THE IMPACTS OF CLIMATE CHANGE ON IRRIGATION WATER REQUIREMENT FOR SPRING SEASON PADDY IN HA NOI CITY, HA NAM, HUNG YEN AND NAM DINH PROVINCES

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Abstract: *In this paper, irrigation water requirement of spring season paddy with the meteorological data at Lang, Ha Nam, Hung Yen, and Nam Dinh rain gauge stations of Vietnam are forecasted, based on the projected meteorological data of 6 global climate models under A1B climate change scenario after using the bias correction and spatial downscaling to increase the horizontal resolution. The irrigation water requirements are simulated by CROPWAT model version 8.0. The calculation results show an increasing trend under the climate change in the most models when compared with present result, except the results of the CCCMA_CGCM3_1 model. The results of MIROC3_2_MEDRES, and MRI_CGCM2_3_2a models gives the highest increasing values. In Ha Nam province, the irrigation water requirement increases significantly to over 360 mm compared with 260 mm of referent period. Next increase value is in Ha Noi and Nam Dinh provinces, around 300 mm in 5 models. The irrigation water requirement would continue increasing trend in the far future from 2080-2099 when compared with the year 2050-2069 and reference period (1980-1999) in all models. It means that the increment/decrement of irrigation requirement has a strong relationship with the climate variable such as temperature and rainfall under the impacts of climate change.*

Keywords: spring season paddy, irrigation water requirement, Global climate models,

1. INTRODUCTION

Climate change is now one of the serious problems of human society and the threats of the planet. Under the global warming, the rainfall and temperature would significantly change and caused many of the economic and human losses. Especially, in recent decades, the climate change is one of the challenges that humanity has to face. Climate change impacts on most of the sectors such as agriculture, industry, services. Global Warming and changes significantly when the temperature series throughout the world as the most important aspects of climate change in the twenty-first century are assessed. Several studies, increasing the average surface temperature have been confirmed. Calculations based International Institute for (IPCC) land and ocean temperatures average between 0.3-0.6 degree Celsius between the years 1900 to 1995 and have an upward trend in temperature about 0.2 to 0.3 degree Celsius in 40 years (IPCC, 2001). Daily and night temperatures in the Centre, South, and East Europe have reviews (Neidzweidz, 2012). For hundreds of years, the global climate is gradually warming as the main characteristic of the significant change; average temperature has increased 0.74°C.

The water demand for all sectors such as industrial and municipal uses in developing countries would be expected to exceed water demand for agriculture purpose between 1995 and 2020 (Rosegrant and Ringler, 1997). The requirement of food in the world will increase significantly in the future. An estimated results of Lee et al show an increase to 35% in 2020 in global rice demand when compared to the demand in 1995. Due to the upward trend in the rice production, so constraints on water resources for agriculture would be more aggravated not only in the developed countries but also in the developing countries (Lee and Haque, 2005).

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In the past decade, the impact of climate change has been particularly evident in Vietnam with the repeated occurrence of extreme events such as typhoons, heavy rain, droughts, and floods. Global warming is the significant influence in agricultural and food security. Every year, Viet Nam is the second export rice country in the world. The northern region of Vietnam, one of the biggest region of rice production, is heavily affected by climate change. Crop water and irrigation water requirements should be changed under the background that the relationship of precipitation and soil moisture has been influenced by the global climate change. General Circulation Model (GCM) from the IPCC was used to assess the impact of climate change. Using the climate variable data from the output of GCM, the change trends of crop water and irrigation water requirements are analyzed in the future. Serious water shortages are being occurred in many countries in the world, especially in Vietnam and water requirement for agriculture is becoming increasingly more and scarcer because of the water demands from different sectors increase too. The agricultural sector is the largest water consumer in Vietnam with near 80% of total water demand, so the more efficient use of water in agriculture needs to be the topmost priority.

