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Stable oxygen isotope analysis reveal vegetation influence on soil water movement and ecosystem water fluxes in a semi-arid oak woodland

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Mechanistically disentangling the role and function of vegetation within the hydrological cycle is one of the key questions in the interdisciplinary field of ecohydrology. The presence of vegetation can have various impacts on soil water relations: transpiration of active vegetation causes great water losses, rainfall is intercepted, soil evaporation can be reduced and infiltration, hydraulic redistribution and translatory flow might be altered. In drylands, covering around 40% of the global land surface, the carbon cycle is closely coupled to water availability due to (seasonal) droughts. Specifically savannah type ecosystems, which cover large areas worldwide, are, due to their bi-layered structure, very suitable to study the effects of distinct vegetation types on the ecosystem water cycle.

Oxygen isotope signatures (δ^{18}O) have been used to partition ecosystem evapotranspiration (ET) because of the distinct isotopic compositions of water transpired by leaves relative to soil evaporated vapor. Recent developments in laser spectroscopy enable measurements of δ^{18}O in the vapor phase with high temporal resolution in the field and bear a novel opportunity to trace water movement within the ecosystem.

In the present study, the effects of distinct vegetation layers (i.e. trees and herbaceous vegetation) on soil water infiltration and redistribution as well as ecosystem water fluxes in a Mediterranean cork-oak woodland are disentangled. An irrigation experiment was carried out using δ^{18}O labeled water to quantify the distinct effects of trees and herbaceous vegetation on 1) infiltration and redistribution of water in the soil profile and 2) to disentangle the effects of tree cover on the contribution of unproductive soil evaporation and understory transpiration to total ET.

First results proof that stable δ^{18}O isotopes measured onsite with laser spectroscopy is a valuable tool to trace water movement in the soil showing a much higher sensitivity than common TDR-type probes. It was possible to track soil water redistribution even beyond zero net water flux measured with TDR probes. Under shaded conditions beneath tree crowns, infiltration of precipitation reaches much deeper depths due to the limited radiation energy input and thus, reduced evaporative losses, compared to open areas between crowns. As a consequence, the isotopic enrichment back to initial conditions (as observed before the artificial precipitation event) was strongly delayed. Despite the higher water availability beneath tree crowns, transpiration of understory plants and soil evaporation rates were reduced compared to the open area due to the lack of energy. However, transpiration could be maintained much longer and at higher rates after the precipitation event then soil evaporation. These first results support previous findings at this site where a clear difference in understory plant community structure was observed. Beneath tree crowns, favorable water conditions enables a higher occurrence of grasses and nitrogen fixing forbs, whereas in between tree crowns drought adapted native species became dominant.