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Groundwater recharge estimates with soil isotope profiles – is there a bias on coarse-grained hillslopes?

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Due to continuous changes in the meteorological conditions of Mediterranean regions, it is becoming increasingly important to improve knowledge of hydrological and hydrogeological recharge processes and their dependency on climate conditions to adapt the use of limited water resources. Within the IsoMed project (isotope hydrology in Mediterranean areas), soil profiles were sampled in November 2018 and February 2019, from various hydrogeological settings in Cyprus to estimate groundwater recharge using stable isotope equilibration methods combined with soil water balance modeling. A total of 11 soil profiles were taken from the Troodos massif (Galata and Platania) and the Mesaoria plain in Deftera, Nicosia. A vertical profile of stable isotopes has been determined with a 2 cm resolution and measured with Tunable Diode Laser spectrometry. Percolation through the soil profile has been estimated based on the convolution of a seasonal input function using advection-dispersion transport models. In Galata, groundwater percolation estimates range from 20-30 mm/y on clayey soil with natural vegetation to 100-120 mm/y at an irrigated terraced orchard. The results in Platania vary from 20-60 mm/y at steep hillslopes under natural vegetation and amount to 220-340 mm/y in the root zone at the irrigated site with olive trees in Deftera. The comparison of groundwater percolation rates based on stable isotope profiles with those derived from soil water balance modeling indicates a significant bias. While percolation rates correspond well to results obtained from a daily soil water balance model for irrigated fine-grained soils in the plain, recharge rates obtained from stable isotope profile methods on coarse-grained hillslopes tend to be much lower than expected. The observed bias suggests that stable isotope methods, regardless of water extraction or equilibration technique, mainly record the isotope signal of matrix flow. Thus, macro-pore and preferential flow components in coarse-grained soils may not be accounted for. Data collected from the same profiles in late autumn and spring suggest that macro-pore and preferential flow constitute a major component of percolation in coarse-grained shallow hillslope soils of Troodos indeed, without leaving measurable isotope traces in the soil water profile. Additional approaches need to be applied in conjunction with methods based on the evaluation of soil water isotope profiles to overcome this limitation.