Pore water isotope fingerprints to understand the spatiotemporal groundwater recharge variability in ungauged watersheds

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Reliable groundwater recharge quantification at the regional scale (e.g., watershed or sub-watershed) is fundamental to sustainable water resource management. While modelling at the watershed scale is gaining wide support, the long-term monitoring needed for model calibration is often not readily available, as many watersheds worldwide remain ungauged. Fortunately, in ungauged watersheds, pore water stable isotope fingerprints can provide valuable information to accurately and quickly estimate soil hydraulic parameters, and hence recharge, at a lower cost when meteorological conditions are known. We propose here a new approach based on a vapor phase isotopic equilibrium. This fast and accurate analytical breakthrough requires only a single field campaign to acquire soil water content and pore water isotopic composition along depth profiles. Then we extended a physically-based, one-dimensional unsaturated zone flow model from the local- (i.e., profile) to the watershed-scale, using an index method for distributed recharge based on a Geographical Information System. The methodology was validated in a gauged watershed, where previous studies have estimated recharge using a spatialized water balance model calibrated using long-term discharge monitoring data. Scaling was investigated by comparing recharge values obtained using the local-scale approach at ten study sites within the watershed with coinciding values obtained at the watershed scale. Recharge values were similar in terms of both dynamics and quantity. Using the pore water isotopic fingerprint of ungauged watersheds is therefore confirmed to be a suitable approach for understanding spatiotemporal recharge variability.