The objective of this research is to study the variation of irrigation water requirement for spring season paddy using the CROPWAT model under the climate change with A1B scenario, with two periods 2050-2069 and 2080-2099 at Lang, Ha Nam, Hung Yen, and Nam Dinh stations of Vietnam. The location of research area showed in **Figure 1**. This paper has been organized in the sections, In Section 2, an overview of the dataset and methods is presented. Section 3 gives the discussion of the variation of irrigation water requirement for spring season paddy. Finally, a summary is given in Section 4.

2. DATA AND METHODS

2.1 Overview of General Climate Models (GCMs) and the selection of GCM models for this research.

General Circulation Models predicts the variation of climate parameters in the future 100 years by using the motion equation. Every GCM has its unique grid resolution and global area coverage. The selection of a particular GCM model is based on the grid resolution that is required for modelling and the purpose for which the researcher is modelling the climatic scenario. For example, if the purpose is to estimate the irrigation requirement in the watershed over the time period, then the GCM has to be selected based on which GCM is considering the vegetation characteristics is aclimatic variable prediction. However, the GCMs models have very coarse in the horizontal resolution, usually from 1.5^{o} to 4.5^{o}C (200 km to 450 km in resolution). So that, in this research, to improve the spatial resolution, the author used Global climate model output, from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset (Meehl GA Covey C, 2007), were obtained from www.engr.scu.edu/~emaurer /global_data/. These data were downscaled as described by (Maurer, 2009) using the bias-correction/spatial downscaling method (Wood, 2004) to a 0.5-degree grid, based on the 1950-1999 gridded observations of (Adam, 2003). The number of models listed in **Table 1** as below.

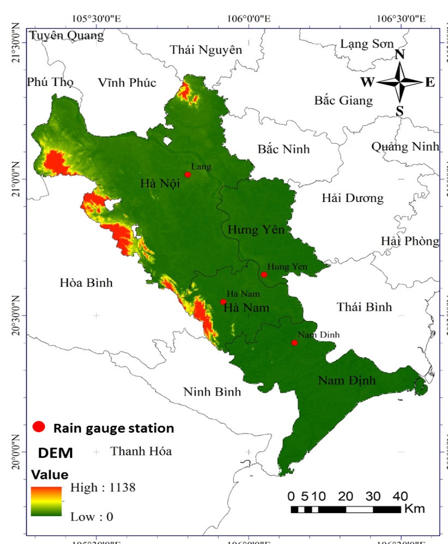


Figure 1. The location of study area and four meteorological stations

2.2 Materials and methodology

First of all, daily meteorological data such as rainfall and temperature either from observation or projection are needed for estimating the evapotranspiration of crops. Second, the effective rainfall and irrigation water on paddy fields could be estimated by simulation method based on the water balance

In addition, data concerning the crop coefficient, percolation rate, conveyance loss rate, and farming area are collected. In this study, the present and future are represented by the periods 1980 ÷1999, 2050 ÷ 2069 and 2080 ÷ 2099 respectively

