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Dynamic groundwater recharge rates at field scale: how to successfully use soil moisture from cosmic-ray neutron sensing

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Cosmic-ray neutron sensing (CRNS) is a non-invasive method that provides an average soil moisture for a large support volume (radial footprint up to 240 m, depth up to 80 cm) with high temporal resolution. It covers the most dynamic part of the vadose zone at a scale that is already a more substantial part of the landscape then local point measurements. This integral soil moisture value overcomes the limitations regarding issues of small-scale heterogeneity. Therefore, the use of CRNS soil moisture could improve the estimation of potential groundwater (GW) recharge at the field.

Besides the stochastic integration of point-scale soil moisture profiles, CRNS soil moisture estimates could be used for the inverse estimation of effective soil hydraulic properties by applying unsaturated soil hydrological models and to determine environmental fluxes such as GW recharge.

Within this study CRNS soil moisture is used to estimate the effective soil hydraulic properties within the model HYDRUS 1D. Resulting GW recharge represents the field scale because of the integrated nature of the soil moisture product, even though the model is calculating percolation fluxes for 1D - profiles. These integrated GW recharge fluxes are compared to established point scale methods of GW estimation using soil moisture from a distributed sensor network to inversely estimate the effective soil hydraulic properties within HYDRUS 1D.

CRNS is, however, sensitive to the vertical distribution of water content and this behavior should be explicitly considered. Two approaches are assessed further to account for that. On the one hand, a correction of CRNS, based on measured soil moisture profiles, is tested and CRNS soil moisture is directly used for recharge calculation in HYDRUS. On the other hand, the COSMIC-Operator, as implemented within HYDRUS, is used for calibrating the model by directly comparing neutron count rates from simulated soil moisture. Both approaches are assessed with respect to their ability to estimate natural groundwater recharge rates.