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A stochastic simulation-optimization approach for estimating highly reliable soil tension threshold values in sensor-based deficit irrigation

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In arid and semi-arid regions where water is scarce, farmers heavily rely on irrigation in order to grow crops and to produce agricultural commodities. The variable and often severely limited water supply thereby poses a serious challenge for farmers to cope with and demand sophisticated irrigation strategies that allow an efficient management of the available water resources. The general aim is to increase water productivity (WP) and one of these strategies to achieve this goal is controlled deficit irrigation (CDI). One way to realize CDI is by defining soil water status specific threshold values (either in soil tension or moisture) at which irrigation cycles are triggered. When utilizing CDI, irrigation control is of utmost importance and yet thresholds are likely chosen by trial and error and thus unreliable. Hence, for CDI to be effective systematic investigations for deriving reliable threshold values that account for different CDI strategies are needed.

In this contribution, a method is presented that uses a simulation-based stochastic approach for estimating threshold values with a high reliability. The approach consist of a weather generator offering statistical significance to site-specific climate series, an optimization algorithm that determines optimal threshold values under limiting waters supply, and a crop model for simulating plant growth and water consumption. The study focuses on threshold values of soil tension for different CDI strategies. The advantage of soil-tension-based threshold values over soil-moisture-based lies in their universal and soil type independent applicability. The investigated CDI strategies comprised schedules of constant threshold values, crop development stage dependent threshold values, and different minimum irrigation intervals. For practical reasons, fixed irrigation schedules were tested as well. Additionally, a full irrigation schedule served as reference. The obtained threshold values were then tested in field experiments in 2010 and 2011 at TU Munich in Freising, Germany, where corn was cultivated in containers in a greenhouse. Since tension thresholds lay distinctly beyond 800hPa and thus exceeding the measurement range of ordinary tensiometer, all treatments were monitored and controlled by sensors called pF-meter, whose measurement principle is based on heat capacity.

Achieved yields, applied irrigation water, as well as obtained water productivity from these experiments are presented and compared to the simulation results supporting this methodology to be a viable approach to improve water productivity.