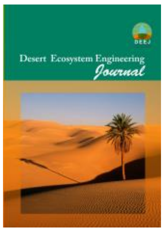
DEEJ (2024) 13 (3) 1-2

University of Kashan

Desert Ecosystem Engineering Journal

Journal homepage: http://deej.kashanu.ac.ir



Downscaling of CMIP$_6$ Rainfall Data Using Digital Elevation Model (Case Study: Yazd Province)

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Received: 19/09/2024 Accepted: 14/03/2025

Extended Abstract

Introduction: Climate change, driven by the increasing concentration of greenhouse gases—particularly carbon dioxide—in the atmosphere, leads to significant alterations in rainfall patterns, runoff volumes, wind speed, solar radiation reaching the Earth's surface, and air temperature. In recent years, the economic and social consequences of climate-related events have heightened the importance of addressing climate change. To study the impacts of climate change on future trends in rainfall, temperature, and other parameters, projected data from climate models, known as General Circulation Models (GCMs) or Atmospheric and Oceanic General Circulation Models (AOGCMs), are widely used. A critical step in utilizing GCM data for projecting climate parameters (e.g., rainfall) is the downscaling process, which converts data from large-scale grid cells to smaller-scale cells or specific points. In this research, rainfall data from CMIP6 climate models (such as TaiESM1, ACCESS-CM2, and CanESM5) were employed to project future rainfall patterns in Yazd Province, located in central Iran. As an arid region, Yazd heavily relies on rainfall as a fundamental component of the hydrological cycle, making it a critical factor in groundwater resource management.

Materials and methods: the study area is Yazd Province, covering an area of 73,000 square kilometers. It is geographically located between latitudes 29.5° to 33.5° N and longitudes 52.5° to 56.5° E. The data used in this research include:

1. Annual rainfall records from 53 rain gauge stations across Yazd Province.
2. A Digital Elevation Model (DEM) map with a spatial resolution of 90 meters.
3. Rainfall data from several climate models included in the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), specifically the TaiESM1, ACCESS-CM2, and CanESM5 models.

These models have spatial resolutions of 0.942° × 1.25°, 1.875° × 1.25°, and 2.813° × 2.791°, respectively, corresponding to approximate cell dimensions of 105 × 118 km, 175 × 138 km, and 270 × 310 km. The area covered by each cell of the TaiESM1, ACCESS-CM2, and CanESM5 models is approximately 12,400 km², 23,600 km², and 83,700 km², respectively. Each model incorporates four Shared Socioeconomic Pathway (SSP) scenarios for carbon dioxide emissions: SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5. These scenarios were used to simulate monthly and annual rainfall for future periods. Monthly rainfall data were extracted for two time periods: the base period (1850–2014) and the future period (2015–2100), under the aforementioned emission scenarios. Additionally, a regression-based relationship between annual rainfall data and the altitudes of the rain gauge stations was established to derive the rainfall-altitude gradient for the study area. This relationship was then used to generate a rainfall map and, subsequently, a dimensionless rainfall map with a spatial resolution of 90 × 90 meters. The dimensionless rainfall map represents the ratio of each pixel's annual rainfall to the long-term average rainfall of the region. This map was instrumental in downscaling the coarse-resolution rainfall data from the CMIP6 models into high-resolution rainfall maps with a pixel size of 90 × 90 meters.

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DOI: 0.22052/deej.2025.255109.1063

Results: the results of this study indicate that the proposed method for downscaling CMIP6 rainfall data exhibits varying levels of efficiency across the three climate models with different spatial resolutions. Specifically, the method demonstrated higher accuracy with the TaiESM1 model compared to the ACCESS-CM2 and CanESM5 models. As previously mentioned, the area covered by each cell of the TaiESM1, ACCESS-CM2, and CanESM5 models is relatively large, resulting in low spatial resolution for these models. It is concluded that the accuracy of the proposed downscaling method is generally higher for climate models with finer spatial resolutions. Among the CMIP6 climate models examined, the following models have smaller cell sizes and are therefore recommended for applying the proposed downscaling method: BCC-CSM2-MR, CAMS-CSM1-0, CESM2-WACCM, CIESM, CMCC-CM2-SR5, FIO-ESM-2-0, GFDL-ESM4, MRI-ESM2-0, INM-CM4-8, Additionally, the findings of this research suggest that the average annual rainfall in Yazd Province is projected to increase in the coming decades. The models predict a rainfall increase ranging from 1% to 23%, with an average increase of 13% compared to the base period. Among the three climate models analyzed, the ACCESS-CM2 model predicted the highest increase in rainfall, particularly under the SSP3-7.0 scenario.

Discussion and Conclusion: In this research, a method for downscaling large-scale rainfall data from CMIP6 climate models was introduced, utilizing the rainfall-altitude gradient and a Digital Elevation Model (DEM) of the region. This method was successfully applied to downscale data from three CMIP6 models: TaiESM1, ACCESS-CM2, and CanESM5. Although these models have relatively large cell sizes, the proposed method enabled the generation of high-resolution rainfall maps for the study area with a spatial resolution of 90 × 90 meters. The results indicate that the accuracy of the proposed downscaling approach is higher for CMIP6 climate models with finer spatial resolutions compared to those with coarser resolutions. This method is recommended for downscaling CMIP6 rainfall data in regions with similar land surface topography. However, for regions with different topographical characteristics, further investigations may be required to adapt and validate the method.

Keywords: land surface topography, rainfall-altitude gradient, dimensionless rainfall map, General Circulation Models, SSP scenarios.