EUROPEAN JOURNAL OF CLIMATE CHANGE - VOL. 02 ISSUE 01 PP. 32-37 (2020)

European Academy of Applied and Social Sciences – www.euraass.com

European Journal of Climate Change

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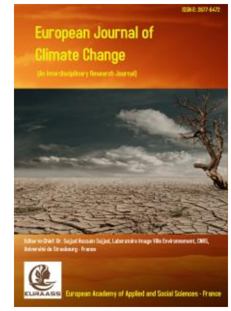

Research Article

Projection of rainfall under representative concentration pathways scenarios in a data scarce region of Iraq

Saleem A. Salman[a*], Mohamad Rajab Houmsi[a], Ghaith Falah Ziarh[a], Tarmizi Ismail[a]

[a] *Department of Water & Environmental Engineering, School of Civil Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.*

Received: 04 April 2019 / Revised: 15 August 2019 / Accepted: 27 September 2019

Abstract

A study has been conducted for projection of monthly rainfall in Baghdad of Iraq using a General Circulation Models (GCM) of Coupled Model Intercomparison Project Phase 5 (CMIP5) under four representative concentration pathways (RCP) scenarios namely RCP2.6, RCP4.5, RCP6.0 and RCP8.5. For this purpose, monthly gridded precipitation datasets produced by the centre for climatic research, University of Delaware (UDel) and GCM BCC-CSM1-1 simulated precipitation data at 46 grid points surrounding Baghdad were used. The statistical downscaling models were developed using Support Vector Machine (SVM) and Random Forest (RF). The performance of downscaling model assessed using different statistical measures showed that SVM could simulate historical rainfall in the region very well. Projection of rainfall using SVM revealed that rainfall at Baghdad will change in the range of 3.5% to -6.2% in the end of this century.

Keywords: Statistical downscaling, monthly rainfall, support vector machine, representative concentration pathways.

1. Introduction

The impact of climate change has become the most severe environmental problems being faced by world ever. It is anticipated that like many other parts of the world, climate change will cause sharp increases in temperature, which in turn will affect evapotranspiration and change the rainfall pattern (Wang et al., 2016). Arid and semi-arid regions are more sensitive to climate change compared to other climatic regions. Therefore, it is anticipated that it can have severe implication in arid region of Iraq. Adaptation and mitigation planning is very essential to combat with climate change in the region.

The climate change impact and adaptation studies need reliable projection of future changes in climate at local scale. General Circulation Models (GCMs) are generally used to project the future climate. However, GCMs cannot be used to project local- and regional-scale climate and their changes because of their coarse spatial resolutions. Therefore, GCM simulations are downscaled into much finer spatial resolution for climate change impact studies at local scale (Ahmed et al., 2015). Two major downscaling approaches are often used namely, dynamical downscaling methods that are based on high-resolution regional climate models (RCMs) (Laprise,

* Corresponding author: Email: sleem_bd@yahoo.com (Salim A. Salman)
Available online: 24 February 2020
DOI: https://doi.org/10.34154/2020-EJCC-0201-32-37/euraass
Journal reference: Eur. J. Clim. Ch. 2020, 02(01), 32 – 37.
ISSN-E: 2677-6472.

Cite as: *Saleem A. Salman S. A, Houmsi M. R, Ziarh G. F, Ismail T (2020). Projection of rainfall under representative concentration pathways scenarios in a data scarce region of Iraq. Eur. J. Clim. Ch. 02(01), 32 – 37.*

2008; Liu et al., 2013) and statistical downscaling methods based on some established statistical relationships between large-scale atmospheric variables (predictors) and local climate variables (predictands) (Wilby et al., 2004). Compared to dynamic downscaling, statistical downscaling methods are widely used for their simplicity, easiness, flexibility, quickness and ability to provide local-scale information (Pour et al., 2014).

