

ASSESSING FUTURE RUNOFFS UNDER CLIMATE CHANGE SCENARIOS IN THE MAE KLONG RIVER BASIN, THAILAND

ÉVALUATION DES DÉBITS DE RUISSELLEMENT FUTURS SELON DIFFÉRENTS SCÉNARIOS DE CHANGEMENT CLIMATIQUE DANS LE BASSIN VERSANT DE MAE KLONG, EN THAÏLANDE

Thepprasit C.¹, Vongphet, J.², Puttrawutichai, S.³, Ruangrassamee, P.⁴, Chaowiwat, W.⁵ and
Sittichok, K.^{6*}

ABSTRACT

Climate change is influencing increasing challenges to irrigation water management, particularly in river basin scales where water is used in various sectors, and policy-driven allocation systems must operate under high climate variability. This study aims to examine future changes in runoffs under various climate change scenarios to support basin-scale decision-making for irrigation water management in the Mae Klong River Basin, Thailand. Climate projections were obtained from the Coupled Model Intercomparison Project Phase 6 (CMIP6) for four Shared Socioeconomic Pathways (SSP126, SSP245, SSP370, and SSP585). Three global climate models, which were BCC-CSM2-MR, CanESM5, and CESM2, were selected for this study.

The DWCM-AgWU hydrological model was applied to generate runoffs under these conditions. The model was calibrated and validated with six locations, and results revealed that an R^2 of 0.82-0.90/0.74-0.90, an NSE of 0.49-0.89/0.46-0.88, and a PBIAS in the absolute of 53.8–0.46 / 54.3–1.09. Future hydrological responses were analyzed for two planning horizons: a near-future period (2025–2037), aligned with Thailand's 20-year national development strategy, and a far-future period (2038–2100). Results indicated that most climate scenarios projected an increase in average monthly precipitation during the rainy season, while a reduction was consistently projected during the dry season. Simulated monthly runoff at three main locations (Srinagarind Dam, Vajiralongkorn Dam, and Mae Klong Dam) generally increased during the late rainy season (August–October).

The peak runoff shifting was also revealed in the Srinagarind and Mae Klong dams. Annual runoffs presented a significantly increasing trend under SSP5-8.5 for all locations and both periods. This output can support and understand climate-driven hydrological risks and informed irrigation water management strategies at the basin scale.

Keywords: irrigation water management; runoffs; hydrological responses; climate-driven hydrological risks; irrigation water management.

1 Department of Irrigation Engineering, Faculty of Engineering at Kamphaengsaen campus, Kasetsart University, Nakhon Pathom province, Thailand, Email: fengcph@ku.ac.th

2 Department of Irrigation Engineering, Faculty of Engineering at Kamphaengsaen campus, Kasetsart University, Nakhon Pathom province, Thailand, Email: fengjtv@ku.ac.th

3 Department of Irrigation Engineering, Faculty of Engineering at Kamphaengsaen campus, Kasetsart University, Nakhon Pathom province, Thailand, Email: Songsak.pu@ku.th

4 Department of Water Resources Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand, Email: Piyatida.H@chula.ac.th

5 NHC Steering and Operations Center (NHCSOC), Hydro Informatics Institution, Bangkok Province, Thailand, Email: winai@hii.or.th

6 Department of Irrigation Engineering, Faculty of Engineering at Kamphaengsaen campus, Kasetsart University, Nakhon Pathom province, Thailand Email: fengkrs@ku.ac.th

RESUME

Le changement climatique rend la gestion de l'eau d'irrigation de plus en plus complexe, en particulier à l'échelle des bassins versants où l'eau est utilisée dans divers secteurs, et où les systèmes de répartition définis par les politiques doivent fonctionner dans un contexte de forte variabilité climatique. Cette étude vise à examiner les évolutions futures des débits de ruissellement selon différents scénarios de changement climatique afin de soutenir la prise de décision à l'échelle du bassin concernant la gestion des eaux d'irrigation du bassin versant de Mae Klong, en Thaïlande. Les projections concernant le climat ont été obtenues à partir de la phase 6 du Projet d'intercomparaison des modèles couplés (CMIP6) pour quatre trajectoires socio-économiques partagées (SSP126, SSP245, SSP370 et SSP585). Trois modèles climatiques mondiaux, à savoir BCC-CSM2-MR, CanESM5 et CESM2, ont été retenus pour cette étude. Le modèle hydrologique DWCM-AgWU a été utilisé pour simuler les débits de ruissellement dans ces conditions. Le modèle a été calibré et validé sur six sites, et les résultats ont montré un R^2 compris entre 0,82 et 0,90 / 0,74 et 0,90, un NSE compris entre 0,49 et 0,89 / 0,46 et 0,88, et une PBIAS en valeur absolue comprise entre 53,8 et 0,46 / 54,3 et 1,09. Les réponses hydrologiques futures ont été analysées pour deux horizons de planification : un avenir proche (2025-2037), alignée sur la stratégie nationale de développement de 20 ans de la Thaïlande, et un avenir lointain (2038-2100). Les résultats ont indiqué que la plupart des scénarios climatiques prévoyaient une augmentation des précipitations mensuelles moyennes pendant la saison des pluies, tandis qu'une diminution était systématiquement prévue pendant la saison sèche. Le ruissellement mensuel simulé sur trois sites principaux (les barrages de Srinagarind, de Vajiralongkorn et de Mae Klong) a généralement augmenté vers la fin de la saison des pluies (août-octobre). Un décalage de ruissellement maximum a également été observé au niveau des barrages de Srinagarind et de Mae Klong. Les débits annuels ont présenté une tendance à la hausse significative dans le cadre du scénario SSP5-8.5 pour tous les sites et les deux périodes. Ces résultats peuvent contribuer à la compréhension des risques hydrologiques liés au climat et à l'élaboration de stratégies éclairées de gestion de l'eau d'irrigation à l'échelle du bassin.

