The assessment of climate change impact on extreme flood and drought in Yom and Nan River basin, Thailand

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***Abstract*—The climate change effects will be intensified continuously and become a severe problem in the future. The majority of people are anxious about the damage caused by this problem. Thailand always has been suffered from flood and drought disasters which are likely to be intensified by climate change especially in Yom and Nan River basin. Damages to the local people and also country income loss are concerned because this region is the important agriculture area. This study aims to assess the impacts of climate change on extreme natural hazard events consist of flood and drought in the Yom and the Nan River basins. The climate change are considered from rainfall and temperature predicted by Global Climate Model (GCM). These variable are adjusted by using a bias correction method namely the shifting and scaling method. In addition, the hydrological model is used for river runoff simulation with climate data and topography data. The model is validated by comparing the simulated results with observation data and using the efficiency coefficient. As for analysis of extreme events, we calculated the Standardized Precipitation Index and (SPI) and Standardized Runoff Index (SRI) of each subbasin.**

Keywords—Climate change; Extreme flood; Extreme drought; Standardized Precipitation Index; Standardized Runoff Index; Yom River basin; Nan River basin

I. INTRODUCTION

Over, the past few decades. The heat waves and bushfire weather are intensified continuously due to the climate change. The change of climate condition cause more intense extreme weather events and devastation around the world such as intense cyclones and heavy rainfall events [1]. These have directly impact to the occurrence of various natural extreme events. To prepare for several severe impacts, many researchers have attempted to study in this issue.

In Thailand, flood and drought disaster have always occurred and caused a widely damaged to lives and property especially at the northern part. Moreover, there is a tendency to intensify in this issue in the future, according to several study. For example, there was a high risk of water deficit in several basins due to the water demand increase while the rainfall are decreased. This is suitable for severe drought conditions and water shortages especially in the upper part of Thailand where the water demand tends to increase more than lower part [2]. Next, when the availability of irrigation water in the main supply area of irrigation water for the hill tribes is declined, it influences to the inhabitant of local people because their livelihoods have related with the irrigation water and cause a limitation of agricultural adaptations especially in dry season [3]. The increasing trend of water availability in wet season indicates more flood frequency and intensity [4]. In the southern part of Thailand, there was an upward trend in annual rainfall and mean annual maximum temperature. It effects to the increase of discharge especially in southwest monsoon season then the flood disaster can occur easily [5]. Moreover, the difficulties in water management of reservoir which are formed by the fluctuation between rainfalls from spatial uncertainties and averaged has a direct impact on the agricultural sector [6]

Hence, it is necessary to study in the future phenomena of extreme flood and drought for a sustainable management and protection. This study aim to assess the probability of extreme flood and drought in Yom and Nan River basins by considering on change of river runoff due to the climate change.

II. HYDROLOGICAL MODEL

The Soil and Water Assessment Tool (SWAT) model is the conceptual model. Watershed is divided into a subdivision by considering a direction of main stream channels. The features of land use activities and soil properties are defined in Hydrologic Response Units (HRUs) of each sub-watersheds. The HRUs is represented in term of four storage volumes which are snow, soil profile (0–2 m), shallow aquifer (2–20 m) and deep aquifer (>20 m). For river routing, the direction of streamflow is controlled by the river path in order to flow through a channel, reservoirs and outlet of the watershed, respectively. This model uses the principle of SCS curve number or Green-Ampt infiltration equation (layered storage routing technique combined with a crack flow model) to simulate the Hydrology processes. In addition, the storage routing technique is applied to predict the water that flow through each soil layer. When the field capacity of the soil layer is exceeded and the lower soil layer was not saturated at that time, the flow had been dropped. On the other hand, if the field capacity of the next lower layer is over, the upward flow may be occurring. The ratio between soil water content and field capacity of both layers is the variable that control the movement of lower layer to an adjoining upper layer. The groundwater flow contribution to total streamflow and flow rate are simulated by routing a shallow aquifer storage component to the stream and saturated hydraulic conductivity of the soil layer respectively [7].

