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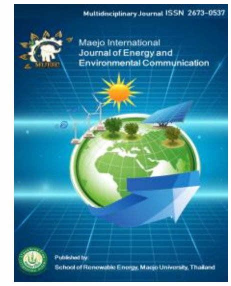

ARTICLE

Optimal Long-term Rainfall Trends Prediction under Climate Change Scenarios in Small Basin: Case study Sedon Basin, Lao PDR

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A R T I C L E I N F O

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A B S T R A C T

This research aims to predict the long-term rainfall trends under climate change (CLiM) within the next 30 years (2021–2050) under greenhouse gas emissions (GHGs) of two Representative Concentration Pathway; RCP) scenarios namely, moderate (RCP4.5) and very high (RCP8.5) from the Mixed Resolution version of the Max Planck Institute Earth System Model (MPI-ESM-MR). The climatic data (rainfall) from MPI-ESM-MR was bias corrected by employing Climate Model data for hydrologic modeling (CMhyd). Three of bias correcting methods such as linear scaling (LS), delta change (DC), and power transformation of precipitation (PTP) were used. The result of the research indicated that the monthly and annual rainfall in the future under the RCP4.5 and RCP8.5 scenarios will likely increase, and the RCP8.5 will be higher than RCP4.5 on average of 3%. This difference value suggests that the managing water under RCP8.5 should enhance the degree of management than one of RCP4.5. The RCP4.5 was projected the monthly rainfall to increase and decrease between -57 and 345% and a rainfall trend between -0.467 and 0.31mm/year. The RCP8.5 was expected to increase and decrease between -54 and 174% and its trends between -0.175 and 0.177 mm/year. The changes in annual rainfall are between -26 and 14% (RCP4.5) and -24 and 21% (RCP8.5). The trend of annual rainfall is positive for both RCP4.5 and RCP8.5, with trend 0.075 and 0.092 mm/year, respectively. Key finding from this conducted will be essential for the researcher and water resources scholar's Laos.

1. Introduction

This research aims to predict the long-term rainfall trends under climate change (CLiM) within the next 30 years (2021–2050) under greenhouse gas emissions (GHGs) of two Representative Concentration Pathway; RCP) scenarios namely, moderate (RCP4.5) and very high (RCP8.5) from the Mixed Resolution version of the Max Planck Institute Earth System Model (MPI-ESM-MR). The climatic data (rainfall) from MPI-ESM-MR was bias corrected by employing Climate Model data for hydrologic modeling (CMhyd). Three of bias correcting methods such as linear scaling (LS), delta change (DC), and power transformation of precipitation (PTP) were used. The result of the research indicated that the monthly and annual rainfall in the future

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2. Method

2.1. Bioadsorbent and gallium ion solution preparation

This research aims to develop how to predict the rainfall trends in the future in small basin by considering CLiM under GHGs of two RCPs such as RCP4.5 and RCP8.5 from MPI-ESM-MR. This model is the Regional Climate Models (RMCs) of Southeast Asia (SEA). The study method consists of three procedures: (1) rainfall data consistency test (RFCT) by Double Mass Curve (DMC), (2) screening the precise bias correction (BC) method for adjusting the climatic data (rainfall) obtained from MPI-ESM-MR. Three of BC methods, e.g. Linear Scaling (LS), Delta Change (DC) and Power Transformation of Precipitation (PTP) are used in screening, and (3) analyzing the rainfall trends in the future by Mann-Kendall. The detail of this study method is showed in Figure 1.