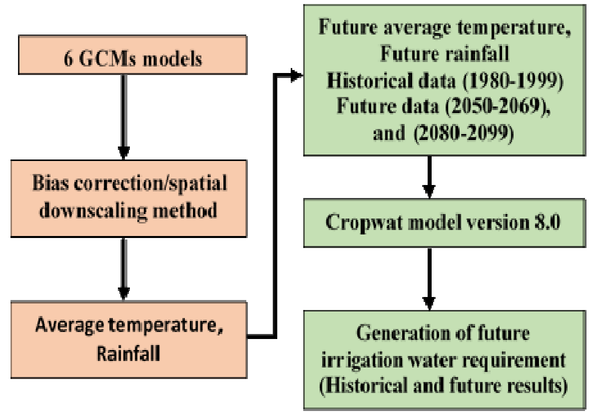


Figure 2. Methodology used in the study

Table 1. GCM models used in this study

Name of models	Resolution (Lat/Lon)	Country	Primary Reference
bccr_bcm2_0	2.81°x2.81°	Bjerknes Centre for Climate Research (BCCR), Univ. of Bergen, Norway	Furevik et al., 2003
cccma_cgcm3_1	3.75° x 3.75°	Canadian Centre for Climate Modelling and Analysis, Canada	Flato and Boer, 2001
miroc3_2_medres	2.81° x 2.81°	Frontier Research Center for Global Change (JAMSTEC), Japan	K-1 model developers, 2004
mpi_echam5	1.875° x 1.875°	Max Planck Institute for Meteorology, Germany	Jungclaus et al., 2006
mri_cgcm2_3_2a	2.81° x 2.81°	Meteorological Research Institute, Japan	Yukimoto et al., 2001
ukmo_hadcm3	2.50° x 3.75°	Hadley Centre for Climate Prediction and Research/Met Office, UK	Gordon et al., 2000

For studying the impacts of climatic change such as temperature, wind speed, rainfall and humidity on the irrigation water requirement on a temporal scale, climate crop water requirement integrated framework has been developed.

The Climate Crop Water Requirement (CCWR) framework integrates the crop water requirement model (CROPWAT) and spatial climate variable downscaling technique developed by Maurer et al. (Maurer, 2009) using the bias-correction/spatial downscaling method (Wood, 2004) is used in this study.

Figure 2 describes the methodology using in this paper, in the first step, the author used 6 GCM models listed in Table 1, because GCM models have too coarse in resolution, so the bias correction/spatial downscaling method is used following the results of Maurer et al 2009 (Maurer, 2009) to increase the resolution up to 0.5 degree. The climate variables from GCM models include mean air temperature and rainfall from 1950 to 2099. Next step, the author used the Cropwat model's version 8.0 for calculation the irrigation water requirement for spring season paddy with different future mean temperature, future rainfall, and compared the computed value between future and present to find the variations of irrigation water requirement for paddy. Finally, some discussion and conclusion about the effect of climate change on the crop in this region.

3. RESULTS AND DISCUSSIONS

3.1 Model calibration and validation

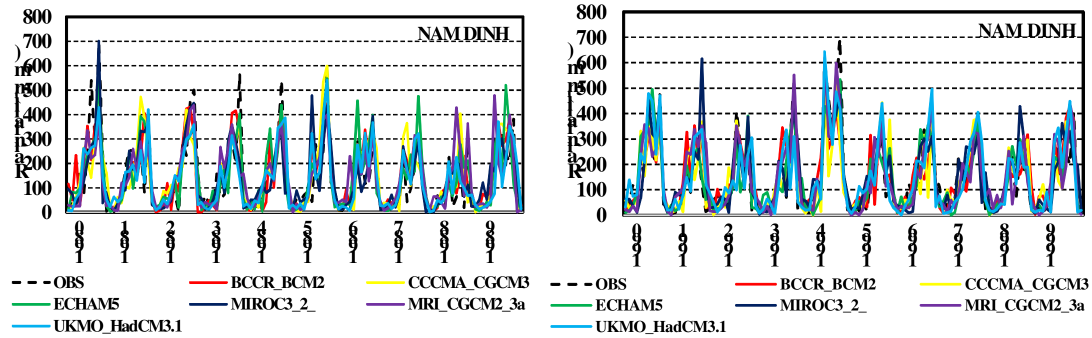
Model calibration and validation are one of the most important steps of the process. The objective was to assess the performance of the model in simulating climate at the chosen site to determinate whether or not it is suitable for using. In this study, the spatial climate variable downscaling technique developed by Maurer et al. (Maurer, 2009) using the bias-correction/spatial downscaling method (Wood, 2004) is used. The rainfall for calibration and validation used in-situ rainfall observed data from 1980 to 1999 at Nam Dinh rain gauge station.