III. STUDY AREA

Yom and Nan River basin, two important basins of Thailand, are almost half of Chao Phraya River basin. Both basin locating in the north of Thailand as show in *Fig. 1* cover 58,728.93 sq.km of 11 provinces.

Yom River basin has the area of 24,046.89 sq.km from the north to the south between lat. 14°50´ long. 99°16´ and lat.18°25´long. 100°40´. Upstream area begin at Doi Khun Yuam in Phayao province and confluent with Nan river at Nakhon Sawan province. The large majority of rainfall are occurred during wet season (May to October) approximately 1,260.4 mm. per year on average. Main water demand is used for agriculture about 80%. In addition, there is no dam in Yom River basin. That is one of the reason that flood and drought disaster always occur in this basin.

Nan River basin locating between lat. 15°42´ long. 99°51´ and lat.18°37´long. 101°21´ from the north to the south cover the area of 34,682.04 sq.km. Watershed started at Luang Prabang Mountains which is the boundary between Thailand and Laos. There was a similar pattern of average annual rainfall with Yom River basin that occur in rainy season (May to October) around 1,287 mm. and also the trend of water use as the most of water is used for agriculture. However, there was Sirikit dam located at the central of basin for water management so when compare with Yom River basin, the problem of flood and draught hazard are not severe [8].

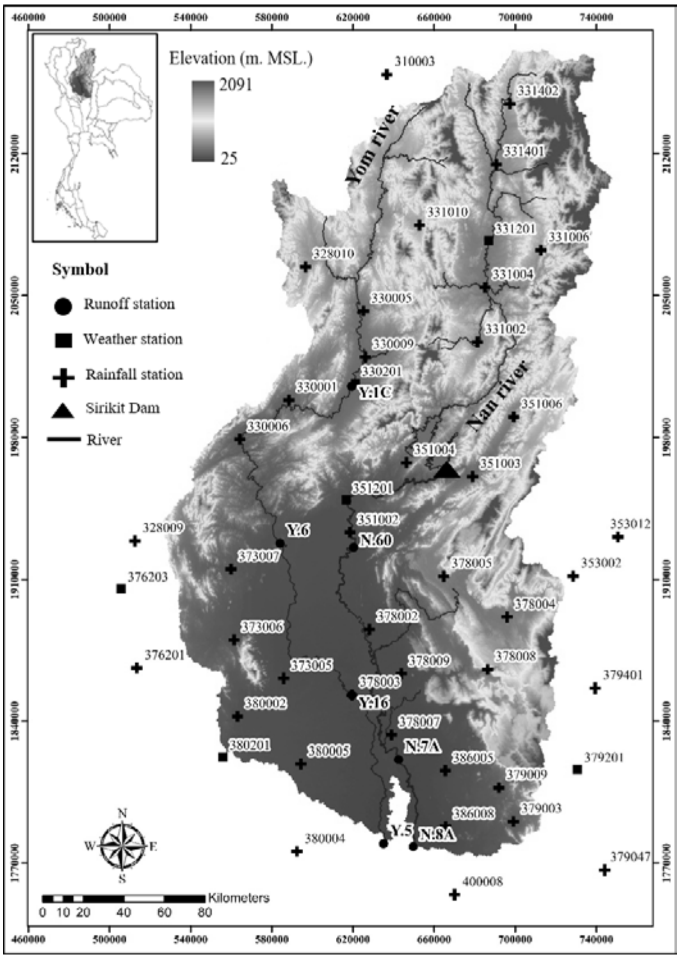

Fig. 1. Yom and Nan River basin

IV. GCMS DATA AND BIAS-CORRECTION METHOD

The GCMs data which is a predicted climate data such as precipitation and temperature can be downloaded via data server of H08 model collected by National Institute for Environmental Studies, Japan (NIES). There are many GCMs data provided in this server but the most complete of information available for study area are 10 GCMs listed in *Table 1*.

However, it is almost impossible to use these GCMs output directly due to a systematic distributional biases from grid sizes in several scale of area [9]. To remove this bias, these GCMs output are compared with observation data and use the Bias-correction method for adjustment. The Bias-correction method is statistical technique that have been profusely developed and used so there are several type of them in recently. The shifting and scaling method is one of the bias correction method that widely use due to its simplicity and straightforward application [10]. In this method, biases is adjusted base on the observation data.