Mots-clés : Gestion de l'eau d'irrigation; Ruissellement; Réponses hydrologiques; Risques hydrologiques liés au climat; Gestion de l'eau d'irrigation.

INTRODUCTION

Climate change has become a major challenge to global water security, leading to the risk of agricultural productivity decreasing. As temperature and precipitation variability increase, the traditional management of water resources experiences high challenges, complicating water allocation due to unpredicted hydrological variables such as rainfall and runoff, leading to the difficulty of a robust assessment of future hydrological conditions to inform long-term adaptation strategies (Bhat et al., 2024; Shayanmehr et al., 2022). Thailand is one of the countries being particularly vulnerable due to its high reliance on monsoon-dependent water resources. The country has experienced a consistent warming trend over several decades, specifically the changes of rainfall patterns leading to both severe floods and prolonged droughts (Pimpa, 2024; Kimmany et al., 2024; Shin et al., 2024). These changes directly impact the agricultural sector, which is a main livelihood of Thailand's socio-economic stability, often leading to reduced crop yields and increased economic risk for farming communities.

To assess these potential impacts, a global climate model (GCM) was usually employed as a tool to simulate the climate variable changes under various greenhouse gas emission trajectories. Various GCMs were developed from different institutions, and their outputs have been worked into the Couple Model Intercomparison Project (CMIP) as an international collaboration group under climate model experiment with the latest generation called CMIP6. The CMIP6 offers emission scenarios, also known as the Shared Socioeconomic Pathways (SSPs), and the scenarios in Tier 1 group, such as SSP126, SSP245, SSP370, and SSP585, are widely applied to seek the change of significant climate and hydrological variables in specific study areas (Feyissa et al., 2023; Zhou et al., 2023; Bian et al., 2021). A rainfall-runoff model is an essential tool and widely used to estimate the change of water resources under climate change scenarios. The model is able to simulate hydrological components for understanding basin responses to climate variability and future climate scenarios such as surface runoff, streamflow, and water yield (Banda et al., 2024; Lamichhane et al., 2024; Muleta and Marcell, 2023;

Sittichok et al., 2022). The changes under different climate situations generated using a rainfall–runoff model can support the development of strategies and planning measures for water resources management, such as water allocation, reservoir operation, flood and drought preparedness, and water storage planning.

From the situation of climate change impact to the change of climate and hydrological variables mentioned above, the objective of this research is to estimate the change of both rainfall and runoff in the Mae Klong River Basin, which is one of the main basins in Thailand. Outputs of GCMs with four scenarios (SSP126, SSP245, SSP370, and SSP585) were applied by initially adjusting the bias of the data using a bias correction method. The rainfall-runoff model, the Distributed Water Circulation Model incorporating Agricultural Water Use (DWCM-AgWU), was calibrated. Projected runoffs were then generated at key locations in the basin and divided into two periods: the short-term period between 2025 and 2037, which was selected to correspond with Thailand's 20-Year National Strategy ending in 2037, and the long-term future period from 2038 to 2100. The results of this study can support long-term water resources planning and decision-making at the basin scale.

STUDY AREA

The Mae Klong River Basin is located in the western part of Thailand, covering nine provinces. This basin can be divided into two main parts: the upper basin, which consists of mountainous forested headwaters in various areas; and the lower basin, which is characterized by lowland plains extending to the Gulf of Thailand. The two major tributaries of the basin, the Khwae Yai River and the Khwae Noi River, join to form the Mae Klong River, which flows into the Gulf of Thailand (**Figure 1**). The Mae Klong River Basin contains two main important reservoirs, which are Vajiralongkorn Dam and Srinagarind Dam, including a diversion dam, which is Mae Klong Dam.



