

Precipitation Projection Using LARS-WG and CMIP6 Models

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Received Apr.19, 2025

Revised May.11, 2025

Accepted May.11, 2025

Online Dec.1, 2025

ABSTRACT

Climate change has significantly impacted the environment across various regions worldwide. The growing interest in these impacts has raised the incentive of scholars to investigate and predict variations in critical weather variables, such as precipitation, to supply helpful baseline results for future planning and control. This research attempts to assess the effects of global warming on precipitation in Soran City in northern Iraq. The daily rainfall is downscaled utilizing the LARS-WG (8.0) model with six General Circulation Models (GCMs) and the SSP585 scenario for 2021-2040. These outcomes establish that the statistical analysis confirmed the LARS-WG model's ability and reliability in downscaling precipitation.

Additionally, the average rainfall of six GCMs will likely fluctuate during the year. The highest increase is anticipated in January and October, while the most decrease is expected in February, March, and November. The findings can enhance the understanding of the effects of climate change on water availability and motivate managers and stakeholders to develop the most effective techniques for mitigating these impacts.

Keywords: CMIP6, LARS-WG, Precipitation, SSP585, Climate Change, CHIRPS

1. Introduction

Global warming is one of the most pressing problems that humanity has ever encountered. A growth in the average temperature of the global surface that causes shifts in plant and animal life is known as global warming (or simply climate change). Thus, humans and their environments feel these changes' short- and long-term impacts [1,2]. The ecosystem is expected to face substantial challenges due to climate change and variability, such as reduced rainfall and future changes in rainfall patterns [3]. More greenhouse gases were released into the Atmosphere due to industrialization and the extensive use of fossil fuels, amplifying the effects of climate change [4,5].

According to all Intergovernmental Panel on Climate Change (IPCC) emission scenarios, the world's temperature is projected to rise in the twenty-first century due to global warming and decreasing rainfall as well. Not only that, but this will also significantly impact hydrological processes [6,7].

Previous studies have widely employed GCMs combined with Representative Concentration Pathways (RCPs) to project future climate impacts. However, due to the coarse spatial resolution of GCM outputs, they are unsuitable for direct use at the regional level. Therefore, downscaling techniques are essential to enhance spatial detail and accuracy [8].

The current study used statistical downscaling methods because of their computational efficiency, simple application, and low resource requirements compared to dynamical downscaling techniques [8]. The Long Ashton Research Station Weather Generator (LARS-WG), which is one of the statistical downscaling techniques, was applied successfully in different regions, including Iraq [9], Pakistan [10], Iran [11], China [12], and the United States [13].

This study aims to use LARS-WG 8.0, which incorporates models from the Coupled Model Intercomparison Project Phase 6 (CMIP6), to forecast future precipitation for the Soran station in northern Iraq over a chosen period (2021-2040). Six GCM models are used and implemented under the Shared Socioeconomic Pathways (SSP585) scenario.

2. Study area and data set

Iraq rests in an arid to semi-arid region [14]. Soran is situated on the northeastern edge of Erbil Governorate, approximately 117 km from the capital city and 75 km from the Iraqi-Iranian border (Fig. 1). It has an area of 809,616 dunams, with roughly 737,000 dunams aimed at agriculture. Soran lies astrologically between the longitudes of 44.31 and 44.34 degrees east and the latitudes of 36.39 and 36.38 degrees north. The study area is located in the Diana Plain, with surface features of relative asymmetry. The region lies between elevations of 560 and 770 meters. The favorable topography, high-quality soil, and consistent rainfall contribute to the Soran has a Mediterranean climate with very hot, dry summers and cool to cold, damp, and humid winters. The present study gathered historical daily precipitation from Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) for the baseline period (1985-2015).