In this study, a GCM of Couple Model Intercomparison phase 5 (CMIP5) known as BCC-CSM1-1 was used for projection of rainfall of Baghdad city of Iraq under four representative concentration pathways scenarios namely, low emission RCP2.6, intermediate emission RCP4.5, intermediate emission RCP6.0, and high emission RCP8.5 in order to understand the possible changes in precipitation of the city. Climate projection using RCP scenarios through statistical downscaling of GCM simulation is still new in Iraq. Therefore, it is expected that the results obtained in this study will help in impact assessment and adaptation studies in Bangladesh at local scale.

2. Methodology

2.1 Study area and data

Baghdad (33.31°N, 44.36°E), the capital city of the Republic of Iraq is located on a vast plain in the central east of Iraq. Location of Baghdad in the map of Iraq is shown in Figure 1. The city experiences a subtropical desert climate (Al-Shalash, 1966). It is one of the hottest cities in the world. In the summer (June to August), the average maximum temperature of the city reaches as high as 44°C. On the other hand, the average maximum temperature ranges between 15.5 to 18.5°C in winter (December to February). The average annual rainfall of the city is 150 mm, which mostly occur during November to March. Inter-annual variability of rainfall is very high (37 to 338 mm).

Due to unavailability of observed rainfall data of Baghdad city, the monthly gauge-based gridded precipitation datasets produced by the centre for climatic research, University of Delaware (UDel) was used (Matsuura and Willmott, 2012). The UDel rainfall data for the period 1961-2012 was downloaded from the website of University of Delaware for this purpose. Previous study suggested that monthly rainfall data of UDel can replicate the observed monthly rainfall of Iraq (Salman et al., 2016). Precipitation data simulated by GCM BCC-CSM1-1 developed by Beijing Climate Center China at 46 grid point having a spatial resolution of 2.8□□2.8□ was downloaded from the website: http://cmip-pcmdi.llnl.gov/cmip5/).

2.2 Methodology

The statistical downscaling of precipitation from a CMIP5 GCMs simulation under four RCP scenarios was conducted in order to assess future changes in rainfall in Baghdad of Iraq. The methodology used for this purpose is outlined below:

1. The predictors for development of downscaling model are selected form GCM BCC-CSM1-1 simulated precipitations at 46 grid points surrounding Baghdad using step-wise regression. Predictors were selected for each month separately to capture seasonal variability of rainfall.
2. RF and SVM models were developed using historical rainfall and predictors of GCM runs for the historical period 1961-2012. Individual models were developed for downscaling rainfall of each month separately. The models were calibrated and validated with historical observe rainfall data.
3. Quantile mapping (QM) was used to remove the biases in GCMs by comparing the downscaled historical simulation with the UDel rainfall.
4. The models and QM bias correction parameters were used for downscaling BCC-CSM1-1 simulations under four RCPs for the time period 2010-2099.
5. The mean variances of precipitation during different time periods (2010 – 2039, 2040 – 2069, and 2070 – 2099) were analyzed against historical period (1971 – 2000).

RF has been applied successfully in precipitation downscaling in different regions. The algorithms for implementing RF can be found in (Hastie et al., 2005). Detail algorithm of SVM can be found in Dibike et al., (2001). The theory of quantile mapping can be found in Panofsky and Brier (1968).

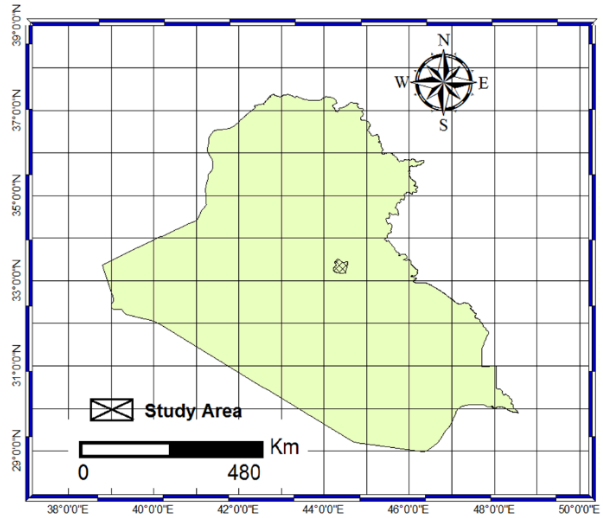

Figure 1: Location of Baghdad in the map of Iraq.