Figure 1. Study area, climate and water monitoring stations

MATERIALS AND METHODS

This study can be divided into two main sections, which are the estimation of rainfalls under climate change scenarios and the use of a rainfall-runoff application to estimate runoffs at the key locations. The details of data used in this study, the rainfall-runoff model, and the study process are presented below, and the process of this study is presented in **Figure 2**.

management and dam operations (Kudo et al., 2013), and flood analysis (Vongphet et al., 2016). The DWCM-AgWU consists of four main sub-models, which are (1) reference crop evapotranspiration estimation, (2) the timing and spatial extent of cultivation, (3) water use in paddy fields, and (4) a runoff sub-model. In addition, a reservoir operation function was developed to enhance the model's capability to simulate water management, particularly reservoir water management, and water allocation models for irrigated areas were developed to estimate water used for paddy fields in order to calculate the volume of irrigation water diverted to paddy fields located within irrigated areas. The model was initially calibrated and validated at the key water monitoring stations to ensure suitable use for the Mae Klong River Basin. Three objective functions were applied to estimate the model performance, which were the coefficient of determination, the Nash-Sutcliffe coefficient, and percent bias.

RESULTS AND DISCUSSIONS

Model calibration and validation results

The DWCM-AgWU calibration and validation were conducted by comparing monthly runoff observed and simulated data for two reservoirs and four monitoring water stations (as shown in **Figure 1**). Various parameters were adjusted, and the suitable values used in the model are presented in **Table 1**. R^2 , NSE, and PBIAS were used as statistical indicators to estimate the calibration period in 2009-2016 and the validation period in 2017-2023. The results are presented in **Table 2** and **Figure 2**. The model showed generally good performance for all five stations during both calibration and validation periods except Vaj Dam. R^2 , NSE and PBIAS were 0.83-0.90, 0.81-0.89, and -2.88% to 12.44%, respectively, for the calibration period. During the validation period, small differences compared to the calibration period were observed with R^2 of 0.85-0.90, NSE of 0.76-0.88, and -10.30% to 16.86%.

In contrast, the lowest performance was observed at Vajiralongkorn Dam, where R^2 decreased from 0.82 in calibration to 0.74 in validation, similar to NSE, which decreased from 0.49 to 0.46. The strongly negative PBIAS values (-53.80% and -54.30% for calibration and validation periods) indicate substantial underestimation of runoff. This suggests that the model was able to capture part of the temporal variability but was less effective in reproducing runoff magnitude at this location. Overall, the results indicate that the model is suitable for runoff simulation in most parts of the Mae Klong River Basin. However, the systematic underestimation at Vajiralongkorn Dam and the overestimation at K35A suggest that further consideration of input data and parameterization may be needed for these stations.

Table 1. Parameters applied for DWCM-AgWU

No.	Type	Parameter	Value
1	Division of the target basin	Divided meshes (cells)	1,620
		Sub-basins	11
2	Calculation	Time step	1 day
		Starting year	2007
		Stopping year	2021
		Total years	15 years
		Spin-up year (initial)	1 years
3	Water allocation, management	Number of reservoirs	10
		Number of large, irrigated areas	1
4	Paddy fields	Water depth management	10 mm
		Percolation rate in paddies	1.0 mm/d
		Hight of outlet weir in paddies	175 mm
5	Runoff	Root zone thickness (Paddy fields)	45 mm
		(forest)	120 mm
		(Upland crops)	250 mm
		Moving average for surface flow	5 days
		Moving average for paddy runoff	30 days
		Kinematic parameter (K) (channel)	1.5-8.6

Table 2. Objective functions of model calibration and validation

Station	Calibration (2009-2016)			Validation (2017-2023)		
	R ²	NSE	PBIAS	R ²	NSE	PBIAS
Vaj Dam	0.82	0.49	-53.80	0.74	0.46	-54.30
Sri Dam	0.89	0.89	6.33	0.85	0.83	-10.30
K 37	0.83	0.81	-4.95	0.89	0.87	-2.22
K 35A	0.89	0.82	12.44	0.90	0.76	16.86
K 58	0.88	0.87	-2.88	0.89	0.85	5.27
K 10	0.90	0.89	-0.46	0.90	0.88	-1.09

