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Hydrological response of a forested mountain catchment: a tracer-based experimental analysis

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The hydrological functioning of forested catchments in mountain regions is complex due to spatially and temporally variable hydrological processes. As such, the main sources of water contributing to streamflow and the dominant controls governing the runoff response still need to be identified more clearly. We therefore used stable isotope and electrical conductivity (EC) data, and hydrometric measurements in a small forested catchment in the North-Eastern Italian Pre-Alps to assess: i) the fraction of pre-event and event water during rainfall-runoff events; ii) the spatial sources of stream water during events; and iii) the temporal dynamics of groundwater.

The measurements were taken during late summer and early autumn of 2011 and 2012 in the 2-ha Ressi catchment. The area is densely vegetated with broad-leaf trees. Hydrometric measurements include precipitation at two rain gauges, discharge at a V-notch weir, soil moisture at four locations along a riparian-hillslope transect, and groundwater levels in four piezometers. We collected samples on a weekly basis from bulk precipitation, groundwater and soil water (using suction lysimeters). Stream water samples were taken by an automatic sampler at a variable frequency. Additionally, samples were collected at a high temporal resolution during seven rainfall-runoff events. The deuterium and oxygen-18 isotopic composition was determined by laser absorption spectroscopy and EC was measured in the field using a portable conductivity meter. Since summer 2012, EC and water temperature in the stream are measured continuously.

Two-component hydrograph separation shows that pre-event water dominates the stream response, as observed in many other forested catchments worldwide. The fraction of pre-event water for the different events ranged between 71% and 97% based on deuterium data and between 65% and 97% based on oxygen-18 data. The runoff coefficient and the groundwater peak increased linearly and the fraction of event water decreased linearly with increasing pre-event soil moisture conditions. This suggests that for small storms during dry conditions that result in low runoff coefficients, event water is mainly derived from channel interception and rainfall falling on the riparian area. These events are characterized by a quick streamflow response and large event water contributions during the initial storm response. Conversely, larger storms during wet conditions result in higher runoff coefficients and have larger contributions of pre-event water. Three-component hydrograph separation and mixing analysis revealed that the flood hydrograph mainly consists of groundwater; soil water and precipitation have smaller and similar contributions. The role of groundwater on the storm response was confirmed by the strong correlation between EC in stream water and peak water table. For summer storm events water table peaks occurred after the discharge peaked, whereas for longer and larger autumn storms the opposite was observed. This highlights the importance of groundwater contributions to streamflow, especially during wet periods.

Keywords: water stable isotopes, electrical conductivity, groundwater, soil water.