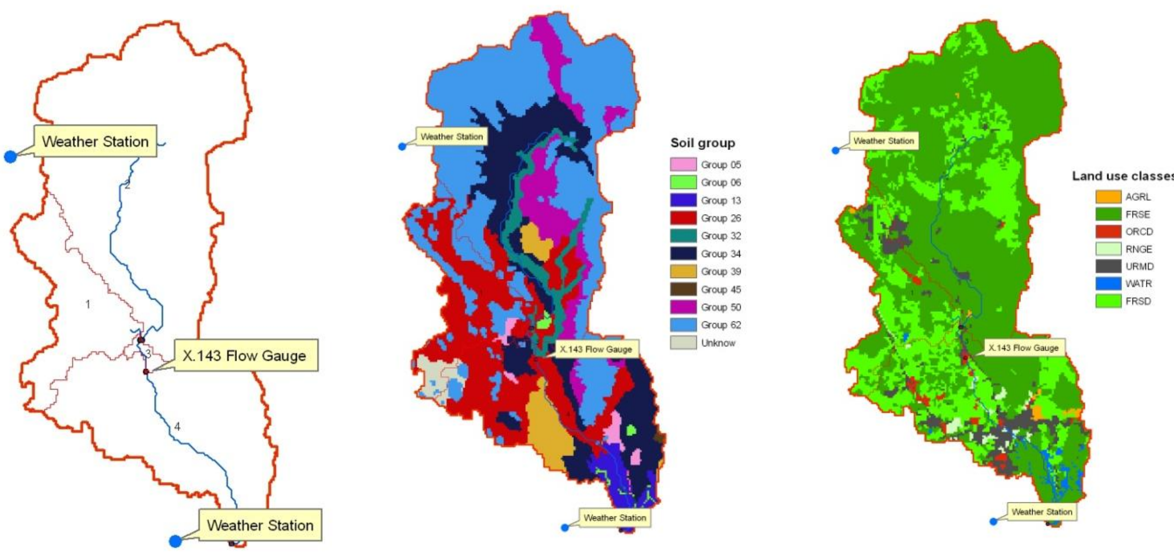
Figure 5.(a) Mean monthly maximum temperature comparison between present and future. (b) Mean monthly minimum temperature comparison between present and future

3.2 SWAT model setup

SWAT model has undergone continuous development by U.S. Department of Agriculture since 1990 (Williams et al., 2008; Gassman et al., 2007). SWAT was developed to predict the impact of land management practice on water, sediment and agricultural chemical yields in large complex water shed with varying soils, land use and management conditions over long periods of time (Neitsch et al., 2005). Simulation of hydrology of a watershed can be separated into two major divisions, land phase and routing phase of hydrological cycle base on water balance. The sub division of the watershed enables the model to reflect differences in evapotranspiration for various crops and soils. Runoff is predicted separately for each HRU (Hydrologic Response Unit) which is unit of analysis in the model and routed to obtain the runoff for the watershed (Neitsch et al., 2005).

The model requires topographic, soil, landuse and weather data for simulating hydrological regime of the watershed. Digital Elevation Model (DEM) was provided by SRTM (Shuttle Radar

Topography Mission) at 90 meter to delineated watershed by the model. The delineations of the Khlong Krabi Yai watershed was done by using SWAT which divided the basin into 4 sub-basins according to DEM, soil data and theirs properties was based on soil group which was classified by Land Development Department (LDD) as shown in figure5c. Landuse data chosen for calibration is based on landuse of 1985 by LDD, which is the same period as the time of measured flow period. The more update landuse of 2007 as shown in figure 6b is chosen for analyzing change in hydrological regime in both present and future period. Observed data from 2 stations, which were used as baseline data, were collected from the Thai Meteorological Department (see figure 6a). These data consisted rainfall, maximum and minimum temperature during 1987 to 2006. Measured stream flow at x.143, Ban Khlong Yai, during 1987 to 1989 was collected from Royal Irrigation Department (RID) and used for model calibration.



(a) (b) (c)

Figure 6. (a) Khlong Krabi Yai watershed delineated by SWAT model base on SRTM DEM (b) Soil group map and (c) Landuse classes in 2007

3.3 SWAT Model Calibration

Hydrologic model calibration is based on comparisons between simulated and measured flow rates. There is only 3 years of measured flow data at x.143 Flow Gauge, from 1987 to 1989 for SWAT model calibration. Although there is limitation in the data but SWAT model can well simulate the river flow as indicates by the result of R^2 statistics for daily and monthly of 0.73 and 0.91 respectively (see Table 3) . Figure 7 shows comparison of river flow between measured and simulated during 1987-1989 and alsorainfall.