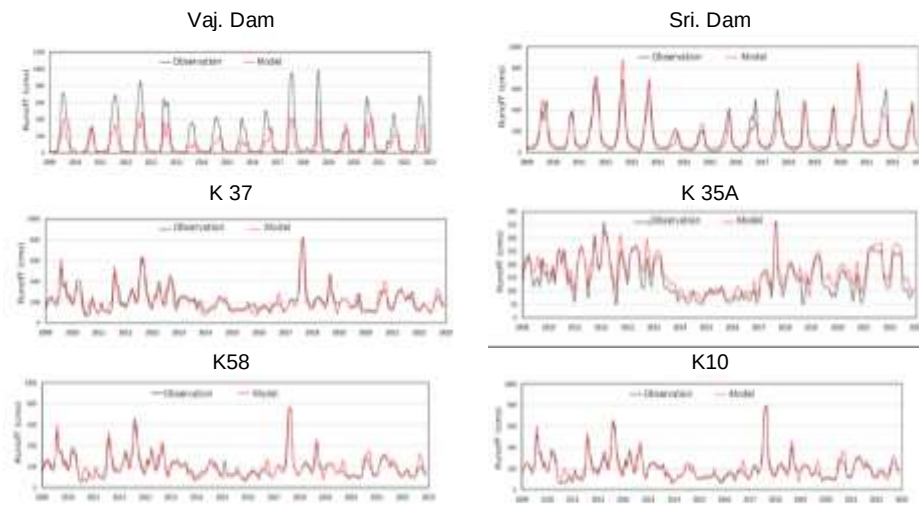


Figure 2. Calibration and validation results for six stations

The changes of rainfall under climate change scenarios

The changes of rainfall under SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 were observed at three main dams: Vajiralongkorn Dam, Srinagarind Dam, and Mae Klong Dam. Rainfall outputs of three models after the bias correction process compared to historical data are illustrated in **Figure 3** to **Figure 5**. Rainfall estimation at Vajiralongkorn Dam presented hydrological instability, and results from each model are different during particular times. In August during the wet season, the BCC model under the SSP2-4.5 (near-future) predicted around a 570 mm rainfall peak (40% increasing from the historical period). The CAN model gave a more moderate amount, around 460 mm over the same period, while the CESM2 model showed generally a dry outlier across scenarios. In addition, the comparison between the relatively steady SSP1-2.6 and the high-emission SSP5-8.5 scenario caused the most significant oscillations in both directions. The BCC model under SSP5-8.5 projected a 95% rise in December rainfall, almost doubling the volume, while SSP1-2.6 presented only around 10% in the far future. Seasonally, the data revealed a seasonal pattern where wet conditions become wetter and dry situations tend to be drier, with severe deficits in the dry season (January to March) and intensifying monsoon maxima in the wet season (May to October).

For the Srinagarind Dam (**Figure 4**), increased hydrological instability with large models, scenarios, and season fluctuations can be observed. The BCC model under the SSP2-4.5 for the near future showed projected rainfall increased around 45%, reaching 370 mm relative to the historical baseline of 250 mm, throughout the rainy season, mainly in August. However, the CESM2 model occasionally predicted lower volumes, such as around 300 mm for the same scenario, and severe dry season deficiencies. Under SSP1-2.6, the CESM2 model forecasted around a 70% reduction in January rainfall, whereas the BCC model gave a 45% rise. The high-emission SSP5-8.5 presented the most dramatic intensifications; in the far future, the CESM2 model estimated an August rainfall increase of around 75% (around 300 mm). This tendency is much worse than SSP1-2.6. All scenarios show a wet-gets-wetter and dry-gets-drier

pattern from the near to far future, with monsoon peaks like the BCC model with a 300 mm rise in September (30%) becoming more frequent. All models showed that while the near future was highly fluctuated, the far future had more extremes, with dry-season shortages often exceeding 50% and wet-season peaks leading to a significant water management change at this reservoir.