For evaluation of the suitable of the simulation results, Nash - Sutcliffe coefficient and correlation coefficient were used. In general, the simulation model can be judged as a satisfactory if Nash > 0.5 and correlation > 0.70 for rainfall.

Table 2. The results of calibration and validation of model parameters for rainfall

Process	Models	Index	Value	Simulation level
Calibration (1980-1989)	BCCR_BCM2_0	NASH	0.52	medium
		COR	0.74	good
	CCCMA_CGCM3_1	NASH	0.48	poor
		COR	0.73	good
	MPI_ECHAM5	NASH	0.60	medium
		COR	0.79	good
	MIROC3_2_MEDRES	NASH	0.56	medium
		COR	0.76	good
	MRI_CGCM2_3_2a	NASH	0.51	medium
		COR	0.72	good
	UKMO_HadCM3	NASH	0.55	medium
		COR	0.75	good
Validation (1990-1999)	BCCR_BCM2_0	NASH	0.60	medium
		COR	0.78	good
	CCCMA_CGCM3_1	NASH	0.62	medium
		COR	0.79	good
	MPI_ECHAM5	NASH	0.72	good
		COR	0.85	good
	MIROC3_2_MEDRES	NASH	0.61	medium
		COR	0.80	good
	MRI_CGCM2_3_2a	NASH	0.69	medium
		COR	0.84	good
	UKMO_HadCM3	NASH	0.63	medium
		COR	0.82	good

Table 2 shows the results of calibration and validation of 6 model parameters for rainfall. The results showed that in both calibration and validation process for rainfall, the most models show the values of Nash and correlation indexes were with the simulation level from the medium to good (excepted the CCCMA_CGCM3 model in calibration process, Nash coefficient simulation level was poor). These were considered to be acceptable for simulated and predicted future rainfall and irrigation water requirement for spring season paddy.



(a) *(b)*

Figure 3. The observed and simulated precipitation of 6 models at Nam Dinh station for (a) Calibration process; (b) Validation process

Figure 3 shows the results of obseved and simulated rainfall at Nam Dinh station for both two processes (calibration and validation).

3.2 The variation of climate variables under the global warming.

a. Variation of temperature

Figure 4 indicated the temperature of the respective scenario A1B extracted from 6 GCM models after using downscaling technic. In term of seasonality, all the outputs of temperature from GCM models suggest that there are likely to be higher temperature in all season. As shown in **Figure 5**, the highest increases in temperature are estimated from MPI_ECHAM5, UKMO_HADCM3 models with near 2.5^{o}C and 3^{o}C in the year 2050-2069 and 2080-2099 higher than referent period (1980-1999) respectively from April to August at all four meteorological stations. The lowest increase for the winter period usually from December to March with approximately 0.5^{o}C to 1^{o}C in all models.

