Geophysical Research Abstracts
Vol. 19, EGU2017-17214, 2017
EGU General Assembly 2017

Constraining water uptake depths in semiarid environments using water stable isotopes

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The biophysical process of transpiration recently received increased attention by ecohydrologists as it has been proven the largest flux of the global water balance. However, fundamental aspects related to the questions how and from which sources plants receive their water are not fully understood. Especially the process of plant water uptake from deeper soil and its impact on the water balance requires increased scientific effort.

In this study we combined tracer experiments with the analysis of natural isotopic compositions in order to: i) derive a suitable site-specific root water uptake distribution for hydrological modeling; ii) find indicators for groundwater use by specific plants; and iii) evaluate the importance of deep unsaturated zone water uptake using HYDRUS 1D. The bayesian mixing model MixSIAR was applied at a semiarid site with a deep unsaturated zone in northern Namibia in order to identify source water contributions of the most abundant species (A.erioloba, B.plurijuga, C.collinum, S.luebertii and T.sericea). In addition, a previously developed method for the investigation of root water uptake depths based on deuterium labeling ($2H_2O$) at specific depths (0.5 to 4 m) and monitoring of tracer uptake by plants was carried out with a focus on the deeper unsaturated zone. With the experimental results a root water uptake distribution for the lateral root zone was derived which allows to constrain the source water contributions estimated with MixSIAR. Finally, a HYDRUS 1D model was established and unsaturated zone water transport was evaluated.

The analysis of the natural isotopic compositions reveals a significant contribution of groundwater (median: 48%) to the isotopic composition of A.erioloba at the end of the dry season indicating the presence of deep tap roots for a number of individuals. All other investigated species obtain their water from the shallow (median: 22%) or deeper (median: 62%) unsaturated zone at this time of the year. The water uptake distribution based on the labeling experiments implies main water uptake occurring in the upper two meters of the soil; however, infrequent uptake up to four meters depth was registered. The HYDRUS 1D model reveals a strong impact of the implemented root distribution on unsaturated zone water transport and transpiration to evaporation rates of 3:1. Lessons learned from this field and modeling study for semiarid environments are: i) Using soil profiles from the dry season are suitable for investigating groundwater use by certain plant species. Soil profiles from or shortly after the rainy season as input for mixing models lead to ambitious results, mainly due to the fact that water sources are too similar; ii) A variety of techniques is required in order to improve the understanding of water uptake in deep unsaturated zones; and iii) Characteristic parameters such as deep percolation are subject to large uncertainties and cannot be modeled accurately if the root distribution on site is not represented correctly. There is an urgent need to incorporate these aspects into any modeling approach and for investigating ecohydrological separation across environments.