ANALYSING PERFORMANCE AND CONTRIBUTING AREAS OF A SUBSURFACE DRAINAGE SYSTEM WITH A HYDROLOGICAL MODEL

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Abstract. *Subsurface drains are imperative in cultivated Nordic clayey soils to manage water balance especially during wet autumns and spring snow melt periods. The performance of a subsurface drainage system can decrease with time due to compaction of the soil, clogging of the pipes, and decrease of hydraulic conductivity in the drain trenches. The efficiency of an existing system can be improved by reinstalling the drainage system, by installing supplementary drains in wet problem areas or by attempting to clean the existing drain pipes. The resulting spatially heterogeneous drainage system complicates the estimation of the water balance, water contributing areas and nutrient loads in the field. Also, annual variations in the hydro-meteorological conditions can effectively hide changes in the performance of the subsurface drains. We present a computational method, in which we use the FLUSH model in conjunction with data to estimate the relative performance of different parts of a subsurface drainage system installed in a field area. FLUSH is a three-dimensional hydrological model developed for structured soils such as clays in Nordic conditions. Model input data, including precipitation, potential evapotranspiration, air temperature, short and long wave radiation, humidity and wind speed, are given as hourly time series. In the simulations, the model applies varying time step lengths up to the used data time step (one hour). Simulation results are comprised of hourly surface and drainage runoff, evapotranspiration and groundwater outflow series. The model can also save time series of point like variables such as soil moisture, groundwater table depth and soil temperature in selected locations. FLUSH is able to simulate heterogeneous subsurface drainage systems with a varying drain spacing and depth due to the spatially distributed nature of the model. A sensitivity analysis is used in the study to derive a parametrisation for the distributed drainage system. The method is used to study the subsurface drainage system in the clayey Hovi agricultural monitoring site (12 ha, slope 2.8%) in southern Finland and to assess the efficiency of different parts of the system installed in 1971 (drainage spacing 22 m, installation depth 1 m), 1995 (spacing 14 m, depth 0.7 m) and 2005 (spacing 15 m, depth 1 m). The lateral drains are plastic pipes with a diameter of 0.05-0.065 m, and the collector drains are steel and plastic pipes with a diameter of 0.08-0.09 m. Gravel was used as an envelope material. The undocumented supplementary drains installed in 1995 and found in our analysis caused uncertainties and errors into the estimation of the water balance components (tillage layer and subsurface drainage runoff) after 1995 in the site. Intermittent hourly data on drainage and total runoff were available from the field, and data from 2010-2011 was used for model calibration and 2012 for validation. We were able to quantify the components of the water balance (% of precipitation) including tillage layer runoff (< 10%, surface runoff 4-6%), drainage runoff (32-34%), evapotranspiration (46-53%) and groundwater outflow (5%) in the field area with the model. The Nash-Sutcliffe model efficiency coefficients for total runoff (sum of tillage layer and drainage runoff results) for the whole year were 0.43 (2010), 0.70 (2011) and 0.18 (2012). Corrected precipitation during the study years was 577-678 mm a^{-1}. The relative contribution of the original drainage system (1971) to drain runoff was lower compared to the fraction from the newer parts (1995 and 2005), which suggested that the performance of the original system had decreased. According to the simulations, influx of groundwater from the surrounding terrain affected the hydrology of the field during moist periods (late autumn and spring snow melt periods). A simulation scenario was conducted to test the effect of groundwater inflow to the field area from the surrounding terrain. Our study shows that distributed hydrological models provide the tools to close the field-scale water balance, quantify all key water flux components at field boundaries, and evaluate the efficiency of multiple drainage systems. This quantification provides a promising basis for estimating nutrient loads.*

Key words: *FLUSH model; clay; subsurface drain; water balance; subsurface drain performance.*