TABLE I. LIST OF CMIP5 GCMS USED [11]

Model	Institution
bcc-csm1-1-m	Beijing Climate Center(BCC),China Meteorological Administration,China
CNRM-CM5	Centre National de Recherches Météorologiques / Centre Européen de Recherche et Formation Avancée en Calcul Scientifique
CSIRO-Mk3-6-0	Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence
GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory, National Oceanic and Atmospheric Administration (NOAA)
HadGEM2-ES	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
IPSL-CM5A-MR	Institut Pierre-Simon Laplace
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies and Japan Agency for Marine-Earth Science and Technology
MPI-ESM-MR	Max Planck Institute for Meteorology Earth System Model MR.
MRI-CGCM3	Meteorological Research Institute
NorESM1-M	Norwegian Earth System Model, Norwegian Climate Centre

V. METHODOLOGY

A. *Model simulation and calibration*

Initially, the watershed is divided into several subbasins and then classified into a number of Hydrological Response Units (HRUs) with specific land use and soil type. The geological data define a characteristic of watershed consist of Digital Elevation Model (DEM), land use and soil properties data. DEM has 90 m. resolution created from Shuttle Radar Topography Mission (SRTM) by The National Aeronautics and Space Administration (NASA). Meanwhile, the land use and soil properties data can be received from Land Development Department (LDD). The meteorological data are precipitation, maximum and minimum air temperature, dew point temperature and wind speed. This determine a weather condition that directly relate to the hydrological regime in watershed. In this study, the precipitation data is daily rainfall intensity, but the other are monthly. It is interpolated by using Thiessen Polygon method for distribution. These observation weather data are collected from 38 rainfall stations and 10 weather stations of Thai Meteorological Department (TMD) as show in *Fig.1*.

Model are investigated by compared a results with hydrological observation data. The hydrological data used for calibration consist of daily river discharge and information of Sirikit dam from Royal Irrigation Department (RID) and Electricity Generating Authority of Thailand (EGAT), respectively.

B. *Climate change effect and extreme event assessment*

The GCMs output (precipitation) are compared with observation data during reference period from 1981-2005 to select the most three appropriate GCMs. Then, after adjusted the bias by using shifting and scaling method, these predicting data are simulated by SWAT model to assess the future situation of hydrological regime between 2021 and 2095. It is considered on scenarios RCP 2.6 and 8.5 which are and the minimum and maximum issues of global annual GHG emissions, respectively and separated into 3 phases, namely near future (2021-2045), immediate future (2046-2070) and far future (2071-2095). The comparison regarding every future scenario and reference period

For extreme flood and drought analysis, The Standardized Precipitation Index (SPI) and Standardized Runoff Index (SRI) are widely used. Both index are estimated by considering on the probability of precipitation and runoff for any time scale. The rainfall from bias correction method and runoff from SWAT model simulation are transformed into index by fitting to a probability distribution and transforming into a normal distribution, respectively. The timescales of SPI and SRI used for extreme event consideration is 6 months because this timescales is effective to represent the precipitation over distinct seasons and related with unusual streamflows and reservoir levels. The violence of flood and drought based on SPI and SRI is shown in *Table 2* [12]**.** In addition, Peak discharge value and Flow Duration Curve (FDC) of each predicting cases are compared with observation data for extreme event analysis also.

TABLE II. THE CLASSIFICATION OF SPI AND SRI

Index value	Category
Higher than 2.0	Extremely wet
1.5 -1.99	Very wet
1.0 -1.49	Moderately wet
-0.99 -0.99	Near normal
-1.0 - -1.49	Moderately dry
-1.5 – 1.99	Very dry
Less than -2.0	Extremely dry

VI. RESULT AND DISCUSSION

A. *Model evaluation and GCM selection*

Table 3 provide the information concerning the NSE and RMSE [13] value computed for model evaluation. It can be seen that SWAT model has a high performance of river runoff simulation in every station. The whole stations provide a high value of NSE that totally higher than higher than 0.75 [14]. The second highest value of NSE are Station Y.16 and N.8A which located at the lower part of Yom and Nan River basin, accounting for 0.908 and 0.878, accordingly. Meanwhile, the RMSE value of them are lower than 20% of average discharge that are a good criteria. Station Y.1C has the minimum value of RMSE amounting to 53.871 m3/s., while the maximum value is 117.187 m3/s at inlet flow of Sirikit Dam.

