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Biohydrology – walking on drylands and swimming through pores

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PREFACE

Biohydrology – walking on drylands and swimming through pores

Biology and hydrology are closely linked in nature, with human influences from land management, water use and climate change having a massive impact (Vogel et al., 2015). This special issue of Ecohydrology provides a range of papers on these complex interactions, ranging in scale from the hydrophobicity of biopore surfaces up to landscape vegetation structure affected by soil hydrological characteristics. The papers were first presented at the 4th Biohydrology Conference, held in Almeria, Spain, in 2016. These conferences have provided a forum to bridge between a reductionist understanding of the underpinning interactions between biological and hydrological processes, and a systems understanding of the impacts to ecology, plant productivity and hydrology. This is the second Ecohydrology special issue from the Biohydrology conferences: Volume 3, Issue 4 published 12 papers from the 2nd Biohydrology Conference held in Bratislava, Slovakia, in 2009. Included in that special issue are well cited papers on hydraulic redistribution by tree roots (Nadezhdina et al., 2010) and ecological versus topographical drivers of run-off in the Ethiopian highlands (Bayabil et al., 2010).

The 4th Biohydrology conference had the theme ‘walking on drylands”, which was appropriate for its location in southern Spain and addressed a major hydrological challenge. Drylands cover about 45% of the global land area (Prăvălie, 2016), contain more than 38% of the human population and a high biodiversity that plays an essential role in maintaining the multiple functions of these ecosystems. Although an emerging body of literature in the last decades has focused on researching dryland ecosystems, there is a surprisingly weak understanding of biohydrological processes. One of the processes is groundwater access by vegetation, which Guirado et al. (2018) studied using a non-destructive low-cost remote-sensing-based approach. This approach combined object-based image analysis of high-resolution orthoimages to map shrub individuals with geomorphometric analysis of a lidar-derived terrain model to map fractures that roots use to access groundwater.

Further research on the establishment of vegetation in drylands by Fan et al. (2018) explored shrub patches along a precipitation gradient on the Inner Mongolia Plateau of Northwest China. While they found shrub cover and height to be affected most by climate, shrub density was mainly affected by soil properties and the size of patches by vegetation. They discussed how the complex interactions between climate, vegetation and soil drove the structure of the observed ecosystems along the precipitation gradient. This included biology influencing the capacity of soils to transport and retain water. Biology affecting soil hydrology can also be observed in biological soil crusts or biocrusts, which are communities of algae, cyanobacteria, fungi, lichens, mosses and other microorganisms that live on the soil surface in very close association with soil particles. Biocrusts play crucial roles in hydrological processes by controlling soil water availability and regulating water and nutrients redistribution to vegetation through runoff generation. This was demonstrated by Rodriguez-Caballero et al. (2018) who found that runoff from source areas with biocrusts to vegetated sink areas constitutes a vital water resource for vegetation. Runoff redistribution from biocrusts leads to greater soil water availability under the plants, promoting more photosynthetically active biomass, net carbon uptake rates and water-use efficiency than plants under run-on exclusion. Kidron & Adoni (2018) also found an increase of survival and biomass of shallow-rooted perennial plants (*Stipagrostis plumosa* and *Cyperus* sp.) in the Negev desert associated with a higher available water content explained by runoff addition and lower evaporation from biocrusts. However, these authors also found a contrasting effect of biocrusts on the same plants in other topographical positions, where the run-on contribution was less. In these positions, biocrusts decreased albedo, increased subsurface temperatures and increased evaporation rates, possibly affecting plant mortality during droughts. Both articles highlight that altering biocrusts through damage or climate will affect vegetation and the whole ecosystem.

In connection with this subject, Lafuente et al. (2018) analysed how ongoing climate change in drylands affects the soil water balance of biocrust covered soils. They evaluated how biocrusts modulate soil water gains and losses using 8 years of continuous soil moisture and rainfall data from a climate change manipulation experiment (2.5ºC temperature warming and 33% rainfall reduction). Warming was found to have a double effect on the hydrological behaviour of biocrusts, by directly increasing evaporation and by indirectly reducing the cover of biocrusts and hence water gains. Moreover, the effects of climate change treatments on biocrusted-soil water gains and losses changed through time, emphasizing the importance of exploring multiple seasons to accurately evaluate the hydrological response of drylands to climate change. Biocrusts are an early stage of vegetation succession that occur in other regions than drylands. Lichner et al. (2018) explored how vegetation succession, from bare soil, to biocrusts and then grasses, affected the soil water repellency of sandy soils in Central Europe. At sites in Germany and Slovakia, but not Hungary, they observed increased soil water repellency with vegetation succession, which was associated with increase soil organic carbon. With greater water repellency, water flow shifted from piston to preferential flow, leaving large volumes of soil dry.

