Geophysical Research Abstracts
Vol. 20, EGU2018-14563, 2018
EGU General Assembly 2018

Top-down vs bottom-up controls on soil and xylem water isotopic composition across multiple riparian sites in the eastern Alps (Italy): the role of groundwater

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Soil and xylem water isotopic composition have been widely used to determine the sources of water used by plants. Improving understanding of the controls on soil water isotopic composition has often focused on above-ground controls: evaporation and mixing with subsequent meteoric water inputs. The role of subsurface moisture sources, however, has received less attention. Here we assess the role of depth to groundwater on soil and xylem water isotopic composition across three riparian sites located in alpine valleys of the eastern Alps in Italy: an irrigated agricultural orchard and two restored riparian floodplains.

We queried how depth to groundwater affects fluxes between water storage compartments, their isotopic composition, and ultimately how this affects the isotopic composition of transpiration sources. Across the three field sites, paired plots with differing proximity to stream and depth to groundwater, yet similar atmospheric inputs and tree species assemblages, were sampled for xylem water, soil water, groundwater, and precipitation inputs. The isotopic composition of water samples was determined by laser spectroscopy and mass spectrometry.

At the irrigated riparian orchard, near surface (0 – 25 cm) soil water isotopic composition was more enriched in deuterium in the plot with depth to groundwater greater than 130 cm relative to the plot with a shallow groundwater (50 cm) table, -42 vs -65 δ^2H ‰ respectively. Both plots reflected evaporative enrichment in the shallow soil with greater enrichment in the deeper groundwater plot than in the shallow groundwater plot, -5 relative to 0 deuterium excess ‰ respectively. The isotopic composition of xylem water fell below the local meteoric water line, ranging from -55 to -72 δ^2H ‰ and -4 to -9 δ^{18}O ‰ and reflected shallow, evaporated soil water sources. Xylem water isotopic composition also increased with increasing depth to groundwater. In the restored riparian floodplain sites, xylem water isotopic composition was enriched in plots with greater depths to groundwater, by as much as 20 for δ^2H ‰ and 4 for δ^{18}O ‰ relative to shallow groundwater plots. Deuterium excess also decreased, suggesting greater evaporation, as depth to groundwater increased. However, at a site with less than 50 cm difference in relative groundwater table levels, differences in xylem and soil water isotopic composition were less clear.

Across sites, plant water sources were derived from shallow soil layers which in turn were related to depth to groundwater; soil water isotopic composition increased with increasing depth to groundwater. Subsurface redistribution of water along hydraulic gradients likely resupplies shallow soil layers; this effect is minimized in plots with greater depth to groundwater. These findings highlight the complex controls on isotopic composition soil and xylem waters and suggest a mediating role for groundwater, particularly in riparian areas or systems with shallow groundwater tables.