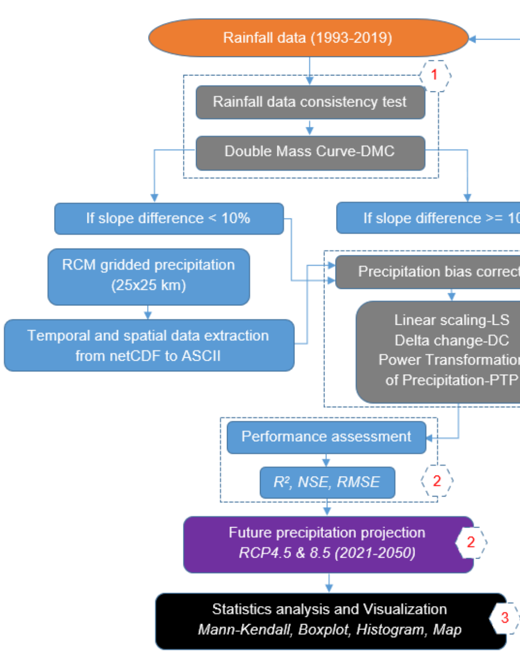


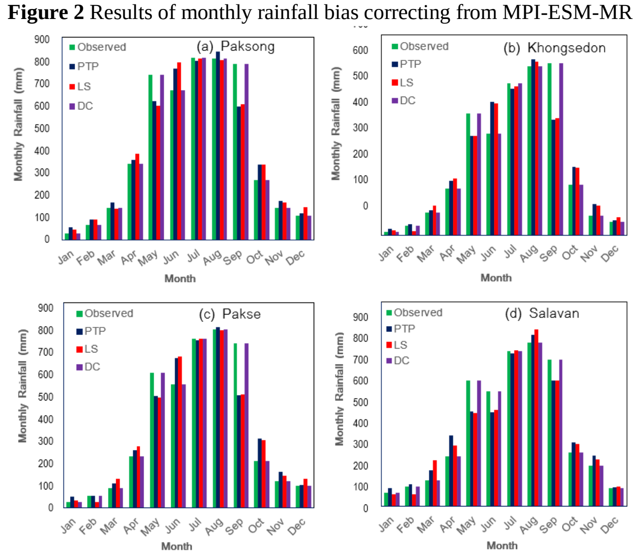
Figure 1 Study method diagram.

3. Result and discussion

3.1 Optimal bias correction method

The output of monthly rainfall bias corrected from the MPI-ESM-MR at four stations, namely Salavan, Khongsedon, Pakse and Paksong for the period 1993-2005 are presented in Fig. 2 and Table 1.

Figure 2 Results of monthly rainfall bias correcting from MPI-ESM-MR



for the period 1993-2005.

Table 1 show the output of the monthly rainfall after bias correcting applied to MPI-ESM-MR during the validation period (1993–2005). The LS method give the between 0.92-0.95, between 0.91-0.94 and between 117.54-154.83 mm. The PTP provided a range of 0.93-0.95, has a range of between 0.92-0.94, and between 134.66-155.86 mm. The DC method provided the highest statistical value than other ones because this method is determined the historical data from model equal to observation's data. Overall, the model bias correcting results imply that the MP-ESM-MR model performs satisfactorily. It is stated that it can be applied to predict future rainfall trends due to CLiM in Sedon basin. For the three of bias correction methods, namely LS, PTP and DC are suitable applying, however we suggest that the PTP method should be applied in Sedon basin.

3.2 Changes in future rainfall

The average monthly rainfall in the next 30 years (2021–2050) in Sedon from MPI-ESM-MR revealed that RCP4.5 is projected to decrease than the baseline (1993–2019) in January to September (except April), and afterwards it will increase until more than the baseline during October to December and April as displayed in Fig. 3 (left).

The lowest monthly rainfall will occur in February by 57% (-57%) while the peak of monthly rainfall is projected to increase in December, with an increase of 345% (+345%). For RCP8.5, monthly rainfall is expected to less than the baseline during January to September (except May) and it provide the monthly rainfall more than the baseline in October to December and May as demonstrated in Fig. 3 (left). The lowest monthly rainfall existed in January by 54% (-54%), and it has increased in December, with an increase of 174% (+174%). Conclusion, MPI-ESM-MR is predicted the monthly rainfall to increase and decrease in between -57 and 345% (RCP4.5) and -54 and 174% (RCP8.5).

Table 1 Result of the measure accuracy of MPI-ESM-MR from the monthly rainfall.