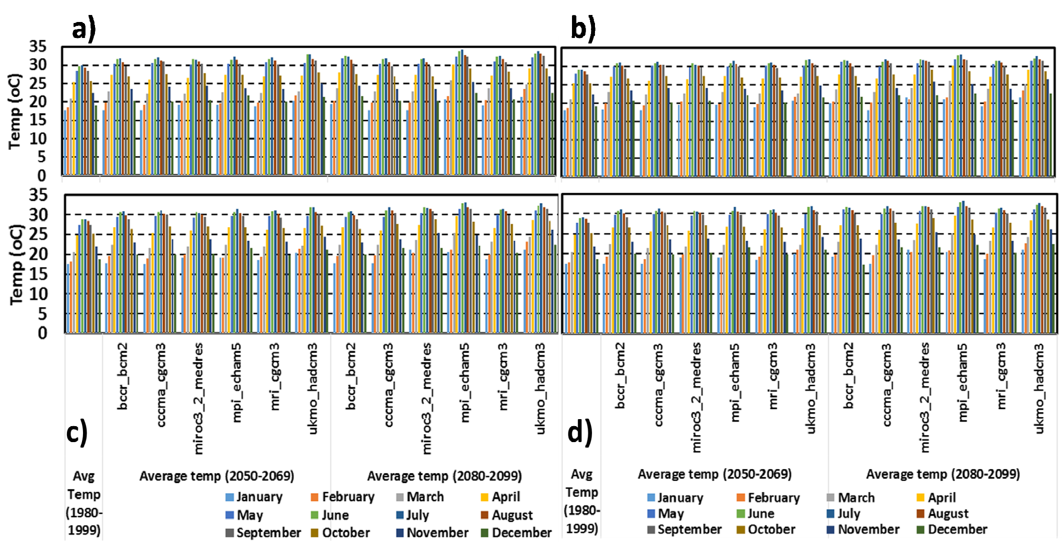


Figure 4. The temperature at four stations: a) Lang, b) Nam Dinh, c) Hung Yen, and d) Ha Nam stations from 6 GCM models at present and in the future.

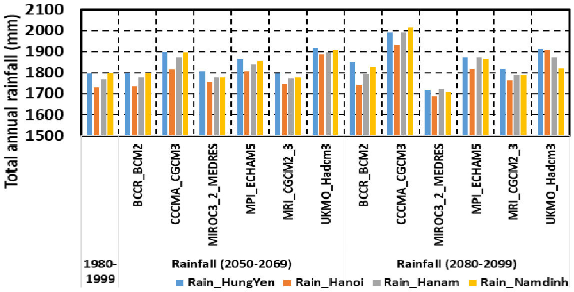


Figure 5. Total annual rainfall for the year 1980-1999, 2050-2069, and 2080-2099 at four rainfall stations in the northern regions of Vietnam.

b. Total annual rainfall pattern

In the future, the average pattern of rainfall is expected to increase with a small difference from the historical data. From **Figure 5**, except the results of MIROC3_2_MEDRES model show the total rainfall slightly decrease in the future, the computed results of 5 other models give an increasing trend in total annual rainfall at four rain gauge stations. Precipitation would increase from 1800 mm in 1980-1999 to over 1850 mm from 2050-2069, and at the end of the 21^{st}century, the annual rainfall is increasing continuously reaching to near 2000 mm/year at Nam Dinh station. The highest increase in total rainfall is the simulation resutl of CCCMA_CGCM3 model.

c. Variations of spatial distribution of average rainfall in three months January, February, and March.

Figures 6 and 7 show the different mean spatial distribution of rainfall in three months, January, February, and March in the northern region of Vietnam during 2050-2069, 2080-2099 and 1980-1999. It is clear that annual total rainfall under the climate change would increase slightly in most models, however, the distribution of heavy rain during the year would concentrate in the rainy season, and the rainfall may have the decreasing trend in the northern region of Vietnam in the dry season. It means that, under the climate change, the water supply for crop may be affected.

3.3 Future irrigation water requirement for spring season paddy

The reference evapotranspiration ETo was calculated by FAO Penman-Monteith method, ETo is multiplied by an empirical crop coefficient (Kc) to produce an estimate of crop evapotranspiration (ETc). The irrigation water requirement (IWR) for spring season paddy in four provinces of the northern regions of Vietnam, Ha Noi city, Ha Nam, Hung Yen, and Nam Dinh provinces is using decision support software –CROPWAT 8.0 developed by FAO. The caculation results of ETc and IWR showed in **Figure 8** and **Figure 9** as below.

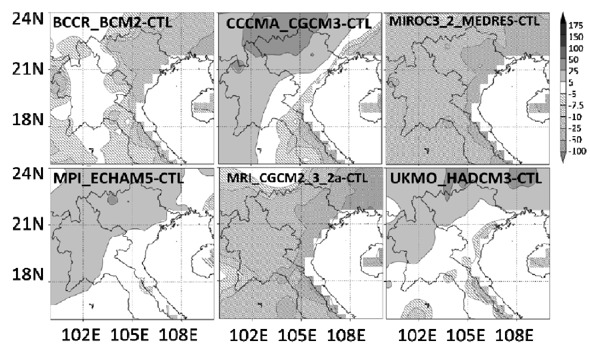


Figure 6. The different mean spatial distribution of rainfall in January, February, and March between duration 2050-2069 and 1980-1999 in the Northern regions of Vietnam.

