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How do runoff processes and vegetation water uptake interact and vary? A hydrometric and isotope analysis in a pre-Alpine forested catchment

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Estimating the fraction of precipitation returned to the atmosphere as evapotranspiration, rendered to groundwater recharge, and exported as surface runoff is a key issue in catchment ecohydrological studies. Water stable isotopes have proven to be useful tracers to determine the origin of water taken up by plants and to quantify the relative contributions of water sources to stream runoff. However, our knowledge on the spatial and temporal variability of the isotopic composition of water sources in forested catchments is still limited.

In this study, we used hydrometric data and isotopic composition data from a 2-ha forested catchment in the Italian pre-Alps (Ressi catchment) to i) investigate the temporal dynamics of shallow water table, soil moisture and sap flow, and ii) analyze the temporal and spatial variability in the isotopic composition of different water sources in the catchment.

Streamflow and rainfall were measured continuously starting in August, 2012. Soil moisture was determined at multiple depths and locations within the hillslope and the riparian zone. Depth to water table was measured in two piezometers installed at a depth of 2.0 and 1.8 m in the riparian zone. Sap flow was monitored in two beech trees located in the riparian zone, and one beech tree and one chestnut tree on the hillslope. Water samples for isotopic analysis were taken monthly from bulk precipitation, approximately bi-weekly from stream water, groundwater and soil water by suction cup lysimeters. Soil water samples and twigs for xylem water extraction by cryogenic distillation were collected starting in June, 2017. All water samples were analyzed by laser spectroscopy, except xylem water that was analyzed by mass spectrometry.

Preliminary results show that during dry periods in summer the shallow water table and soil moisture experienced daily fluctuations. We observed that the minimum water table level lagged peak sap flow by 1-3 hours, implying a role of evapotranspiration on water table variations. Conversely, minimum soil moisture lagged the daily sap flow peak by more than 6 hours. The isotopic composition of stream water was similar to that of riparian groundwater during baseflow, while tended to reflect the isotopic signature of rain water during rainfall-runoff events. Soil water extracted by suction cups was isotopically more similar to rain and stream water, while the one obtained by cryogenic distillation showed an evaporation signature, especially on the hillslope where soil moisture was lower and soil water could be extracted by suction cups only during or just after a rainfall event. This suggests that soil water sampled by suction cups and extracted by cryogenic distillation are stored differently in the soil layers due to the different soil tension and the hillslope tends to store less mobile soil water compared to the riparian zone. At greater depths, soil water extracted by cryogenic distillation was slightly less evaporated (higher deuterium excess) and less enriched in heavy isotopes.

Keywords: water stable isotopes; soil water; sap flow; forested catchment.