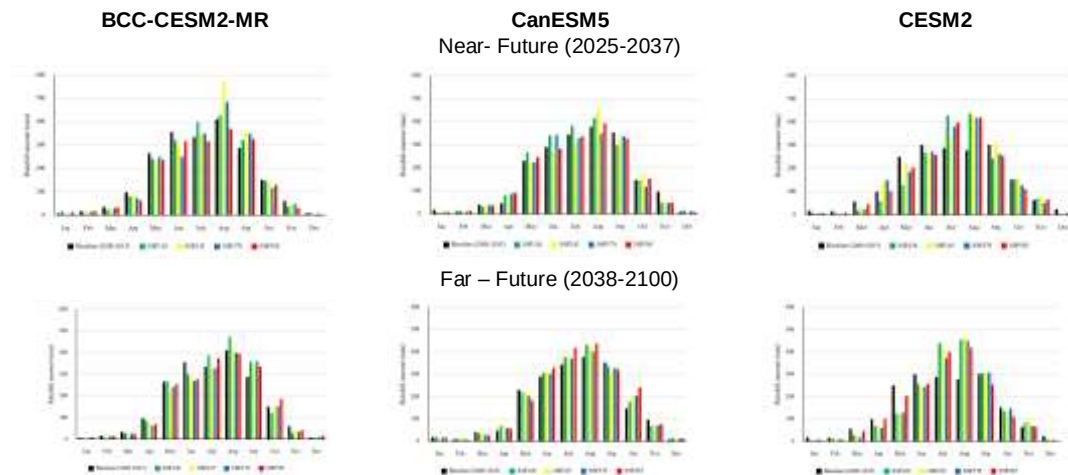


Figure 3. Rainfall under climate change scenarios at Vajiralongkorn Dam

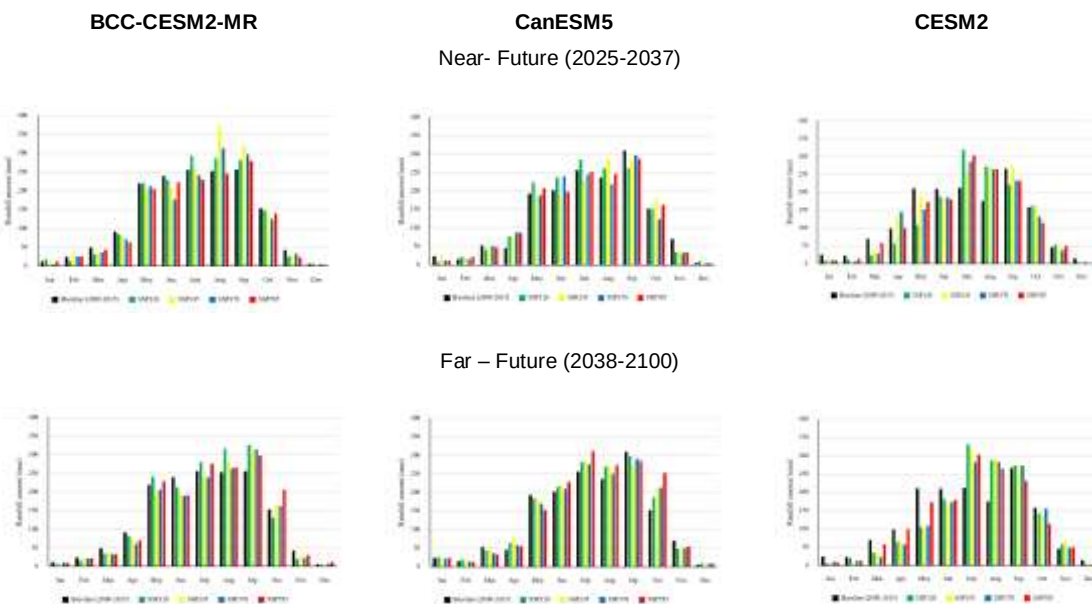


Figure 4. Rainfall under climate change scenarios at Srinagarind Dam

The Mae Klong Dam (**Figure 5**) showed increased seasonal extremes and scenario variation. The SSP2-4.5 scenario (near future) predicted a 40% rise in rainfall (around 350 mm over baseline), specifically in August. The BCC model forecasted a 70% rise in January under the SSP1-2.6, while the CAN model predicted a 65% drop. SSP5-8.5 had the most severe oscillations. The CESM2 model predicted a 50% drop in January rainfall, less than 10 mm. Under the SSP3-7.0 scenario, the CAN model gave the September rainfall deficit from -10% in the near term to around -20% in the far future. The results suggested that the Mae Klong Dam will need more flexible and resilient water management measures to tackle hydrological instability as monsoon intensity and seasonal droughts increase.