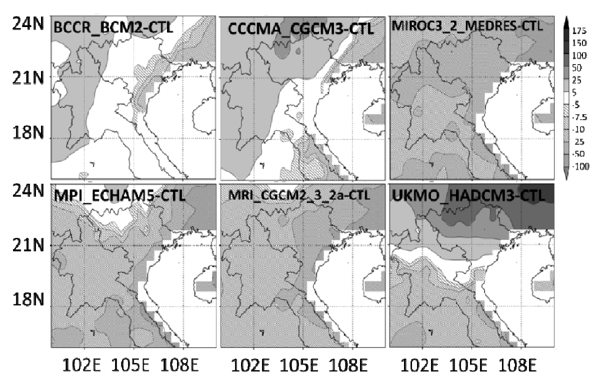


Figure 7. The different mean spatial distribution of rainfall in January, February, and March between duration 2080-2099 and 1980-1999 in the Northern regions of Vietnam

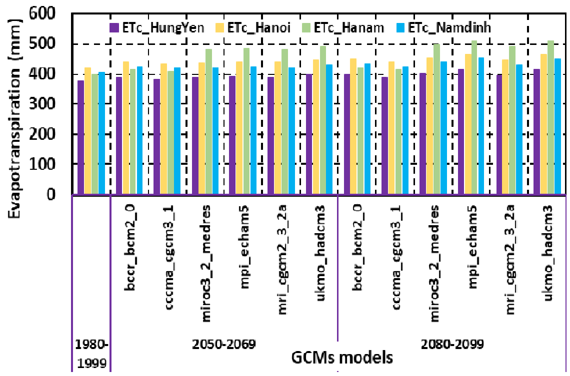


Figure 8. Evapotranspiration of spring season paddy at Lang, Hung Yen, Ha Nam, and Nam Dinh stations of Vietnam calculated by 6 GCM models.

The calculation results indicated that the total evapotranspiration crop (Etc) value **(Figure 8)** at 4 meteorological station increase in all 6 GCM models. The highest increase value is from Ha Nam station. The total average ETc rises from 400 mm at reference data (from January to June) to near 490 mm in MIROC3_2_MEDRES, MPI_ECHAM5, MRI_CGCM2_3_2a, and UKMO_Hadcm3 models in theyear (2050-2069) and over 500 mm in theyear (2080-2099), and results from two models BCCR_BCM2_0 and CCCMA_CGCM3_1 show slight increase in ETc. The values of ETc would increase if the future temperature rise.

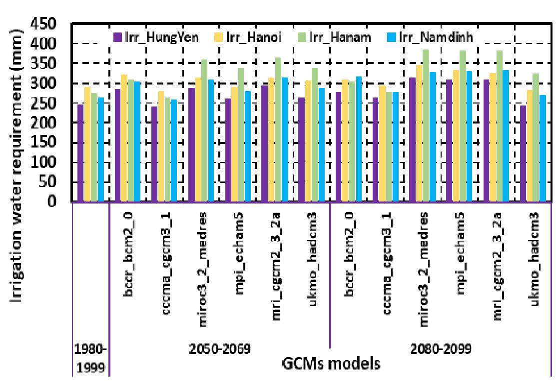


Figure 9. The average irrigation water requirement for spring season paddy in Ha Noi, Hung Yen, Ha Nam, and Nam Dinh provinces of Vietnam calculated by 6 GCM models.

