学 位 論 文 要 旨

Applicability of the AquaCrop model for simulating the growth of winter wheat and cotton under a semi-arid climate in Uzbekistan

ウズベキスタンの半乾燥気候下での AquaCrop モデルによる冬小麦および綿花の成長シミュレーションの適用性

Agricultural and Environmental Engineering

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Human activity influences the hydrological cycle, leading to increased water scarcity globally. Developing societies further strain water resources, especially through expanded irrigated agriculture. In Uzbekistan, the agricultural sector responsible for 92% of all water withdrawal owing to low precipitation condition. With Uzbekistan's population doubling within the 30 years following its independence in 1991, there is a pressing need for optimizing water use to simultaneously address water scarcity, salinity, and low agricultural productivity. Crop model, such as the AquaCrop model, offers a compelling framework for optimizing water use under various environmental and crop conditions in water-limited conditions.

The AquaCrop model, created by the Food and Agricultural Organization (FAO), strikes a balance between simplicity and accuracy. Concretely, the model requires fewer input parameters than other crop models. The AquaCrop model was demonstrated to accurately reproduces biomass accumulation, canopy cover development, and yield of multiple crops, including winter wheat (*Triticum aestivum*), and cotton (*Gossypium hirsutum L.*) under various environmental conditions. However, the small subset of studies that have validated AquaCrop with winter wheat and cotton

under arid or semiarid climates have reported widely different values for the calibrated parameters. This raises questions about the applicability and transferability of these previously validated datasets to Uzbekistan.

To ensure the reliability of simulations and dataset, it is crucial to carefully calibrate the AquaCrop model by strictly adhering to guidelines. Consequently, our research objective is to assess the suitability of the AquaCrop model in simulating the growth of winter wheat and cotton within Uzbekistan's unique climate and growing conditions. The calibration process involved utilizing first-year data for fine-tuning, while the validation phase employed a second-year data set to verify the model's performance.

Experimental data were acquired from two sites, both featuring a semi-arid climate. Winter wheat was cultivated in the Karshi district, during 2010-2012. Cotton was grown during 2021-2022 in Kibray district.

AquaCrop simulations indicated that winter wheat experienced low temperature stress whereas field observations did not indicate any occurrences of temperature stress. This finding suggests the presence of cold stress tolerance traits in the winter wheat cultivar. Dedicated laboratory experiments are required to adequately derive the values of temperature stress-related parameters. Furthermore, AquaCrop consistently overestimated cotton yield. Previous field experiments demonstrated that repeated occurrences of high temperature reduce yield. However, this process, critical in arid and semiarid environments, is not currently implemented into the AquaCrop model.

The impacts of various irrigation managements upon canopy cover development, biomass accumulation, and final yield were assessed. However, model simulations were very similar and often identical between irrigation management. This finding was explained by the scheduling of irrigation water, proactively added to the soil, as soil moisture dropped below management-specific thresholds.

Overall, the canopy cover, biomass, and grain yield of winter wheat were all adequately simulated by the AquaCrop model during the validation period. In contrast, validation results for cotton simulations displayed medium to high performance levels depending on treatments. A key problem was the large inter-annual variability in maximum canopy cover, currently not accounted for in the calibration protocol, leading to an underestimation of canopy cover and biomass.

In conclusion, the AquaCrop model shows promising levels of performance for addressing simulating winter wheat and cotton development under semi-arid condition in Uzbekistan. Further research and refinements to the model are needed to enhance its performance for cotton simulations by incorporating critical factors such as temperature stress and seasonal variability. By continually improving and calibrating the model to the specific climatic and growing conditions of Uzbekistan, intelligent water management can be achieved, enabling sustainable agriculture and alleviating water scarcity challenges.