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Modelling the water balance of irrigated fields in tropical floodplain soils using Hydrus-1D

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Accurate estimation of evaporation, transpiration and deep percolation is crucial in irrigated agriculture and the sustainable management of water resources. Here, the Hydrus-1D process-based numerical model was used to estimate the actual transpiration, soil evaporation and deep percolation from irrigated fields of floodplain soils. Field experiments were conducted from Dec 2015 to May 2016 in a small irrigation scheme (50 ha) called 'Shina' located in the Lake Tana floodplains of Ethiopia. Six experimental plots (three for onion and three for maize) were selected along a topographic transect to account for soil and groundwater variability. Irrigation amount (400 to 550 mm during the growing period) was measured using V-notches installed at each plot boundary and daily groundwater levels were measured manually from piezometers. There was no surface runoff observed in the growing period and rainfall was measured using a manual rain gauge. All daily weather data required for the evapotranspiration calculation using Pen Man Monteith equation were collected from a nearby metrological station. The soil profiles were described for each field to include the vertical soil heterogeneity in the soil water balance simulations. The soil texture, organic matter, bulk density, field capacity, wilting point and saturated moisture content were measured for all the soil horizons. Soil moisture monitoring at 30 and 60 cm depths was performed. The soil hydraulic parameters for each horizon was estimated using KNN pedotransfer functions for tropical soils and were effectively fitted using the RETC program (R2= 0.98±0.011) for initial prediction. A local sensitivity analysis was performed to select and optimize the most important hydraulic parameters for soil water flow in the unsaturated zone. The most sensitive parameters were saturated hydraulic conductivity (Ks), saturated moisture content (θs) and pore size distribution (n). Inverse modelling using Hydrus-1D further optimized these parameters (R2 =0.74±0.13). Using the optimized hydraulic parameters, the soil water dynamics were simulated using Hydrus-1D. The atmospheric boundary conditions with surface runoff was used as upper boundary condition with measured rainfall and irrigation input data. The variable pressure head was selected as lower boundary conditions with daily records of groundwater level as time-variable input data. The Hydrus-1D model was successfully applied and calibrated in the study area. The average seasonal actual transpiration values are 310±13 mm for onion and 429±24.7 mm for maize fields. The seasonal average soil evaporation ranges from 12±2.05 mm for maize fields to 38±2.85 mm for onion fields. The seasonal deep percolation from irrigation appeared to be 12 to 40% of applied irrigation. The Hydrus-1D model was able to simulate the temporal and the spatial variations of soil water dynamics in the unsaturated zone of tropical floodplain soils.
Key words: floodplains, hydraulic parameters, parameter optimization, small-scale irrigation