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Maize Yield Response to Deficit Irrigation using the AquaCrop Model under Shallow Groundwater Conditions in Uzbekistan

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Abstract

Maize is one of the most widely consumed cereal crops grown worldwide under different environmental conditions. The growing global population puts more strain for increased cereal production in the next decades to feed this population which greatly drive the global water demand for different purposes. Meanwhile humankind has to cope with the predicted impacts of future climate change on water resources availability especially in the arid and semi-arid regions. Irrigated agriculture is hence under high pressure to increase the water use efficiency during these conditions. For this purpose several techniques and models have been developed to simulate the current and future scenarios for future planning and management of the water resources. AquaCrop, is among such models which reliably simulates achievable yields of major crops as a function of water consumption under rainfed, supplemental, deficit, and full irrigation conditions, with comparatively less data demand. In this study, carried out in Khorezm province of Uzbekistan, the AquaCrop model was used to derive the optimal and deficit irrigation schedules for maize crop. Groundwater levels in the region are shallow. We used Hydrus-1D model to simulate the capillary rise. Later capillary rise contribution was introduced into the AquaCrop model. Hence, together with optimal irrigation schedule, deficit irrigation strategies were derived as proportionally reduced water supply (RWS) of 20, 40, 50 and 60% throughout the crop growth and as a stress introduced at specific crop growth stages. The results show that proportionally RWS of 20, 40, 50 and 60% resulted into 3, 20, 30 and 45% yield reduction respectively. In these simulations, 20% proportional reduction in irrigation water application led to a negligible 3% yield loss. During stress at the late yield formation stage, at least 25% of the optimal supply can be saved easily for almost no yield loss. It means that deficit irrigation is more feasible in the late yield formation stage rather than vegetative stage. This study is unique due to the fact that capillary rise contribution quantified by Hydrus-1D model has been introduced into AquaCrop. This way it overcomes the missing consideration of capillary rise contribution by the standard version of AquaCrop model.

Keywords: AquaCrop, capillary rise, deficit irrigation, shallow groundwater

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INTRODUCTION

Uzbekistan owns around 1.3 million hectare of irrigated land in the Aral Sea Basin, one of the higher consumers of water from Amu Darya and Syr Darya rivers. This region with shallow groundwater table is known for excessive irrigation water supply as well as inefficiency at the irrigation network. The irrigation norms in practice don't integrate the changing water availability conditions due to climate change in the Amu Darya basin. The existing irrigation norms leave no voids for practicing deficit irrigation strategies in the region too. The major crops of this country are cotton, rice, maize and wheat. From the production point of view, maize holds about 4th position among the cereals grown in Uzbekistan. By using AquaCrop model the optimal and deficit irrigation schedules under shallow groundwater condition were derived in this study. While considering the shallow groundwater conditions, the capillary rise contribution to the crop root zone was estimated by using the HYDRUS-1D model.

EXPERIMENTAL SITE

This study was carried out at the Cotton Research Institute (CRI) in Khorezm province of Uzbekistan. CRI provides control conditions for experimental purposes.



Fig. 1: Location of the research site in Urgench, Khorezm

CLIMATE CONDITION

The climatic conditions of Khorezm has been identified as continental, with cold winters and hot dry and long summers. The mean annual temperature in Khorezm is 12.1°C while the annual estimated potential annual evapotranspiration is about 1500 mm

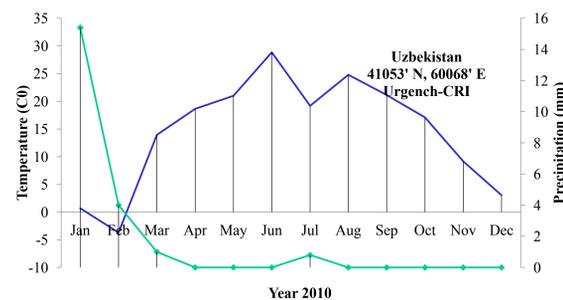


Fig. 2: Climate diagram of CRI, Urgench

RESULTS

- AquaCrop simulation showed that proportionally reduced water supply of 20, 40, 50 and 60% would result in a yield reduction of 3, 20, 30 and 45% respectively.

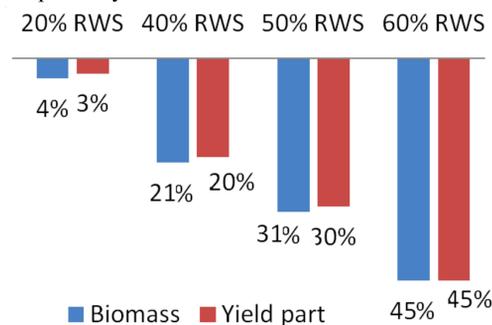


Fig. 3: Yield and biomass response to proportional deficit irrigation

- The yield loss in this case can be further minimized by increasing the application efficiency during the irrigation events throughout the crop growth period.

The average groundwater level during the cropping season of maize was 1.38m added around 10% of soil moisture through the capillary rise contribution to ET_c of maize in sandy loam soils

- During stress at the late yield formation stage, at least 25% of the optimal supply can be saved easily for almost no yield loss. It means that deficit irrigation is more feasible in the late yield formation stage rather than vegetative stage. During stress at the flowering stage, the maximum corn yield loss of 12% was observed.

MATERIALS AND METHODS

Research fields were equipped with observation wells to monitor GW levels. Soil samples were taken from 0-30, 30-60, 60-90 and 90-120 cm below the soil surface.



Fig. 4: Soil sampling at various depths

The meteorological data was collected at the meteorological station located at the Cotton Research Institute in Urgench. The soil relevant data was taken from the GIS laboratory of the ZEF/UNESCO project in Urgench. HYDRUS-1D model was used for the quantification of groundwater contribution.



Fig. 5: On-farm phenological measurements for the parameterization of the AquaCrop Model

The estimated capillary rise contribution due to shallow groundwater level was used as a pseudo-precipitation into the AquaCrop model. AquaCrop was simulated to derive the optimal and deficit irrigation schedules. Using two different deficit irrigation strategies during these simulations, the respective yield and biomass response was analyzed: 1) Proportionally reduced water supply (RWS) of 20, 40, 50 and 60%, 2) stress introduction during a specific crop growth stage.

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