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Research Paper

Projection of precipitation under RCP4.5 and RCP 8.5 in central and southern regions of Iraq

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ABSTRACT

Climate change has significant impacts on natural systems, especially in terms of altering hydrological patterns due to changing precipitation and melting snow and ice. This study examines projected changes in precipitation for central and southern Iraq under the RCP4.5 and RCP8.5 scenarios for the periods 2046–2065 and 2081–2100 using CMIP5 climate model HadGEM2-AO output. The results revealed that under RCP4.5, there was large spatial variation in the projected precipitation over the region during 2064-2065, ranging from as low as 27 mm in western part to as high as 1541 mm in the eastern part. The spatial variability as well as precipitation amount decreased considerably during 2081-2100 periods. Under RCP8.5 the projected precipitation was only 14-164 mm in 2046-2065 and 36-532 mm in 2081-2100 periods. Thus, under RCP8.5 scenario anticipated precipitation will be quite low.

Keywords: CMIP5, RCP 4.5, RCP 8.5, HadGEM2-AO, Precipitation, Iraq

Recent research, indicates continued global warming is expected to amplify the global water cycle, including its variability, global monsoon precipitation, and extreme wet and dry weather and climate events and seasons (IPCC, 2023). The scientific data and conducted simulations suggest that the Earth's climate is currently changing as a result of human activity called "anthropogenic climate change" which include human activities such as deforestation for agricultural reasons, urbanization, and other human endeavors including the combustion of fossil fuels (Riedy, 2016; Aswathi *et al.,* 2022). As a result, the ecosystem is impacted by climate change in terms of altered precipitation patterns and air temperatures, which may result in severe droughts. These effects can be observed in either the near or far future (Bayatavrkeshi *et al.,* 2023). The consequences of climate change in Iraq in recent years have included rising sea levels, extreme temperatures, inadequate precipitation, desertification, drought, and water scarcity (Hashim *et al.,* 2022; Shweta *et al.,* 2021). Iraq can expect yearly average temperatures to rise 2 °C and more heat waves. Rising temperatures are leading to drier soils and more arid conditions, which are exacerbated by less precipitation and longer droughts (Al-Lami *et al.,* 2021; Al-Timimi *et al.,* 2021). These changes have also affected the annual stream flow quantities of the Tigris and Euphrates Rivers. Many studies indicate that these unfavorable patterns will persist till the end of the current century and may intensify as long as the emissions of greenhouse gases (GHG), including CO_2, remain at their current levels (Özdoğan, 2011; Bakr *et al.,* 2024). There will be a reduction in rainfall ranging from 15 % to 25 % in a significant portion of this region, which includes sections of Turkey, Syria, northern Iraq, and northeastern Iran, this region also encompasses the crucial headwaters of the Euphrates and Tigris Rivers, which have strategic importance (Adamo *et al.,* 2018).

The analysis of climate change predictions for the 21st century has become more accessible with the existence of the Coupled Model Intercomparison Project Phase 5 (CMIP5) repository. CMIP5 has developed four RCPs that include various forecasts of future population increase, technological advancement, and social reactions (Taylor *et al.,* 2012). This study seeks to investigate the projected change of precipitation in the central and southern regions of Iraq over the 21st century under the RCP4.5 and