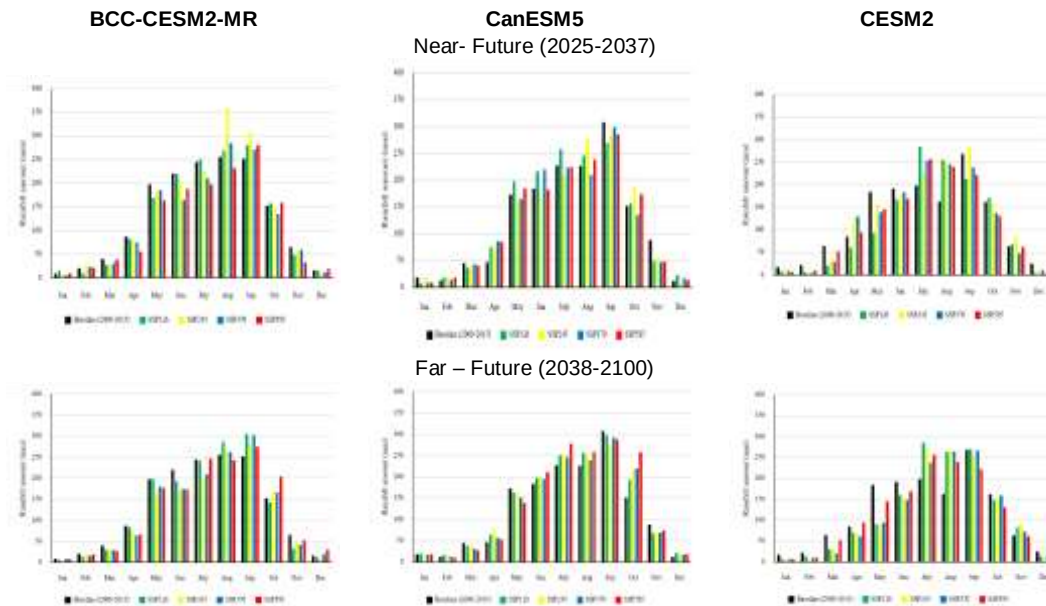


Figure 5. Rainfall under climate change scenarios at Mae Klong Dam

The changes of surface runoff under climate change

To estimate runoff in the basin, the average projected runoff from all models was produced. The climate projections from 2014 and 2100 for the study across the three dams are presented in **Figure 6**. Srinagarind Dam showed the highest runoff volume in the basin, with its 5-year averages predominantly sustained between 3,000 and 6,000 mcm over all SSPs. Conversely, Vajiralongkorn Dam and Mae Klong Dam exhibited a similar range of projected runoff around 3,000 to 4,000 mcm. The long-term impact of the high-emission scenario (SSP5-8.5) generated a significant upward trend for all locations, such as in late-century runoff peaks near 6,000 mcm at Srinagarind Dam and exceeding 4,000 mcm at other sites. Conversely, the SSP2-4.5 and the SSP3-7.0 scenarios produced mostly stable flows and less annual runoff fluctuation, particularly in the late century. This result suggested that moderate climate mitigation could effectively preserve historical mean annual runoff baselines. Meanwhile, the SSP1-2.6 exhibited gradual increases, except at Srinagarind Dam, providing a significant increase that reached 5000 mcm at the end of the century.

Figure 7 presented monthly projections. In the mid-century projection period, Srinagarind Dam indicated a distinct temporal shift from historical baseline peaks from October to September for all scenarios, with SSP2-4.5 runoff peaking up to 1,000 mcm (a 43% increase from historical data). For the far future, the SSP5-8.5 generated the maximum runoff back to October but severely intensified its volume, with the highest runoff nearly 1,200 mcm. Unlike the shifting temporal patterns observed at Srinagarind Dam, the monthly projections for Vajiralongkorn Dam indicated that the wet season peak remained in August, with SSP2-4.5 generating runoffs over 1,300 mcm (around a 50% increase) during the near future. In the late century, the peak flows under all projections occurred in August, which was similar as to the historical period with runoff peaks between 1,000 and 1,200 mcm. Finally, Mae Klong Dam displayed temporal patterns similar to Srinagarind Dam, maintaining stable but low dry-season base flow from January through April at approximately 100 mcm and peak flow in October at roughly 600 mcm. In the near future, under the SSP2-4.5 September runoff, it escalated dramatically to nearly 800 mcm representing a substantial 33% over the historical baseline. In the far future, Mae Klong Dam experienced the highest runoff under the SSP5-8.5; the monthly hydrograph shows a distinct temporal delay and severe amplification of the monsoon peak from September to October around 800 mcm.