Fig.2 show the comparison of precipitation from GCMs output and observation data during the reference period (1981-2005). CNRM-CM5, MPI-ESM-ES and MIROC5 are the most 3 GCMs which overall are consistent with observation data even the result in some month are dissimilar. While, CSIRO-Mk-3-6-0 and bcc-csm1-1-m are overestimated. Whereas, HadGEM2-ES is underestimated

TABLE III. *NSE* AND *RMSE* VALUE OF RUNOFF STATIONS

Station	***NSE***	***RMSE***
Y.1C	0.82	53.871
Y.6	0.809	82.905
Y.16	0.908	68.335
Y.5	0.873	96.313
Inlet of Sirikit Dam	0.802	117.187
N.60	0.759	83.618
N.7A	0.858	108.613
N.8A	0.878	106.773

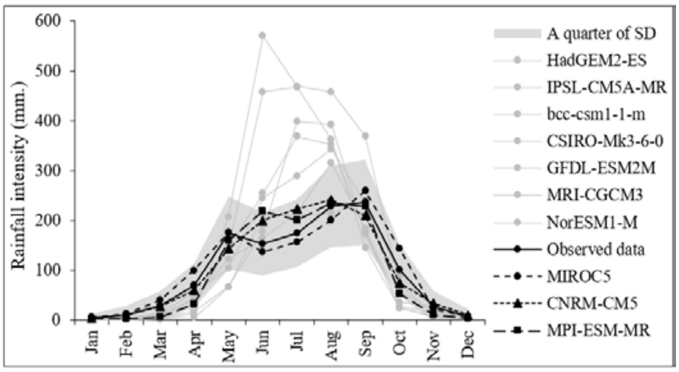

Fig. 2. Rainfall intensity from observation and GCMs during the reference period (1981-2005)

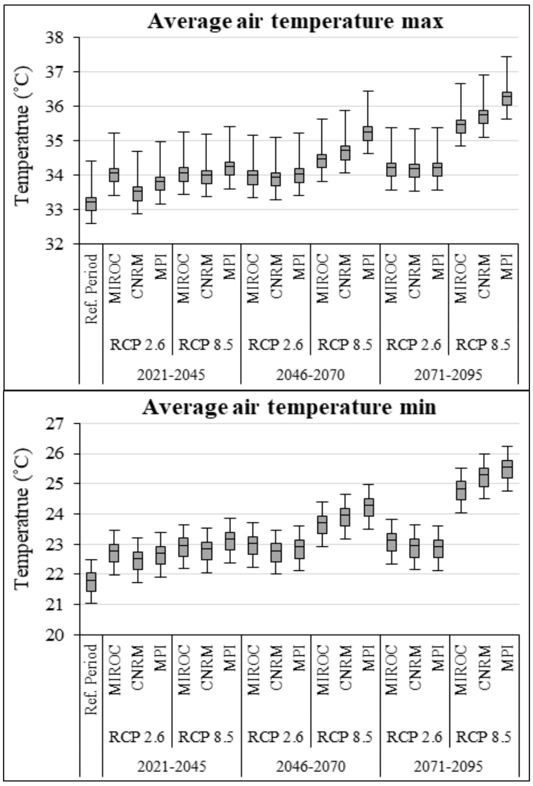

Fig. 3. Box plot of average air temperature max and min in reference period, near, immediate and far future under scenario RCP 2.6 and 8.5

