Geophysical Research Abstracts
Vol. 14, EGU2012-8131-2, 2012
EGU General Assembly 2012

Investigation of spatio-temporal variability of water uptake in a groundwater-dependent ecosystem using a stable isotope approach (δ18O, δ2H): Pfyn Forest, Switzerland

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This work consists of an eco-hydrogeological study of the Pfyn Forest (46o17'35"N; 7o31'59"E, z = 550 m) which is a 6 km long alluvial zone in the upper Rhône valley, near Sierre (Wallis, Switzerland). From a hydrological point of view, the Rhône has a glacio-nival regime type in this area. Between low-flow and high-flow periods, groundwater levels strongly vary (about 8 m) near the main river-aquifer interaction zone in the most upgradient part of the site. In contrast, the downstream part of Pfyn is characterized by a low groundwater level fluctuation of about 1 or 2 m. From an ecological point of view, the riverine fringe at Pfyn presents a broadly recognized natural value but faces many threats due to human activities (derivation channel located upstream, gravel pits). Phytocoenosis vary from dry environments associations (with Scots pines, feather grass) upstream to active floodplain associations (with poplars, alders, willows) and likely dependent on groundwater, downstream. Between these two end-members, a transition mixed forest occurs. In the context of a potential hydrologic alteration due to global climatic change in a close future, this ecosystem should face modifications of the various water source (rainwater, groundwater) proportion and availability.
In order to constrain the meteorological, hydrological, pedological and ecological factors governing water uptakes by trees, isotopic characterizations (δ18O, δ2H) of each water compartment (precipitations, groundwater, river, soil, xylem) coupled with the evaluation of the water balance, has been carried out. The investigation focused on 3 different sites located along a transect through the alluvial valley between April 2010 and February 2011, with a twice-monthly resolution. The data permit to obtain three major findings:
- At first, an overview of both δ18O and δ2H data shows that rainwater, groundwater, soil water and plant water are usually located on the regional meteoric water line. For total humidity of soil, this could be due to rapid infiltration and/or fractionation mainly under equilibrium, i.e. with a relatively high atmospheric humidity, what is possible under forest canopy. Plant water is located under the LMWL in September 2010 when the soil was relatively drought. This evaporative signature could be a clue of water stress. More investigations are however needed to check if this parameter can be used routinely to address water stress.
- Secondly, through an analysis of variance, data reveal that at the ecosystem scale, water uptake depends on the site (type of soil, surrounding vegetation, distance from the river), on the growing status (non growing, flowering, mature, water stress) and on the species (poplar, willow, alder, pine).
- At last, when focusing at the temporal variability for some individuals, it appears that both rainwater and groundwater may participate to water uptake. The water uptake patterns seem more complicated in mature areas (far from the riverbed) than in frequently flooded zones. This could be due to a more complex soil texture patchwork in the former, and a globally finer soil texture. In particular, it appears that groundwater may sometimes replace rainwater through capillary rise during warm periods.