Table 3**.** Calibration result for Khlong Krabi Yai at x.143

Catchment area (km^2)	Calibrated Period	Monthly	Daily
198	1987-1989	0.91	0.73

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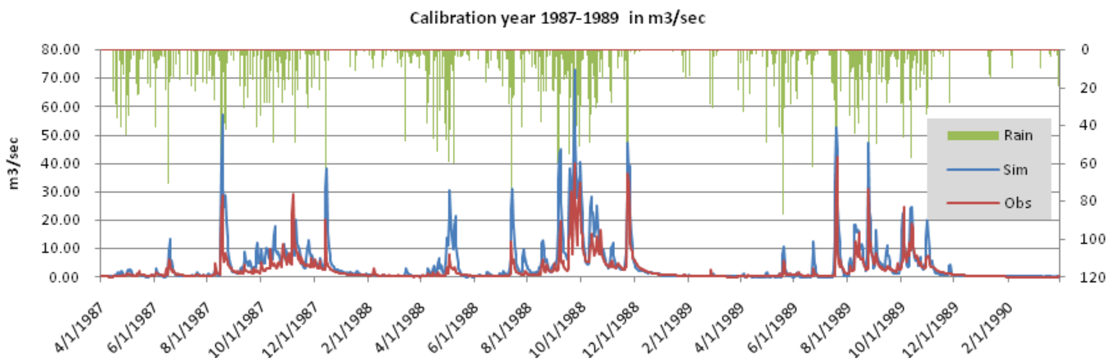

Figure 7. Comparison between simulated and measured flow during1987-1989

4 Result

The analysis result shows that impact of climate change may increase discharge of the watershed. The simulation shows increasing in discharge of the watershed under future climate projections from almost every climate models, namely CCMA CGCM3.1, MPI _ECHAM5, CNRM_CM3, IPSL_CM4 and GFDL_CM2.0 (see Figure 8). Increasing in discharge of the watershed is in the range of 45% - 16%. Only one climate model, MPI ECHAM5 shows decline of river flow in the future, which annual discharge of the watershed may decrease by 8%. However, even though the annual discharge of the watershed would increase, but the increasing of discharge is not equally distributed throughout the year, the increase in river flow would occur during the southwest monsoon season especially during the month of June to October. But in dry season from November to March, river flow trend to slightly decrease. The change of river flow in future under future climate condition as projected by 5 climate models is shown in table 4.

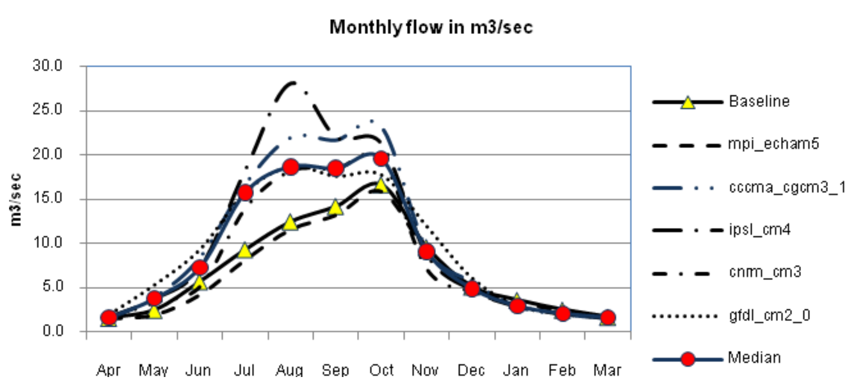

Figure 8. Comparison of river flow between present and future from 5 models, i.e. MPI_ECHAM5, CCMA CGCM3.1, IPSL CM4, CNRM CM3, GFDL CM2 and median values from theirs.

Table 4. Change of river flow in the future based on future climate from 5 climate models

	Change in %					
Monthly	mpi_echam5	cccma_cgcm3	ipsl_cm4	cnrm_cm3	gfdl_cm2_0	**Median**

Jan	-4	-19	-20	-19	-19	**-19**
Feb	-8	-18	-16	-22	-18	**-18**
Mar	-6	-6	-3	-3	2	**-3**
Apr	-6	-2	10	2	24	**2**
May	-22	62	52	34	115	**52**
Jun	-26	49	28	-10	64	**28**
Jul	-13	80	97	51	70	**70**
Aug	-7	76	126	46	50	**50**
Sep	-7	53	55	30	24	**30**
Oct	-5	39	28	18	7	**18**
Nov	-5	-2	-8	-26	25	**-5**
Dec	-4	11	-7	-12	18	**-4**
Annual average	-8	40	45	16	31	**25**

5 Discussion and Conclusions

The analysis on impact of climate change based on data for 5 climate models, even through, the result vary from model but they can provide clear discharge of future change with higher level of confidence than the single climate model. This could lead to future analysis on value on input of climate change on hydrological regime ensemble result of the watershed from multiple models to get a representation.
As analysis on future change in discharge of Klong Krabi Yai watershed based on future climate projection from most climate models suggest that the annual discharge of the watershed would only substantially increase in the rainy season during the southwest monsoon period while discharge of the watershed in the dry season may not change or even decrease in some cases, there would be risk of water shortage during dry season in the future due to increasing in water demand from expanding oil palm plantation and tourism activity. This would raise concern in the adjusting water management policy as adaptation response to impact of climate change on hydrological regime of the watershed. Water harvesting and storage from the rainy season during southwest monsoon season is recommended for policy planner in Krabi Province, especially to support agriculture sector and tourism industry. Moreover, improvement in higher efficiency of water usage needs to be planned to cope with the higher risk of water shortage during the dry season.

6 Acknowledgement

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