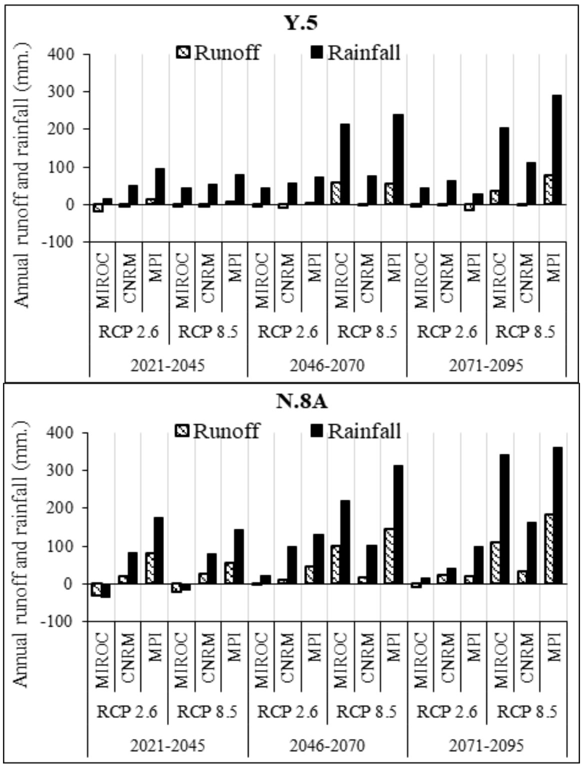

Fig. 4. Annual runoff and rainfall change in reference period, near, immediate and far future under scenario RCP 2.6 and 8.5

B. Impact of climate change assessment

Fig.3 provide the information about the average air temperature in the future compared with reference period in Box plot graph to show a distribution of results in several statistical index. The center line and box limits indicate a value of median, 1st and 3rd quartiles, respectively. Meanwhile, the maximum and minimum values are indicated at top and bottom bar, respectively. This can see that the air temperature max and min in the future both scenarios RCP 2.6 and 8.5 are totally higher than reference period in every statistical index. However, under scenario RCP 2.6, trend of air temperature are slightly increase, but there is a dramatic increase under RCP 8.5.

Considering on the annual runoff and rainfall change, the amount of rainfall has an increasing trend from reference period in the future especially under RCP 8.5 which are a significant trend since near until far future. While, under RCP 2.6, it remains constant after increase at near future. In addition, there are similar number in amount of runoff at Yom River basin throughout every future period under RCP 2.6 including near future under RCP 8.5 as shown in *Fig.4*. This is because most of rainfall rise is in a high evapotranspiration duration of the year (March-June). It effect to the amount of annual runoff value that are not different from reference period. However, there are an obviously upward trend in amount of runoff in almost case at Nan River basin including immediate and far future under RCP 8.5 at Yom River basin.

C. *Extreme flood and drought analysis*

When focusing on the average runoff during wet season (May-October) and dry season (November-April) shown in *Fig. 5*, it can see that most of runoff are increased in wet season. The large majority in runoff increased during wet season are occurred since immediate future onward under RCP 8.5. While, under RCP 2.6, a change of annual rainfall are stay the same from reference period. This mean that the magnitude and frequency of flood disaster are become severe in the future under RCP8.5. Interestingly, upper Nan River basin which is the area over the Sirikit dam has an increase of wet season runoff completely throughout every future period. Moreover, it can also be noted that there are a downward trend in runoff during dry season in some case. This can be simply explained that magnitude and frequency of drought disaster can be greater in some region or some period.