3. Results and Discussion

3.1 Characterisation of Adsorbent

The monthly time series observed and downscaled rainfall were compared first to show the efficacy of the models to downscale rainfall. The comparison was carried out for both the downscaling models individually. Obtained results using RF and SVM are presented in Figures 2(a) and (b). The figures show that both RF and SVM models were able to downscale the GCM simulated rainfall for historical period (1961-2012) reliably. Even the observed precipitation peaks were well captured by both RF and SVM downscaling models. When compared the performance of SVM and RF downscaling models, it was observed that SVM was able to downscale the rainfall more reliably compared to that RF.

Monthly observed and downscaled rainfall were converted to annual and the yearly time series of observed and downscaled rainfall using both RF and SVM compared to show the efficiency of the model. The annual time series of observed and downscaled rainfall by RF and SVM are presented in Figures 3(a) and (b), respectively. The figures show that both RF and SVM models were able to downscale the GCM simulated rainfall for historical period (1961-2012) reliably. When compared the performance of SVM and RF downscaling models, it was found that observed annual time series is much close to downscaled annual rainfall time series by SVM compared to that RF.

The performances of the downscaling models were numerically assessed by comparing the downscaled rainfall for the period 1961-2012. Performances of RF and SVM models were statistically assessed according to biasness, magnitude of error and level of acceptance by using MAE, RMSE, PBias, Md, NSE, and R2. The obtained results are given in Table 1. The table shows SVM performed better compared to RF in term of all statistical indices. Therefore, SVM model was used for downscaling of future projected rainfall by GCM.

Projected rainfall at Baghdad for the time period 2006 to 2099 under different RCPs are shown in Figure 4. The figure shows different magnitude of changes in rainfall under different RCPs. In order to quantify the changes, rainfall during base year (1971-2000) and three projected periods namely, early part of this century (2010-2039), middle of this century (2040-2069) and the last part of this century (2070-2099). Obtained results are presented in Table 2.

Table 2 shows a decreasing trend in rainfall at Baghdad due to climate change. Highest decrease is projected under RCP8.5 in the first part of the century. The rainfall is projected to increase gradually over the century. At the end of this century, the rainfall is projected to change in the range of 3.5% to -6.2%. The increase is projected under RCP2.6 and the decrease under all other RCPs.