Figure 9 shows the predicted results of irrigation water requirement for spring season paddy in Ha Noi, Hung Yen, Ha Nam, and Nam Dinh provinces calculated by CROPWAT model for the historical period (1980-1999) and in the future with different climate variables of 6 GCM models. The results of IWR of referent period (1980-1999) gives from 250 to near 300 mm in four provinces. From **Figure 9**, except the results of CCCM_CGCM3_1, the irrigation water requirement for spring paddy slightly decrease for the future period from 2050-2069, other GCM models show an increase in IWR. The highest value comes from the results of MIROC3_2_MEDRES and MRI_CGCM2_3_2a models. In Ha Nam province, the irrigation water requirement increases significantly to over 360 mm compared with 260 mm of referent period. Next increase in IWR is Ha Noi city and Nam Dinh province, with the values, is around 300 mm in 5 models. The irrigation water requirement would continue increasing trend in the far future (at the end of the21st century) in all models. It means that the increment/decrement of irrigation need has astrong relationship with the temperature and rainfall.

4. CONCLUSION

The results of climate variables from CMIP3 models with bias correction and downscaling method show that in the future, under the climate change, rainfall from 5 over 6 GCM models of four precipitation gauge stations would slightly decrease in the dry season (from January to March), The temperature will increase from 0.5^{o}C to 3.2^{o}C in all outputs of 6 GCM models. Due to the increase in temperature and decrease in precipitation, the irrigation water requirement for spring season paddy would increase in the most of GCM models between the year 2050-2069 and 2080-2099. This study would be very important implications for maker decision in the agricultural sector to give the strategies in adapting to climate variability under the global warming for the northern region of Vietnam.

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Tóm tắt:

TÁC ĐỘNG CỦA BIẾN ĐỔI KHÍ HẬU LÊN YÊU CẦU NƯỚC ĐỐI VỚI LÚA CHIÊM Ở THÀNH PHỐ HÀ NỘI VÀ CÁC TỈNH HÀ NAM, HƯNG YÊN VÀ NAM ĐỊNH

Trong bài báo này, yêu cầu nước tưới cho lúa chiêm xuân tại thành phố Hà Nội và các tỉnh Hưng Yên, Hà Nam và Nam Định ở miền Bắc của Việt Nam được dự báo dựa trên dữ liệu khí tượng của 6 mô hình khí tượng toàn cầu với kịch bản biến đổi khí hậu A1B. Mô hình CROPWAT 8.0 được sử dụng để tính toán yêu cầu nước. Kết quả tính toán cho thấy dưới ảnh hưởng của biến đổi khí hậu, hầu hết các mô hình đều cho kết quả của sự gia tăng yêu cầu nước trong các thời kỳ 2050-2069 và 2080-2099 khi so sánh với kết quả tính toán từ giữ liệu khí tượng tham khảo giai đoạn 1980-1999. Ngoại trừ kết quả tính từ mô hình CCCMA_CGCM3_1, yêu cầu nước giảm nhẹ so với thời điểm hiện tại. Yêu cầu nước tưới tăng lớn nhất đến từ các mô hình MIROC3_2_MEDRES và MRI_CGCM2_3_2a. Kết quả tính toán với số liệu của trạm Hà Nam, yêu cầu nước tưới tăng đáng kể, vượt 360 mm khi so sánh với giá trị 260 mm trong giai đoạn 1980-1999. Tiếp đến là tại Hà Nội và Nam Định với giá trị sấp xỉ 300 mm trong 5 mô hình. Xu hướng gia tăng trong giai đoạn 2080-2099 của yêu cầu nước tiếp tục xuất hiện trong tất cả các mô hình dưới tác động của biến đổi khí hậu.

Từ khoá: Biến đổi khí hậu, lúa vụ chiêm xuân, yêu cầu nước tưới, mô hình khí hậu toàn cầu

Ngày nhận bài: 17/4/2018

Ngày chấp nhận đăng: 16/8/2018