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Understanding the spatial and temporal variability of water sources in a humid forested catchment

Luisa Pianezzola (1), Giulia Zuecco (1), Santiago Pozzoni (2), Daniele Penna (3), and Marco Borga (1)

(1) Department of Land, Environment, Agriculture and Forest, University of Padova, Italy (luisa.pianezzola@studenti.unipd.it), (2) Department of Earth Sciences "Ardito Desio", University of Milan, Italy, (3) Faculty of Science and Technology, Free University of Bozen-Bolzano, Italy

The detailed understanding of the hydrological response of humid forested catchments is hampered by the marked spatial and temporal variability of water sources. In this work, we use environmental tracers (major ions, electrical conductivity and stable isotopes of water) coupled to hydrometric data to infer the main contributors to streamflow and their spatio-temporal variability during rainfall events in a small forested catchment in the Italian pre-Alps. Specifically, we aim to i) identify the main end-members for stream runoff; ii) evaluate their spatial and temporal variability, and iii) quantify the component fractions in stream runoff.
Data collection took place in the 1.96-ha Ressi catchment between August 2012 and November 2015. Streamflow, precipitation, air temperature, shallow groundwater levels at six spatially-distributed locations and soil moisture at four locations along a riparian-hillslope transect were continuously measured. Monthly water samples were collected from precipitation, stream, shallow groundwater, soil water at 20 cm depth in two suction cups in the riparian and hillslope zone. Electrical conductivity was measured in the field by a portable meter, isotopic composition was determined by laser absorption spectroscopy and ionic concentrations by ion-chromatography. Samples for major ions were collected from September 2015 also during three rainfall-runoff events at high temporal frequency. End-member mixing analysis and tracer-based two- and three-component hydrograph separation techniques were employed, providing different scenarios of streamflow component fractions according to the use of isotopic data and of the three cations with largest concentrations (calcium, magnesium and sodium), and groundwater in different wells.
Preliminary results reveal that precipitation, soil water in the riparian zone, and shallow groundwater are the main contributors to stream runoff. Riparian groundwater in the lower part of the catchment sustains streamflow during baseflow conditions. Shallow groundwater shows a remarkable spatial variability in its hydrochemical signature, but a relative smaller temporal variability. On the contrary, soil water shows a large temporal variability, especially in its isotopic composition, partly reflecting the signal of infiltrating rainfall.
The largest sampled event (131 mm) is characterized by four streamflow peaks of increasing size, proportionally matched by fluctuations in soil moisture and water table. Three-component hydrograph separation for this event shows that, on average, according to different scenarios, the rainfall component accounts for 3%-14% of the total streamflow, soil water fractions range between 45% and 58%, and groundwater fractions vary between 30% and 46%, with maximum instantaneous contribution up to 90% during the last and largest streamflow peak. The temporal analysis reveals that at the beginning of the event streamflow is mainly composed by riparian groundwater. With increasing rainfall amount and wetness conditions, streamflow is principally influenced by soil water and rain water likely due to the saturation of the near-stream riparian corridor. At the end of the event the sharp rise of water table on the hillslopes and the development of subsurface connectivity contribute to sustain groundwater in the lower part of the catchment producing a marked streamflow response.

Keywords: humid catchment; isotopes; ions; runoff response; shallow groundwater.