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Modeling the Effects of Climate Change on Irrigation Requirement and Water Use Efficiency of Wheat Fields of Khuzestan Province

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Introduction: One of the most important consequences of the future climate change is its impact on water use and water use efficiency (WUE) in agriculture which could challenge the water resources management. Khuzestan province is one of the most important areas of crops production in Iran particularly for wheat, so that 15.73 percent of total irrigated wheat production and 8.85 percent of total arable land is located in this province. Therefore, investigating climate change effects on irrigated wheat production, WUE and irrigation requirement will be necessary in the Khuzestan province. In this context, this study was conducted to simulate the growth and yield of irrigated wheat under climate change conditions, and to calculate WUE and irrigation requirement in this province.

Materials and Methods: The current study was done at six locations of Khuzestan province in southwestern Iran, included Ahwaz, Behbahan, Dezful, Izeh, Omidiyeh and Ramhormoz. Historical daily weather data including solar radiation (MJ m^{-2} d^{-1}), precipitation (mm) and maximum and minimum temperatures (˚C) for the baseline period gathered for each study location from their established meteorological stations. To predict the climatic variables in the future, HadCM3 climate model was applied under three emission scenarios (B1, A1B and A2) for one future time period (2046-65). The observed historical daily weather data at each location was used to generate the future scenario files to be applied in LARS-WG (Long Ashton Research Station-Weather Generator) program. These parameters are necessary for future projection of weather variables. The downscaled daily weather data obtained from the LARS-WG included maximum and minimum temperatures, rainfall and solar radiation for each period of future climate. These data are required for running crop simulation model. The Agricultural Production Systems simulator (APSIM) was used to predict the impacts of climate change on wheat yield, WUE and irrigation requirement. The model requires daily weather variables (maximum and minimum temperatures, precipitation and solar radiation), soil properties, type of genotype (as cultivar-specific parameters), and crop management information as inputs to simulate crop growth and development. In order to evaluate the climate model NRMSE (Normalized Root Mean Square Error) index was used. Finally, the outputs obtained from the model simulation experiments were analyzed using excel, SAS and Sigma Plot.

Results and Discussion: Results of climate model evaluation indicated that LARS-GW well predicted radiation (NRMSE from 0.63 to 1.67%), maximum (NRMSE from 0.63% to 1.05%) and minimum (NRMSE from 0.63% to1.97%) temperatures. However, the accuracy in prediction of rainfall (NRMSE from 11.42% to 21.47%) was not as good as the other climatic variables. The simulation results in the baseline by APSIM-Wheat showed that maximum and minimum grain yield were obtained in the Izeh (6764.2 $Kg.ha^{-1}$) and Omidiyeh (5230.2 $Kg.ha^{-1}$), respectively. Under climate change conditions (rising temperature and elevated CO_2), on average, the highest and lowest grain yield were obtained in Izeh (7755.3 $Kg.ha^{-1}$) and Omidiyeh (6290.76 $Kg.ha^{-1}$), respectively. The simulation results in the baseline also indicated that the highest and lowest evapotranspiration (ET) were obtained in the Izeh (441.7 mm) and Ramhormoz (401.5 mm), respectively. When averaged acrossall future scenarios, themaximum and minimum ET were obtained in Izeh (409.56 mm) and Ramhormoz (375.38 mm), respectively. The future rising temperature will intensify the ET, whereas reducing stomata conductance due to higher CO_2 concentration in one hand, and shortening growing period due to rising temperature on the other hand, will reduce the cumulative ET in wheat.The simulation results in the baseline showed that the highest and lowest WUE were obtained in Izeh (15.32 $Kg.ha^{-1}.mm^{-1}$) and Omidiyeh (12.7 $Kg.ha^{-1}.mm^{-1}$), respectively. In climate change conditions (rising temperature and CO_2 elevated), on average the highest and lowest WUE were obtained in Izeh (18.93 $Kg.ha^{-1}.mm^{-1}$) and Omidiyeh (15.76 $Kg.ha^{-1}.mm^{-1}$), respectively. Wheat crop would be benefitted under future climate change in Khozestan province as it is a C3 plant, and under optimal conditions (no water and nitrogen limitations), it will produce more grain because of reduced stomata conductance and increased photosynthesis and WUE owing to elevated CO_2. Simulation results also indicated

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that under climate change conditions, on average, the highest and lowest irrigation requirement were obtained in Ahwaz (315.39 mm) and Izeh (225.96 mm), respectively.The reduced irrigation requirement of wheat under climate change conditions could be attributed to decreasing length of growing season and increasing CO_2 concentration.

Conclusion: In the current study, the effects of climate change caused by rising temperature and elevating CO_2 concentration on WUE, irrigation requirement, growth and yield of wheat were investigated in the Khuzestan province. The simulation results showed that, wheat grain yield under climate change conditions (averaged across all scenarios) will increase by 16 % compared to the baseline. In addition, WUE will be increased 23 percent owing to increasing grain yield (+16%) and decreasing ET (5%) under different scenarios. Overall, under climatic conditions of Khuzestan province in 2046-2065, WUE would be increased by 23% and irrigation requirement would be decreased by 9%. The reasons behind these increases and decreases are rising temperature (7%), elevating CO_2 concentration (up to 526 ppm for 2046-65) and decreasing the length of growing season and ET both by 5%.

Keywords: APSIM, Climate scenario, GCM, Simulation