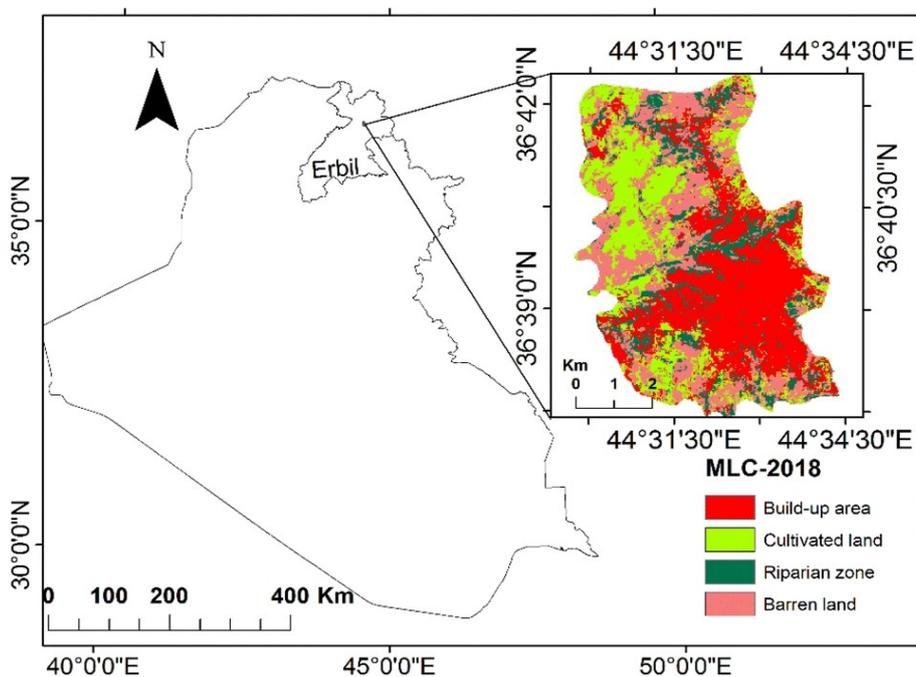


Figure 1. Location Map of Soran

3. The LARS-WG model

The LARS-WG is a statistical downscaling approach that simulates and produces daily weather time series to determine the effect of climate change under current and future climatic factors [15,16]. It was developed to realistically represent climatic variables such as precipitation and temperature, using historical weather records and outputs from Global Circulation Models (GCMs). LARS-WG is known for its computational simplicity and accuracy in modeling local-regional scale climate, and it has proven effective in various regional studies worldwide, including in arid and semi-arid regions. However, the findings demonstrated that the technique can reasonably forecast climatic parameters [17]. In order to generate future climatic parameters based on CMIP6 models, the baseline period 1985-2015 is used to validate and calibrate the statistical downscaling technique. Relying on multiple climate models helps reduce uncertainty and clarifies possible future climate conditions [18].

The LARS-WG model will also use the SSP585 emissions scenario to explore the most extreme climate change outcomes. This choice allows for a deeper understanding of potential worst-case scenarios and helps plan

adaptation strategies under maximum-risk conditions. Check here to learn more about the LARS-WG technique and its operation [19].

4. Results and discussion

4.1. Validation and calibration of LARS-WG

The daily rainfall data for Soran City (1985-2015) was employed to calibrate and validate the LARS-WG technique. The mean and standard deviation (Std) of actual and predicted data were visually compared to evaluate the model's capacity and dependability in downscaling future precipitation data. Regarding rainfall, the model fits the data closely (Fig. 2) for the mean and standard deviation. As indicated in[20], the LARS-WG technique has shown similar dependable capabilities in producing climatic factors in different parts of the world. Consequently, the downscaling technique was more positively employed in this study.

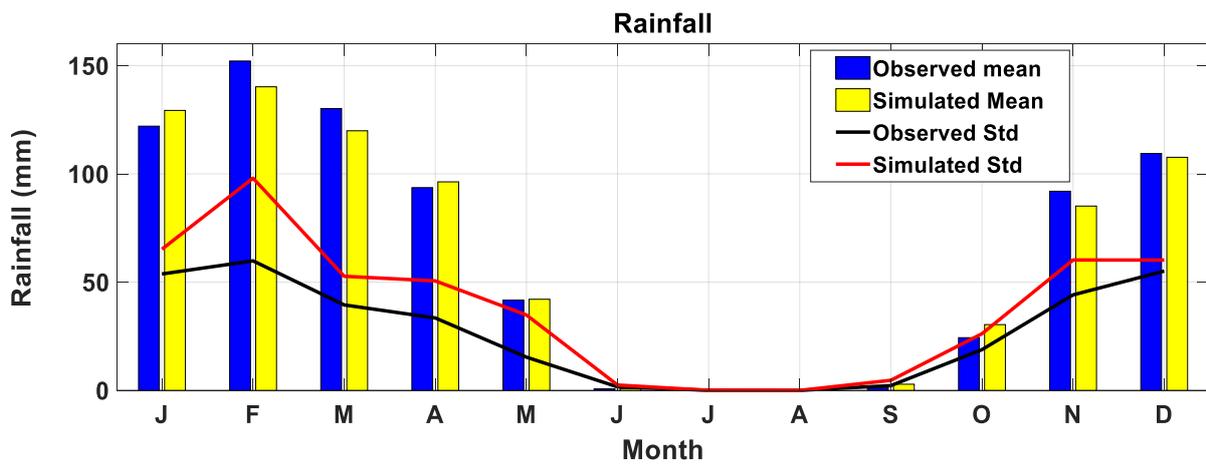


Figure 2. Observed and Projected Standard Deviation and Mean of the Precipitation in the Study Area

4.2. Future precipitation project

The evolved and validated LARS-WG technique for Soran City was then used to project rainfall for the period (2021-2040), dependent on the SSP585 derived from six GCMs. Fig. 3 shows the results of all GCMs' yearly rainfall forecasts and their ensemble mean for the chosen time frame. In general, there is minimal difference in the projected results for all the GCMs from 2021 to 2040 according to scale, as seen in this Fig. Generally, all the GCMs offer the same patterns, except the GFDL-ESM4 model exhibits an irregular trend during the chosen time frame. Moreover, the models with the same patterns show close time series except for HadGEM3-GC31-LL models. The range of the ensemble forecasted is approximately 38-84 mm.