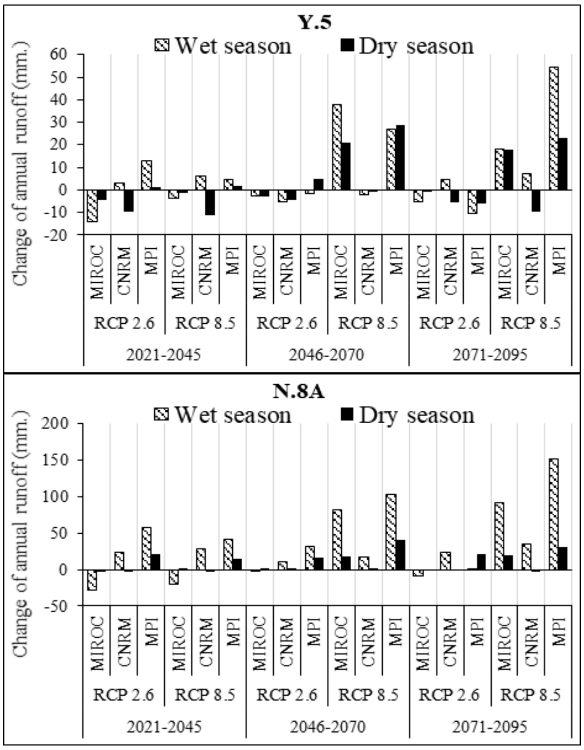

Fig. 5. The runoff change during wet and dry season in reference period, near, immediate and far future under scenario RCP 2.6 and 8.5

Fig.6-9 provide the information concerning SPI and SRI of each runoff station, respectively. In practically, SPI are generally used to analyze extreme flood and drought than SRI because SPI present the amount of runoff from rainfall directly without external factors. However, at the area located below the dam, the behavior of streamflow are controlled by reservoir operation so it is necessary to consider SRI couple with SPI. When compare with SPI during reference period, it found that the possibility of extreme flood and drought in most area of both basins are remain constant from reference period under scenario RCP 2.6. However, there still are a slight upward trend in the number of extreme drought at upper Yom River basin and downstream area below Sirikit dam. Meanwhile, under scenario RCP 8.5, the extreme flood probability rise dramatically since immediate future onward. For extreme drought, there are a slightly upward trend in near future. Next, it decrease at immediate future and increase again in far future except the area over the dam which has a declining in proportion of extreme drought event since near to far future. Furthermore, SRI represent a similar trend in the extreme flood and drought probability to that of SPI. Scenarios RCP 8.5 provide a dramatic increasing trend of extreme flood in Yom and Nan River basin, while trend of extreme drought are similar. However, under RCP 2.6, the upper Yom River basin and downstream area below Sirikit dam have not only a rising trend of extreme drought but also there are the extreme flood.

One noticed that, The Shifting and Scaling method, used for bias-correction, removed only the mean annual/monthly biases. The biases for over/under-estimation of the interannual/diurnal range might still exist in Extreme event analysis. This mean that the possibility of extreme flood and drought in the future are more likely to occur than analyze.

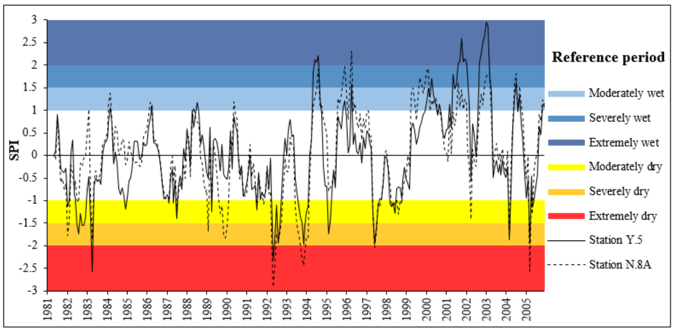

Fig. 6. The Standardized Precipitation Index in reference period of station Y.5 and N.8A