Rainfall station	Bias correcting method								
	LS			*DC*			*PTP*		
	R^2	*NSE*	*RMSE*	R^2	*NSE*	*RMSE*	R^2	*NSE*	*RMSE*
Salavan	0.95	0.94	117.54	1	1	0	0.95	0.94	134.66
Khongsedon	0.92	0.91	154.83	1	1	0	0.93	0.92	152.73
Pakse	0.92	0.91	153.2	1	1	0	0.93	0.92	155.86
Paksong	0.93	0.92	146.9	1	1	0	0.94	0.93	144.35

As shown in Figure 3 (right), the annual rainfall from the model regularly increases, the peak rainfall is estimated to occur in 2026 (RCP4.5) and 2029 (RCP8.5), which give the rainfall 2,436 mm and 2,585 mm, respectively. The lowest rainfall is expected to occurs in 2041 (RCP4.5) and 2045 (RCP8.5) with equal to 1,574.3 mm and 1,569.30 mm, respectively. Uncertainty of annual rainfall is also displayed on Box and Whisker plot (Fig. 4). RCP4.5 and RCP8.5 give different results and they provide max, median, and 75th percentiles less than the baseline, except min and 25th quartiles. Changes in annual rainfall from the model compared to baseline are between -26 and 14% (RCP4.5) and -24 and 21% (RCP8.5).

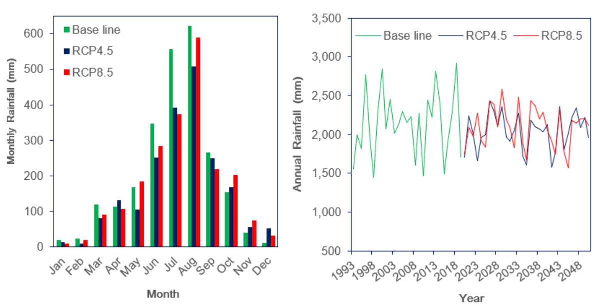


Figure 3 Comparison of monthly (left) and annual (right) rainfall between MPI ESM-MR (2021–2050) against the baseline (1993-2019).

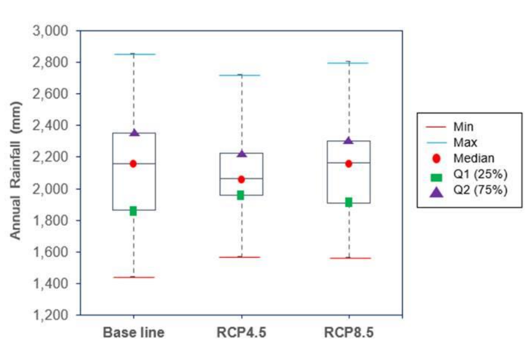


Figure 4 Boxplot of annual rainfall between MPI-ESM-MR (2021-2050) and baseline (1993-2019).

3.3 Future rainfall trends

Figure 5 obviously shows that the monthly and annual rainfall both RCP4.5 and RCP8.5 over the next 30 years have a tendency to be positive (+) and negative (-) significantly. The lowest negative is likely to occur in February (RCP4.5) and March (RCP8.5), which provide the trend approximately -0.467 and -0.175 mm/year, respectively.

A positive trend is estimated to occur in May in both RCP4.5 and RCP8.5, with trend around 0.31 and 0.177 mm/year, respectively. Overall, the model gives the monthly rainfall trends for RCP4.5 between -0.467 and 0.31 mm/year and RCP8.5 between -0.175 and 0.177 mm/year. The trend of annual rainfall is positive for both RCP4.5 and RCP8.5, with trend 0.075 and 0.092 mm/year, respectively. The spatial distribution trends of monthly and annual rainfall are presented in Fig. 6 (RCP4.5) and Fig. 7 (RCP8.5).