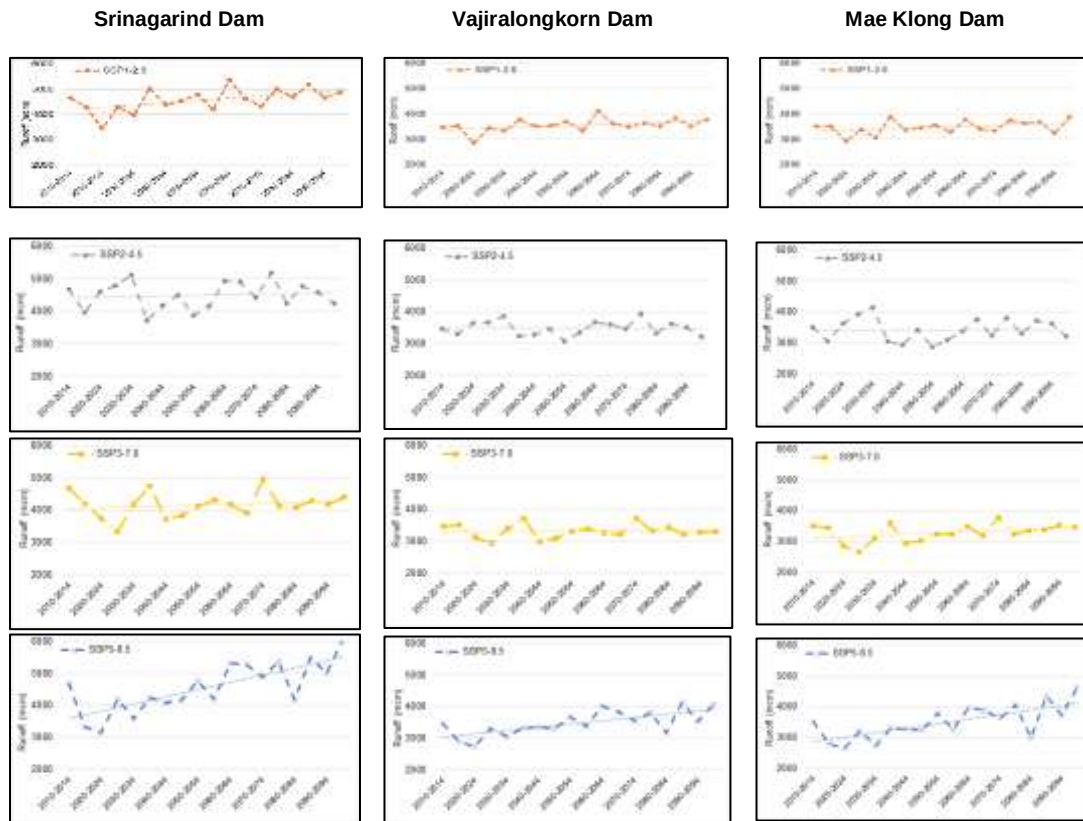


Figure 6. Average 5-year runoffs at three locations under four scenarios

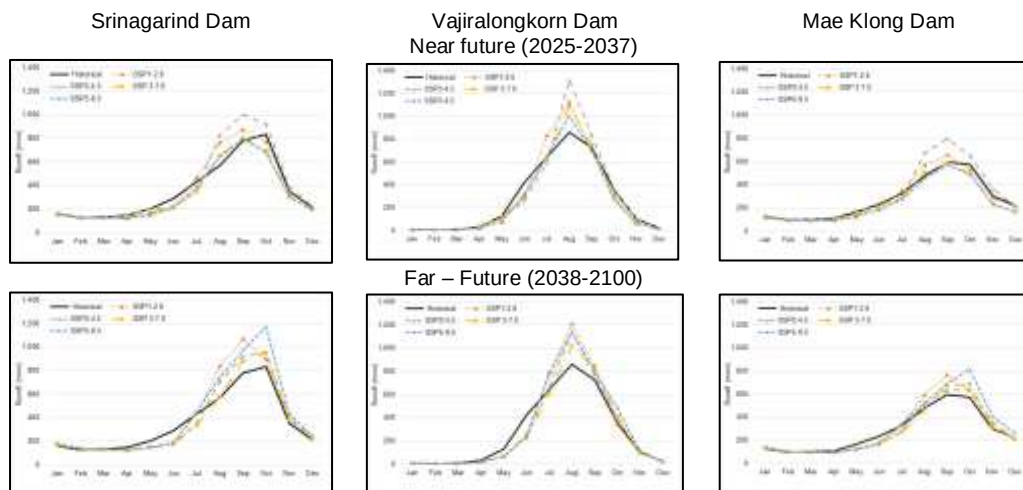


Figure 7. Monthly runoffs at three locations under four scenarios

CONCLUSIONS

This study aimed to evaluate the long-term impact of climate change on rainfall and runoff within the Mae Klong River Basin, Thailand, under CMIP6 climate projections for four scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5). The distributed hydrological model DWCM-AgWU was applied, and two periods, 2025-2037 and 2038-2100, aligned with Thailand's 20-Year National Strategy and were

examined at three main locations, Srinagarind Dam, Vajiralongkorn Dam, and Mae Klong Dam. Future rainfall projections after the bias correction process presented a trend where wet areas become wetter and dry areas become dryer across the basin. Annual runoffs for all three locations, particularly under high emission trajectory SSP5-8.5, indicated a substantial rising trend compared to other scenarios. Projected monthly runoff revealed a shift in the peak runoff from October to September at Srinagarind Dam, and the SSP2-4.5 scenario projected the highest volume for all locations in the near future. In addition, in the far future, SSP5-8.5 produced the largest runoff during the wet season for all locations, except Vajiralongkorn Dam, with the results of SSP5-8.5 and SSP1-2.6 being comparable. In conclusion, the basin should be more concerned with the change of water availability under climate change scenarios. Enhancing reservoir operating rules, optimizing seasonal storage targets at Srinagarind and Vajiralongkorn Dams, and developing resilient agricultural water-use strategies are essential for flood and drought risk management and ensuring multi-sectoral water security in the Mae Klong River Basin.