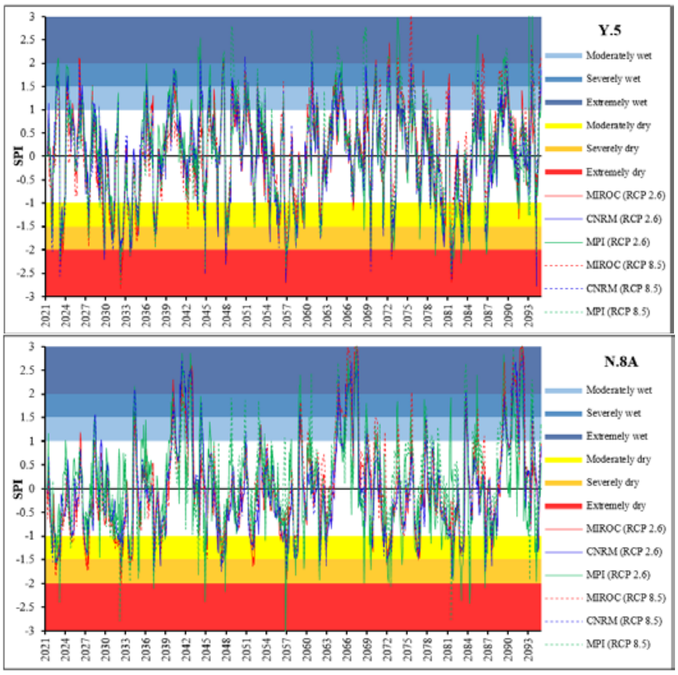

Fig. 7. The Standardized Precipitation Index in predicting period of station Y.5 and N.8A under scenario RCP 2.6 and 8.5

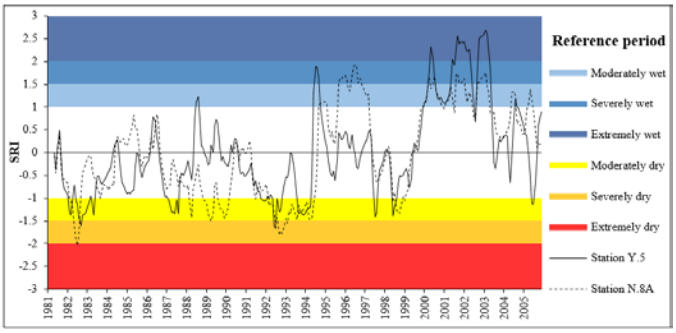

Fig. 8. The Standardized Runoff Index in reference period of station Y.5 and N.8A

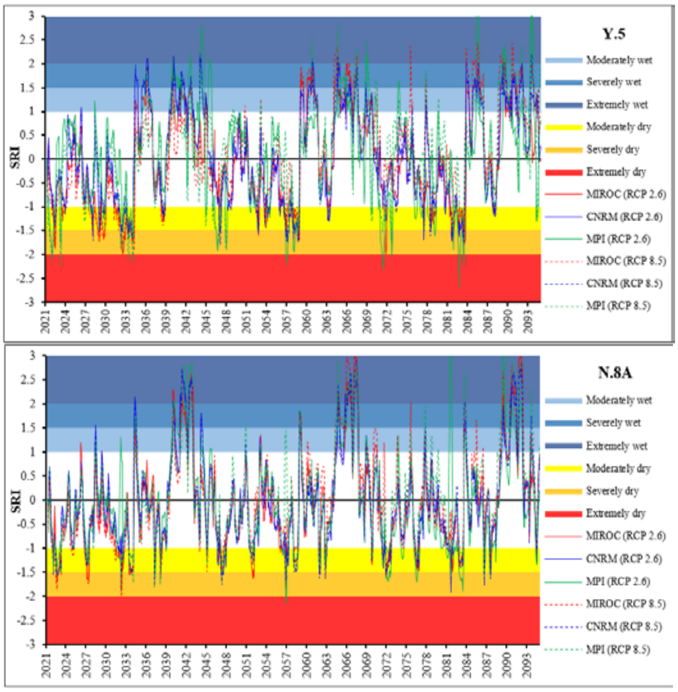

Fig. 9. The Standardized Runoff Index in predicting period of station Y.5 and N.8A under scenario RCP 2.6 and 8.5

VII. CONCLUSION

According to the results, it can be summarized that there is a slow and fluctuated increasing trend in air temperature, annual rainfall and runoff under RCP 2.6. However, scenario RCP 8.5 provide a significant rising trend of them in Yom and Nan River basins during immediate and far future.

Based on the change in rainfall and runoff including Standardized Precipitation Index and Standardized Runoff Index. Under RCP 2.6, the extreme flood and drought in almost area of Yom and Nan River basin are remain constant from reference period. However, there still are a slight upward trend in extreme drought in some period at upper Yom River basin and Lower Nan River basin. Whereas, under RCP 8.5, there are a significant upward trend in the frequency and violence of extreme flood since immediate future onward in both Yom and Nan River basins. While, extreme drought show a slightly upward trend in near future, then decrease at immediate future and increase again in far future except the area over the dam.

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