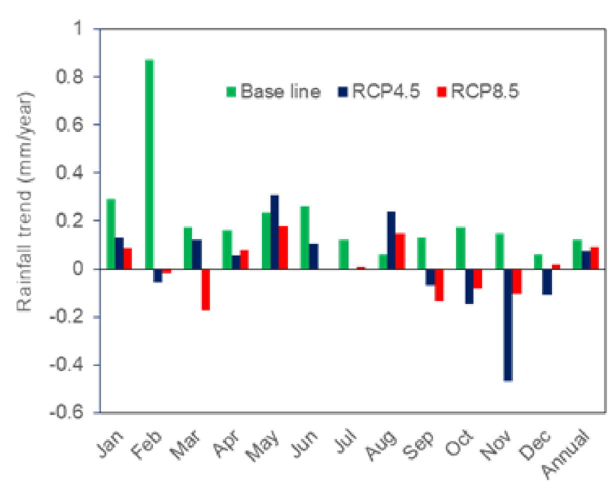


Figure 5 Comparison of monthly and annual rainfall trends between model and baseline.

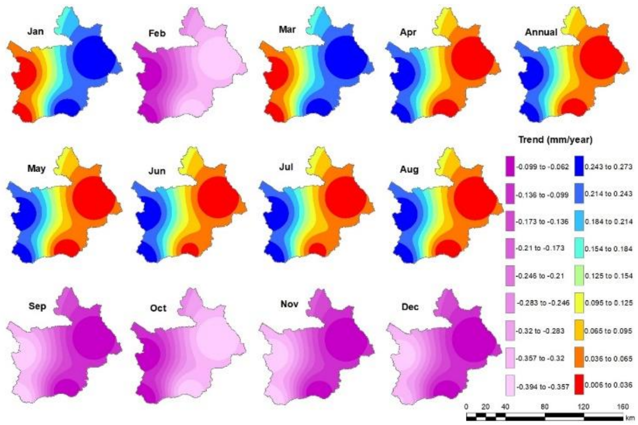


Figure 6 Spatial distribution trend of monthly and annual rainfall of RCP4.5 in Sedon basin.

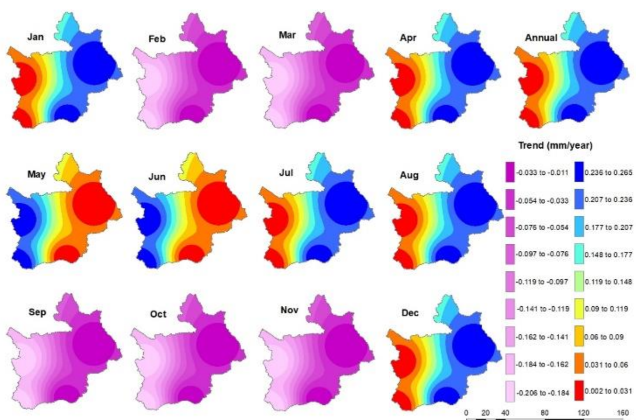


Figure 7 Spatial distribution trend of monthly and annual rainfall of RCP8.5 in Sedon basin.

4. Conclusion

This research is developed the method to predict the rainfall trends due to CLiM under GHGs of two RCPs scenarios such as RCP4.5 and RCP8.5 from MPI-ESM-MR. The rainfall data in future over 30 years (2021-2050) form climate model is bias corrected by employing LS, DC and PTP methods. The Mann-Kendall is applied in predicting rainfall trends. The results reveal that the monthly and annual rainfall of climate model under projection of RCP4.5 and RCP8.5 provide somewhat different outputs and RCP8.5 will likely higher than RCP4.5 by approximately 3%. This difference percentage value has significant at equal 0.05. Although two scenarios give different forecasting output, yet their average annual rainfall outputs are conformable, i.e. both are less than the baseline. The monthly rainfall of each projection is inequitable which has increased and decreased range. In addition, the monthly rainfall trend of all projections mainly increases during the rainy season. These results inform that the consideration of climate model under different RCP scenarios will be very crucial in predicting a rainfall trend. This study, therefore, thus emphasizes to apply different projection scenario instead of using only one projection. This principal will reveal the impossibility impact on rainfall in Sedon basin. Finally, the key finding from this study should be beneficial to the relevant agencies regarding water resources projects planning and managing along the Sedone river in order to cope with CLiM. However, next time prediction should apply multiple of climate change models. This may make the results of prediction more reliable than a single model..

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

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