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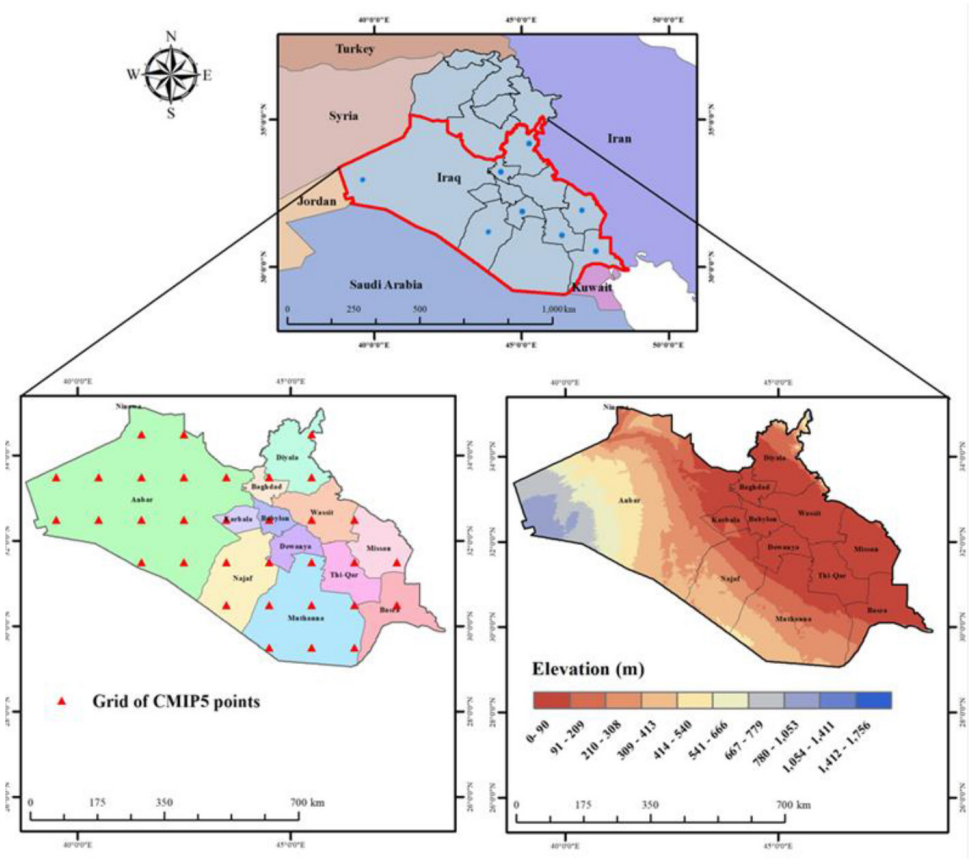

Fig. 1: The study area of mid and southern Iraq with the selected eight stations, elevation map and grid of CMIP5 points.

RCP8.5 scenarios using precipitation observed data from 1980–2023 and the HadGEM2-AO climate model output.

MATERIAL AND METHODS

Study location

Iraq is divided into four main geographical divisions: the western desert, the island plateau in the center, the northern highlands of Iraqi Kurdistan, and the alluvial plain at the mouth of the Arabian Gulf. Central and southern Iraq receives 100–200 mm of rain annually. Northern areas receive above 1000 mm of rain. Most of Iraq receives its yearly rainfall from December to February, and the north from November to April. The rest of the year is dry, notably June–August. The country's average annual precipitation is 154 mm, but it varies. The northeast may receive 1200 mm, whereas 60% of the south receives less than 100 mm (Ahmed *et al.,* 2023). The region selected for this study is the middle and southern regions of Iraq, covering a total area of 166,098 square kilometers positioned between the latitudes of 29° 53′ 5″ and 35° 9′ 25″ N, and the longitudes of 38° 45′12″ and 44° 44′ 4″ (Fig. 1).

Data sources

For this study, the CMIP5 GCMs projections under two climate change scenarios RCP4.5 and RCP8.5 for the middle and southern areas of Iraq for two time period viz. the mid future (2046-2065) and the far future (2081-2100) were obtained. Salman *et al.,* (2019) compared the suitability of CMIP5 GCMs for Iraq using different performance indices and reported that the HadGEM2-AO model is considered one of the best models for climate change projection in the country and also showed a good performance with historical data. Therefore, for the present study HadGEM2-AO model output for the selected study area were used for the analysis. The Canadian Centre for Climate Modelling and Analysis (CCCMa) provided the projected data of yearly precipitation inputs, which may be accessed at (https://climate-scenarios.canada.ca/gridded-data). Projections relative to the reference period of 1986–2005 represent the multi-model ensembles of predicted changes in precipitation. The study area's Digital Elevation Model (DEM) was derived using data from the Shuttle Radar Topography Mission (SRTM3) **(**http://www.webgis.com/srtm3.html**)**.

The Iraqi Meteorological Organization and Seismology (IMOAS) provided the yearly average precipitation data (https://meteoseism.gov.iq). precipitation data of eight meteorological stations were gathered for the years from 1980 to 2023. ArcGIS Pro was used to process the data, transforming it into vector data in the shapefile format. Subsequently, it is resized to fit inside the boundaries of the provinces located in the central and southern regions of Iraq.

