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Quasi 3D modelling of water flow in the sandy soil

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Monitoring and modeling tools may improve irrigation strategies in precision agriculture. Spatial interpolation is required for analyzing the effects of soil hydraulic parameters, soil layer thickness and groundwater level on irrigation management using hydrological models at field scale. We used non-invasive soil sensor, a crop growth (LINGRA-N) and a soil hydrological model (Hydrus-1D) to predict soil-water content fluctuations and crop yield in a heterogeneous sandy grassland soil under supplementary irrigation.

In the first step, the sensitivity of the soil hydrological model to hydraulic parameters, water stress, crop yield and lower boundary conditions was assessed after integrating models at one soil column. Free drainage and incremental constant head conditions were implemented in a lower boundary sensitivity analysis.

In the second step, to predict Ks over the whole field, the spatial distributions of Ks and its relationship between co-located soil ECa measured by a DUALEM-21S sensor were investigated. Measured groundwater levels and soil layer thickness were interpolated using ordinary point kriging (OK) to a 0.5 by 0.5 m in aim of digital elevation maps.

In the third step, a quasi 3D modelling approach was conducted using interpolated data as input hydraulic parameter, geometric information and boundary conditions in the integrated model. In addition, three different irrigation scenarios namely current, no irrigation and optimized irrigations were carried out to find out the most efficient irrigation regime. In this approach, detailed field scale maps of soil water stress, water storage and crop yield were produced at each specific time interval to evaluate the best and most efficient distribution of water using standard gun sprinkler irrigation.

The results show that the effect of the position of the groundwater level was dominant in soil-water content prediction and associated water stress. A time-dependent sensitivity analysis of the hydraulic parameters showed that changes in soil water content are mainly affected by the soil saturated hydraulic conductivity Ks in a two-layered soil.

Results demonstrated the large spatial variability of Ks (CV = 86.21%). A significant negative correlation was found between ln Ks and ECa ($r = 0.83$; $P \leq 0.01$). This site-specific relation between ln Ks and ECa was used to predict Ks for the whole field after validation using an independent dataset of measured Ks.

Result showed that this approach can accurately determine the field scale irrigation requirements, taking into account variations in boundary conditions and spatial variations of model parameters across the field. We found that uniform distribution of water using standard gun sprinkler irrigation is not an efficient approach since at locations with shallow groundwater, the amount of water applied will be excessive as compared to the crop requirements, while in locations with a deeper groundwater table, the crop irrigation requirements will not be met during crop water stress. Numerical results showed that optimal irrigation scheduling using the aforementioned water stress calculations can save up to $\sim$25% irrigation water as compared to the current irrigation regime. This resulted in a yield increase of $\sim$7%, simulated by the crop growth model.