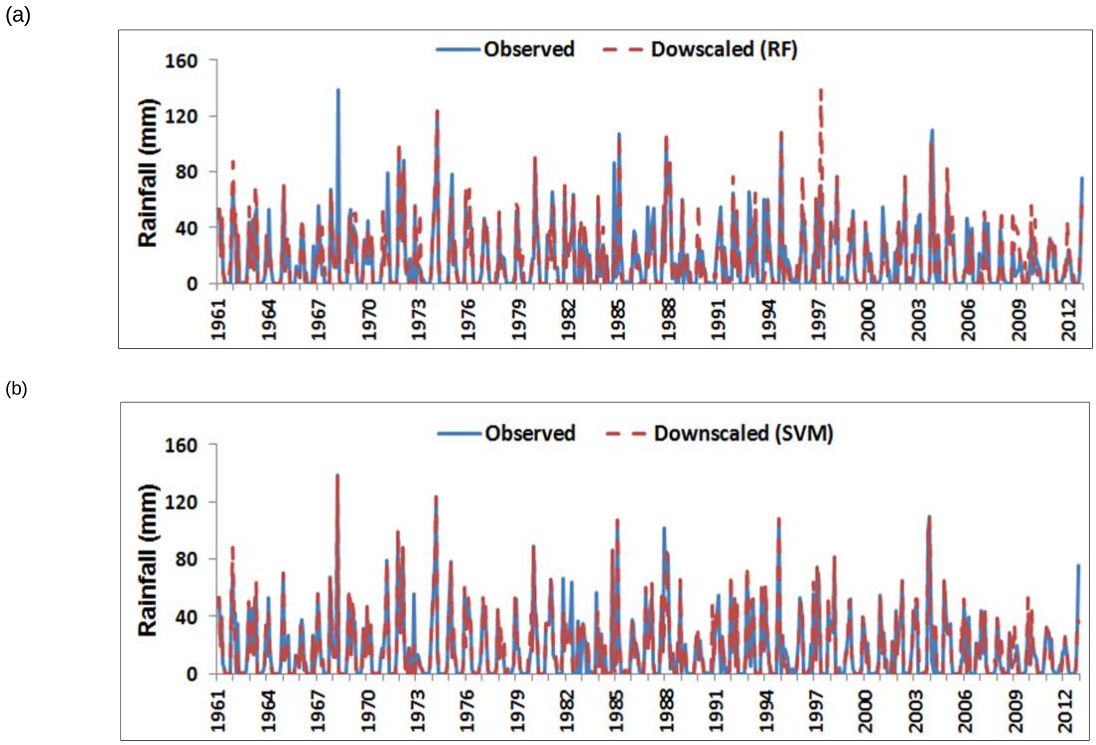

Figure 2: Comparison of monthly observed and downscale precipitation by (a) RF; and (b) SVM.

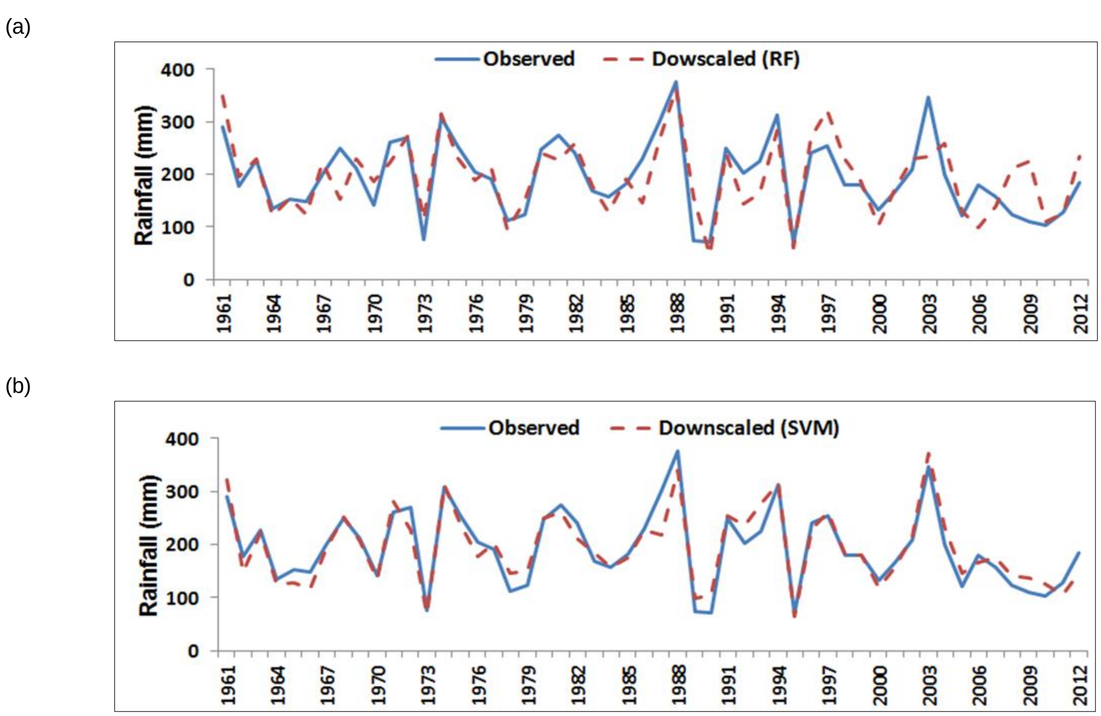

Figure 3: Comparison of annual observed and downscale precipitation by (a) RF; and (b) SVM.