RESULTS AND DISCUSSION

Observed precipitation variation during 1980-2023

Fig. 2 shows that the yearly variation in annual rainfall at

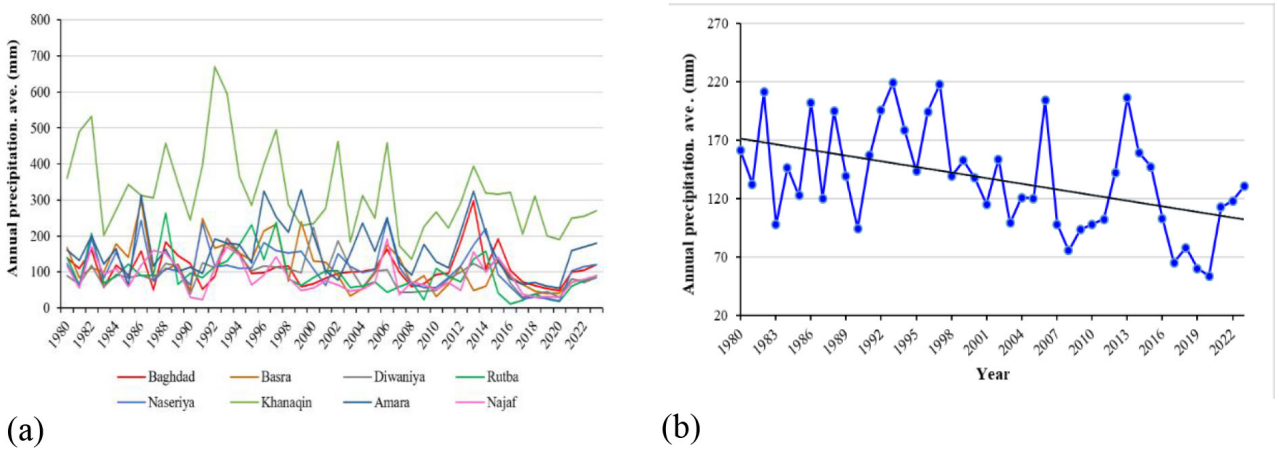

Fig. 2: Annual variation of precipitation during 1980 and 2023 over (a) eight stations (b) mean over the region

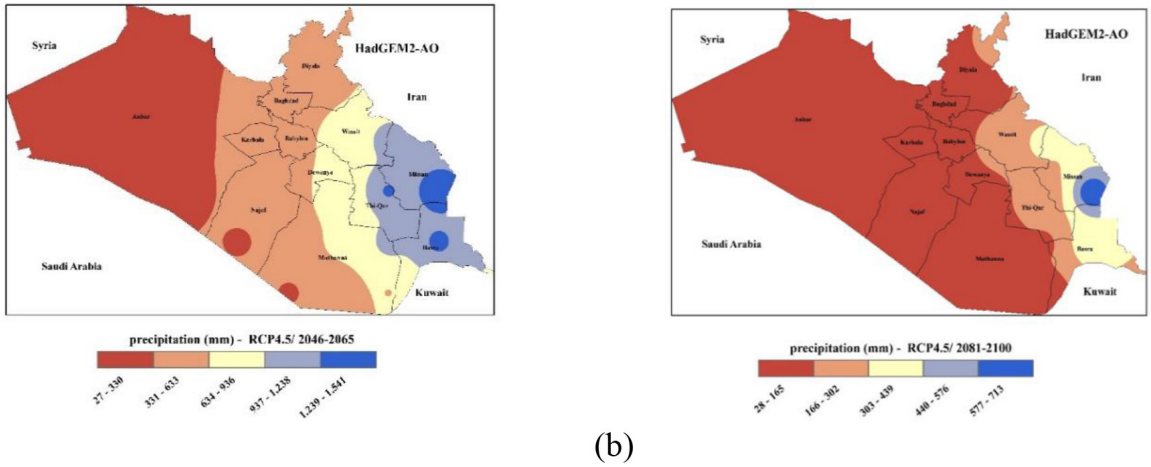

Fig. 3: Projected precipitation in mid and southern Iraq for period (a) 2046-2065 and (b) 2081-2100 under RCP4.5

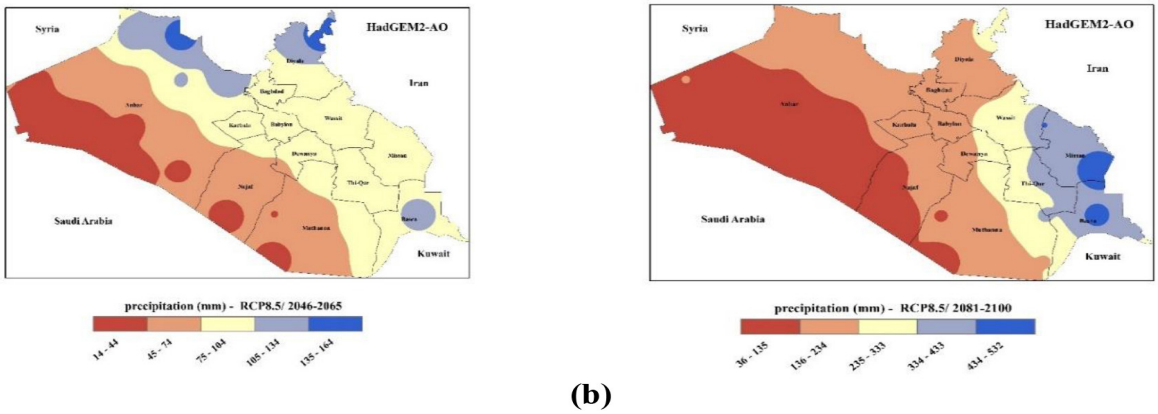

Fig. 4: Projected precipitation in mid and southern Iraq for period (a) 2046-2065 and (b) 2081-2100 under RCP8.5