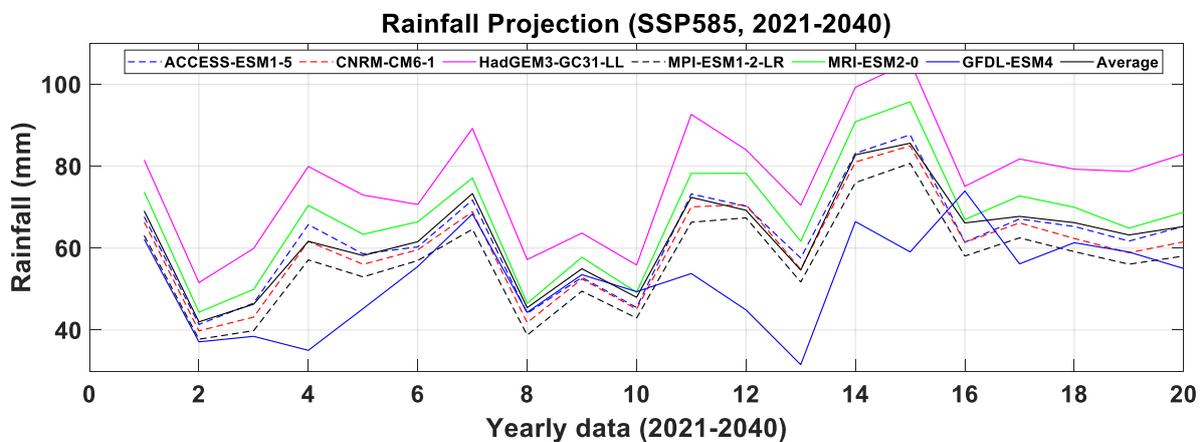


Figure 3. Predicted Yearly Data of the Precipitation for the Selected Period

Fig. 4 shows the results of plotting the deviations between the ensemble mean rainfall forecasts for (2021-2040) period and the baseline (1985–2015) based on the six GCMs. Precipitation patterns will change throughout the year. The months of January and October are likely to see the most significant growth, while the months of February, March, and November are expected to see the most considerable reduction.

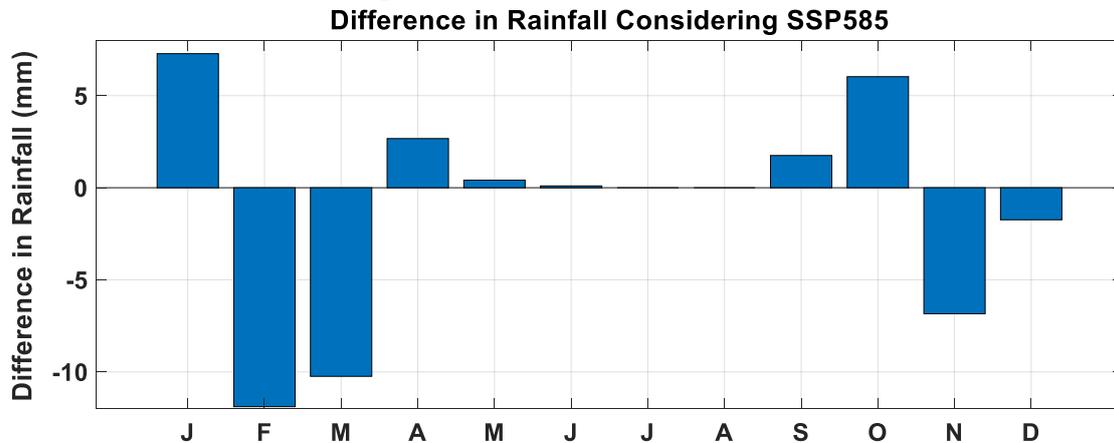


Figure 4. The Differences in Rainfall Between the Selected Period (2021-2040) and the Baseline (1985-2015)

5. Conclusion

This research aimed to assess and employ the LARS-WG technique to downscale daily rainfall in Soran City for 2021–2040 using historical daily rainfall data, six GCMs, and the SSP585 scenario. Data collected between 1985 and 2015 was utilized to calibrate and validate the downscaling technique with potential future scenarios. Findings from the research indicate that:

- The LARS-WG technique can effectively project daily precipitation data from the research region.
- The patterns of the predicted precipitation from the six GCMs seem to vary from one another. This illustrates why it is necessary to mitigate the uncertainty in climate change research by using many GCMs.
- Rainfall will likely fluctuate during the year. The highest increase is anticipated in January and October, while the most decrease is expected in February, March, and November.

The findings could increase our awareness of climate change in a variety of ways and provide a framework for future research. It also helps policymakers better understand how to decide on the most effective ways to prevent climate change's impacts on water availability and achieve sustainability.

Declaration of Competing Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Funding Information

No funding was received from any financial organization to conduct this research.

Author Contributions

All authors proposed the research problem. Tuqa Khalid Abed: Formal analysis, Investigation, Methodology, Validation, Writing - original draft, Writing - review & editing. Salah L. Zubaidi: Methodology, Conceptualization, Project administration, Supervision, Software, Writing - review & editing. YousifAlmamalachy: Data curation, Investigation, Software, Resources, Visualization. All the authors discussed the results and the final version of this paper.

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