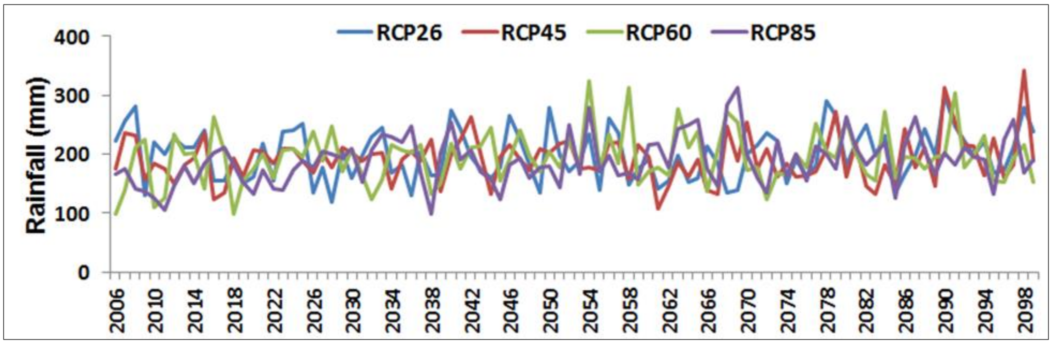

Figure 4: Projected rainfall at Baghdad for the time period 2006 to 2099 under different RCPs.

Table 1: Validation of SVM and RF downscaling model through statistical indices.

Statistics	Monthly		Yearly	
	SVM	RF	SVM	RF
MAE	3.39	5.24	0.2	-0.04
RMSE	8.03	11.35	24.28	44.78
PBIAS	0.1	0.1	0.1	63.4
NSE	0.87	0.74	0.88	0.59
md	0.9	0.85	0.84	0.71
R2	0.88	0.76	0.89	0.64

Table 2: Changes in average annual rainfall during different future periods under different climate change scenarios.

Period	RCP2.6	RCP4.5	RCP6.0	RCP8.5
2010-2039	-7.5	-9.7	-10.7	-13.5
2040-2069	-7.1	-7.8	2.1	-3.2
2070-2099	3.5	-3.0	-6.2	-5.4

4. Conclusions

A CMIP5 GCM developed by Beijing Climate Centre of China (BCC-CSM1-1) is used in the present study for the projection of rainfall of Baghdad of Iraq. Considering the scarcity of observed data, monthly gridded precipitation datasets of UDel was used as the base for the development of downscaling models and projections of rainfall. Two state-of-art machine learning methods were used for the correction of bias in BCC-CSM1-1 simulated rainfall. The performance of downscaling model depends on rainfall pattern and climate of a region. Present study revealed better performance of SVM compared to RF in downscaling rainfall in Baghdad. Therefore, SVM model was used for downscaling of GCM projected rainfall for different RCPs and future periods. The results revealed a large uncertainty in rainfall projections in Baghdad. Both increase and decrease of rainfall was projected for different future periods and RCPs. The results indicate the need of assessment of projection of rainfall in the region with more GCMs. Overall, a large decrease in the range of -7.5 to -13.5% was projected during 2010-2039 by different RCPs, while it was projected to increase by 3.5% for RCP2.6 and decrease by -6.2% for RCP6.0 during 2070-2099. The decrease in rainfall in near future may have severe implications in this arid region where water is major problem for socio-economic development. More GCMs can be used in future for projection of rainfall with uncertainty level. Besides, the impacts on rainfall changes on water resources in the region can be studied in order to aid in adaptation and mitigation planning.

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