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Evaluation of Hydro-Climatic Conditions of Gorganroud Basin under the Effect of Climate Change Using MIROC-ESM Model

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1- Introduction

Climate evolutionary theory reveals that climate change has already been evident in the planet's history, but when opposed to historical climate changes, the climatic changes of the last century have two unique characteristics. First, through the nature of the ongoing climate change, human actions play a significant role Second; the speed of recent climatic changes is greater, so that, many changes will be occurring in the Earth's atmosphere during a short term [Telmer et al. 2004]. Nowadays, global warming has significant effects on precipitation and runoff yield and water resources due to the increased concentration of greenhouse gases [Donyaii et al. 2020]. The average meteorological parameters, in particular the annual or seasonal components of temperature, precipitation and runoff, play a significant role in the hydrological cycle and are typically used as an indicator for climate change evaluation on the water supplies available to Iran now and particularly in the future [Donyaii et al. 2020]. Based on the IPCC Fourth Assessment Report Models [AR4], a number of studies have been undertaken to examine the effect of climate change on the hydrological components of watersheds in Iran. In contrast with the Fifth Assessment Study [AR5] models, these models, along with older pollution scenarios, have limited resolution. Therefore, in the watersheds of Iran, climate change experiments with higher resolution climate models under the latest pollution scenarios [RCPs] of the AR5 seem appropriate. According to historical evidence of Gorganroud's high flood capacity in the province of Golestan, Iran, the recognition of the impact of climate change on the watershed's hydrological regime is important for water resource planners.

2- Methodology

2-1- Study area and data set

The Gorganroud Watershed is located in Golestan Province, Iran. In this study, the Soil and Water Assessment Tool [SWAT] was employed for hydrological simulation of the

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watershed based on the downscaled outputs [using the Bias Correction and Spatial Disaggregation [BCSD] method] of fifth assessment report climate change model [MIROC-ESM] for historical and future periods. The trend analysis of hydro-climatic records was done according to the non-parametric Mann-Kendall test. The future projection was conducted for the near [2025-2050], mid [2051-2075], and far [2075-2100] future periods related to historical records in the period of 1985-2005.

2-2- SWAT set-up and calibration, validation and uncertainty analysis

In this study, runoff was estimated using the Soil Conservation Service [SCS] method. The Manning equation and Muskingum method were utilized to calculate flow velocity and routing phase, respectively. On the other hand, the SUFI-2 algorithm was employed to calibrate and analyze the sensitivity, and uncertainty of the SWAT model. The sensitivity analysis is based on linear approximation and the degree of uncertainty is calculated by two factors called r-factor and P-factor. The calibration and validation were performed using runoff data in the periods of 1995-2015 and 2016-2019, respectively. The coefficients of determination [R^2] and Nash-Sutcliffe [NS] were used as the objective function to determine the goodness of fitness.

2-3- Climate Change scenarios and AR models

In the AR5 new emission scenarios based on emission forcing level until 2100 were employed. In order to investigate the future climate change, the Model for Interdisciplinary Research on Climate-Earth System Models [MIROC-ESM] was selected among the newest extracted models presented in the AR5, because the result of this model in Gorganroud watershed showed the highest agreement with observational data. This model consists of four emission forcing scenarios [RCP2.6, RCP.4.5, RCP6.0 and RCP8.5.

3- Results and Discussion

3-1- SWAT sensitivity analysis, calibration and validation analysis

Seventeen parameters were chosen for SWAT sensitivity analysis using the 500 simulations of SUFI-2. Results showed that the parameters CN, SOL_BD and SOL_K have the highest relative sensitivity. Based on the results, the coefficients R^2 and NS for runoff simulation were estimated to be 0.79-0.77 and 0.74-0.71 in the calibration and validation stage, respectively. Therefore, the results of the model are acceptable and its uncertainty metrics is satisfactory in general.

The study results showed that the model has estimated the amount of peak discharge less than the actual amounts, which is confirmed by the average monthly simulated

discharge during calibration and validation periods. The results also showed that more than 50% of the observational data in both calibration and validation phases are bracketed by the 95PPU uncertainty estimation band, which indicate a rather acceptable degree of certainty in simulation.

3-2- Climate change simulation results and trend analysis

In the near and mid-future, there are increasing changes under the RCP2.6 scenario, but the trends of rainfall are not statistically significant at the 5% level. In the far- future a significant increasing trend is observed under the RCP2.6 scenario, meanwhile in far-future under the RCP4.5 scenario there are increasing changes, but the trends are not statistically significant. In the mid and far future under the RCP6.0 scenario, a significant increasing trend has been observed. Finally, in the mid- future under the RCP8.5 scenario, there is a significant increasing trend. However, the increasing changes in the near and far-future periods are not statistically significant at the confidence level of 95%. The trend analysis of variables indicates that the amount of rainfall will decrease in this watershed during the future periods by the end of the 21st century. The most decreasing alterations in the rainfall and the highest increase in the temperature are achieved under the highest concentration of greenhouse gases [RCP8.5]. Moreover, in the near, mid, and far future, the runoff changes are decreasing under the RCP2.6 scenario, but the trend is not statistically significant. In the mid and far-future periods under the RCP4.5 scenario, there is a statistical significant decreasing trend in runoff; however, the decreasing variation in the near future is not significant. In the near, mid, and far future under the RCP6.0, runoff variations are declining, but the trend is not statistically significant. In the far-future period, under the RCP8.5, there is a significant decreasing trend; however, in the near and mid-future, runoff declining changes are not statistically significant. Reduced rainfall and increased temperature in the watershed will reduce the rate of runoff in the future periods in such a way that the security of the inhabitants of the region will be severely affected.

4- Conclusions

Results of evaluation criteria [R^2 and NS] showed that the SWAT performance for the simulation of runoff in the Gorganroud watershed was not satisfactory, but it was in an acceptable range. Climate change simulation indicated a decreasing trend for rainfall in all future periods, but this trend was not statistically significant. The temperature variable in all RCPs had an increasing trend. However, temperature trend analysis under the RCP4.5 scenario during the near and mid- future and under the RCP6.0 scenario during the near, mid, and far-future showed a significant upward trend. Runoff under the RCP4.5 scenario during the mid to far-future and under the RCP8.5 scenario during

the far-future period followed a significant downward trend. Runoff during the near-future period under the RCP4.5 scenario and throughout the near to mid-future under the RCP8.5 scenario, had declining variations, but its trend was not statistically significant. In general, these results indicated that the amount of temperature will follow an increasing tendency; while rainfall and runoff will follow a decreasing movement in this watershed by the end of the 21st century.

Keywords: Climate Change, Emission scenario, Fifth assessment report, Mann-kendall test, Soil and Water Assessment Tool [SWAT], Gorganroud, Gholestan Province

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