eight meteorological stations in Iraq during 1980-2023. The northern part of Iraq, particularly Khanaqin, experienced the highest average precipitation, while the southwestern sections, especially Najaf, had the lowest average precipitation. The central and northern regions of Iraq had moderate precipitation, ranging from 100 to 200 mm. The overall mean of eight stations shows that the highest amount of precipitation was recorded about 219 mm in 1993, while the lowest was in 2020 at 54 mm with a decreasing trend in annual precipitation over the region (Fig. 3).

Precipitation projection under RCP4.5

The HadGEM2-AO climate model projections for mid future period 2046-2065 under RCP4.5 indicated significant spatial variability in precipitation from as low as 27 mm to as high as 1541 mm across the region (Fig. 3a). Western regions such as Anbar and Muthanna are expected to experience low precipitation less than 330 mm, exacerbating arid conditions. Central regions, including Baghdad and Babylon will see moderate precipitation 331 to 936

mm, while eastern areas like Missan and Basra will receive higher levels 937 to 1541 mm.

Fig. 3b shows the precipitation projections for RCP4.5 for the far future period 2081-2100 which is less than that of period 2046-2065. The HadGEM2-AO climate model projections show significant regional variability in Iraq's precipitation. Anbar, Najaf, Muthanna, and Karbala will receive the lowest precipitation at 28 to 165 mm. Central regions such as Baghdad, Babylon, and Diyala will have moderate levels of about 166-439 mm, with Wasit slightly higher at 440 to 576 mm. Missan will experience the highest precipitation from 577 to 713 mm, while Basra and Thi-Qar will have moderate to high levels at 303 to 576 mm.

Precipitation projection under RCP 8.5

The HadGEM2-AO climate model projections indicate substantial regional variability in Iraq's precipitation under the RCP8.5. There is a drastic reduction in the projected precipitation for the future periods 2046–2065 and 2081-2100 (Fig. 4). Anbar and Najaf will receive the lowest precipitation about 14 to 44 mm, while Diyala will experience the highest from 135 to 164 mm during 2046 to 2065 period (Fig. 4a). Basra will have moderate precipitation of about 105 to 134 mm, and central regions like Baghdad and Babylon will see relatively lower precipitation of 45 to 74 mm. Muthanna and Karbala will also have low levels about 45 to 74 mm, while Missan and Thi-Qar will receive moderate precipitation 75 to 104 mm. The precipitation projection under RCP8.5 scenario for 2081-2100 are displayed in Fig. 4b. Anbar and Najaf will have the lowest precipitation from 36 to 135 mm, while Missan and Basra will receive the highest at 434 to 532 mm. Central regions like Baghdad, Babylon, and Diyala will see moderate precipitation about 136 to 333 mm, with Wasit slightly higher at 235 to 433 mm. Southern regions such as Muthanna will have lower levels recorded 136-234 mm.

CONCLUSION

The results revealed a declining trend in annual precipitation mid and southern region of Iraq during last 44 years (1980 to 2023). The precipitation projections using HadGEM2-AO model output for two time periods (2046-2065) and (2081-2100) also revealed declining trend under RCP4.5 and RCP8.5. The magnitude of reduction under RCP8.5 is more than that of RCP4.5. Similarly, the expected precipitation during 2081-2100 time period is less than that of period 2046-2065. Thus, there is a need for advanced water management strategies in the region to ensure water security and agricultural sustainability amidst changing climatic conditions.

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***Data availability*:** Annual rainfall data for this study were obtained from The Canadian Centre for Climate Modelling and Analysis (CCCMa) and the Iraqi Meteorological Organization and Seismology (IMOS) for 8 meteorological stations distributed across Iraq, representing the three climatic zones from 1980 to 2023.

***Author contribution*: H. K. Abdulhussein:** Investigation, maps, Writing-original draft; **A. M. AL-Lami:** Supervision, editing**; B. M. Hashim** collected data, Writing-review and editing.

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