REFERENCES

- Banda, V.D., Dzwauro, R.B., Singh, S.K. and Kanyerere, T. 2024. Quantifying the influence of climate change on streamflow of Rietspruit sub-basin, South Africa. *Journal of Water and Climate Change*, 15(5), 2282, doi: 10.2166/wcc.2024.690.
- Bhat, A., Gupta, S., Singh, S. M., Meraj, g., Kumar, P., Kanga, S., Singh, S. and Sajjan, B. 2024. Simulating climatic patterns and their impacts on the food security stability system in Jammu, Kashmir and Adjoining Regions, India. *Climate*, 12(7), 99. <https://doi.org/10.3390/cli12070099>
- Bian, G., Zhang, J., Chen, J., Song, M., He, R., Liu, C., Liu, Y., Bao, Z., Lin, Q. and Wang, G. 2021. Projecting hydrological responses to climate change using CMIP6 climate scenarios for the upper Huai River Basin, China. *Frontiers in Environmental Science*, 9:759547, doi: 10.3389/fenvs.2021.759547.
- Farag, R., Zahran, S., Sobeih, M., and Helal, E. (2024). Enhancing uncertainty of regional climate models for climate change projection at Western Nile Delta. *Water Science*, 38(1), 225-238, <https://doi.org/10.1080/23570008.2024.2335582>.
- Feyissa, T. A., Demissie, T. A., Saathoff, F., and Gebissa, A. 2023. Evaluation of general circulation models CMIP6 performance and future climate change over the Omo River Basin, Ethiopia. *Sustainability*, 15(8), 6507. <https://doi.org/10.3390/su15086507>
- Jaiswal, R., Mall, R.K., Singh, N., Lakshmi Kumar, T.V. and Niyogi, D. (2021). Evaluation of bias correction method for regional climate models: downscaled rainfall analysis over diverse agroclimatic zones of India. *Earth and Space Science*, 9, e2021EA001981.
- Kimmany, B., Visessri, S., Pech, P. and Ekkawatpanit, C. 2024. The impact of climate change on hydro-meteorological droughts in the Chao Phraya River Basin, Thailand, 16(7), 1023. <https://doi.org/10.3390/w16071023>.
- Kudo R, Masumoto T, Horikawa N & Yoshida T. 2013. Modeling of Paddy Water Management in Large-reservoir Irrigation Areas and its Integration into Distributed Water Circulation Model. *Applied Hydrology* 25, 61–70. (in Japanese with English abstract).
- Lamichhane, M., Phuyal, S., Mahato, R., Shrestha, A., Pudasaini, U., Lama, S. D., Chapagain, A. R., Mehan, S., and Neupane, D. 2024. Assessing climate change impacts on streamflow and baseflow in the Karnali River Basin, Nepal: A CMIP6 multi-model ensemble approach using SWAT and web-based hydrograph analysis tool. *Sustainability*, 16(8), 3262. <https://doi.org/10.3390/su16083262>
- Muleta, T.N. and Marcell, K. 2023. Rainfall-runoff modeling and hydrological responses to the projected climate change for Upper Baro Basin, Ethiopia. *American Journal of Climate Change*, 12(2), 219-243, <https://www.scirp.org/journal/ajcc>
- Masumoto, T., Taniguchi T., Horikawa N., Yoshida T. & Shimizu K. 2009 Development of a distributed water circulation model for assessing human interaction in agricultural water use From Headwaters to the Ocean: Hydrological Changes and Watershed Management, Taniguchi M., Burntt W.C., Fukushima Y., Haigh M. & Umezawa Y. eds. Taylor and Francis, 195–201.
- Pimpa, N. 2024. Climate change challenges: case of the Thai agriculture business sector. *Sustainable Economies*, 2(2), 112. <https://doi.org/10.62617/se.v2i2.112>
- Shayanmeh, S., Porhajašová, J. I., Babošová, M., Sabouhi Sabouni, M., Mohammadi, H., Rastegari Henneberry, S., and Shahnoushi Foroushani, N. 2022. The Impacts of climate change on water resources and crop production in an arid region. *Agriculture*, 12(7), 1056. <https://doi.org/10.3390/agriculture12071056>

- Shin, N., Lee, Y., and Lee, S. 2024. Enhancing Thailand's drought management: strategies and policy implications. *International Area Studies Review*, 27(3), 219-237. <https://doi.org/10.69473/iasr.2024.27.3.219>
- Taniguchi, T., Masumoto, T., Yoshida, T., Horikawa, N., & Shimizu, K. (2009). Development of a Distributed Water Circulation Model Incorporating Various Paddy Water Uses. *Journal of Japan Society of Hydrology and Water Resources*, 22(2), 126-140. <https://doi.org/10.3178/jjshwr.22.126>
- Vongphet, J., Masumoto, T., Minakawa, H., & Kudo, R. (2016). Modification of DWCM-AgWU Model Applied to A Paddy-Dominant Basin with Large Dams. *Irrigation and Drainage*, 66(1), 60-70. <https://doi.org/10.1002/ird.2013>
- Sittichok, K., Vongphet, J. and Seidou, O. 2022. Predicted rainfall, surface runoff and water yield responses to climate change in the Phetchaburi River Basin, Thailand. *Asian Journal of Water, Environment and Pollution*, 19(3), 1-13. DOI 10.3233/AJW220033.
- Zhou, Z., Zhang, L., Chen, J., She, D., Wang, G., Zhang, Q., Xia, J., and Zhang, Y. (2023). Projecting global drought risk under various SSP-RCP scenarios. *Earth's Future*, 11, 5.