Central Europe is also affect by drought, which Nalevanková et al. (2018) studied in a mature beech forest during the growing seasons of 2012–2014. Stem contractions of trees under drought were much greater than irrigated trees, suggesting a lower water potential of the stem-conducting tissues and an increased use of internally stored water to maintain daily transpiration. Water use by plants also occurs at night, which is expected to increase with rising temperature and greater vapour pressure deficit. Kupper et al. (2018) investigated night and daytime water fluxes in response to environmental stimuli of five tree species with different water-use strategies. They found that the ability of trees to open stomata and lose water at night was not directly related to the daily water-use strategy, but was determined more by their photosynthetic capacity, growth potential, and nitrogen-use strategy. Different species of vegetation can also have different impacts on soil processes. Zegeye et al. (2018) compared how grasses, shrubs and trees with contrasting root structures affected soil stabilisation along streambanks in the Ethiopian Highlands. Fibrous roots that spread widely in shallow soil offered about double the additional soil cohesion from roots compare to tap-root systems in the top 0.6 m. This great capacity of plant roots to physically stabilise soils was concluded by the authors to be an important component of rehabilitating gully erosion that plague this region.

Erosion at landscape scale causes a redistribution of topsoil and carbon that also affects soil structure along a slope. Fér et al. (2018) took intact specimens from along an eroded slope of loess soil to explore how its wetting from an air-dry state affected CO_2 efflux. The unique aspect of this study is the combination of impacts of soil organic matter content with the soil hydraulic condition of eroded affected soils. They found that soils from less eroded parts of slopes had greater net CO_2 efflux upon wetting, with maximum rates when soils had a low level of water saturation. In eroded areas the net CO_2 efflux was less affected by soil water content, demonstrating the combined impacts of organic matter quality, hydraulic properties and associated soil structure.

The interactions between organic matter and soil structure on a range of soil processes was also demonstrated by Luna et al. (2018) who explored the use of organic amendments and mulches to restore an opencast mine covered in degraded calcareous soil. They found that by improving soil hydraulic conditions, composts and sewage sludge greatly improved plant growth, whereas gravel and woodchip mulches applied to the soil surface had little impact on plant responses or soil properties. A longer-term study on vegetation succession impacts on the soil water regime of post-mining soils that had either been reclaimed or left to natural recovery is presented by Cejpek et al. (2018). They found that in the 30 years since mining ceased, the water regime on the mining sites was similar to surrounding forests, and that spontaneous forest regrowth in unreclaimed areas resulted in a similar water regime to reclaimed areas. The vegetation was dominated by high water use alder trees, which they argued compensated for high transpiration by creating much greater soil water storage over time.

Such a biological impact on soil hydrological properties has been a common theme of many of the papers appearing in this special issue. These impacts are particularly strong at the surfaces of biopores, which serve as rapid channels for bypass flow. Using a range of approaches to measure soil water repellency, coupled with DRIFT spectroscopy to measure organic matter composition, Haas et al. (2018) contrasted earthworm channels and root channels occupied briefly by earthworms. Biopores always had greater water repellency than bulk soil, with the organic matter composition related to organic matter composition. However, mechanical bioturbation by earthworms was found to increase wettability, which they argued should be combined with deeper rooting plants to increase water storage for plant production. An even smaller-scale investigation of coupled biological, physico-chemical and chemical particle surface properties on soil water transport was conducted by Krueger et al. (2018) who used a flow cell to explore processes at mm scale. Intact soil specimens could be observed using this technological leap, that allowed for DRIFT to be applied to measure organic matter composition, biological activity with a spatial gel (zymography), wettability (contact angle) and water transport from radiography or dye tracers. They observed a strong interdependency between biology, physics and chemistry, providing an incredibly powerful approach to disentangle biological drivers of soil hydrology.

From such fundamental small-scale studies, through to larger scale interactions of biology and hydrological processes, the collection of papers in this special issue have highlighted the diversity of biohydrology research. The Biohydrology conferences provide an excellent forum to discuss emerging research, with each conference building considerably on the last. The 5th Biohydrology Conference to be held in July 2019 in Valencia, Spain, will carry forward our interdisciplinary science, unravelling the fascinating and complex ways that hydrology works in nature (https://biohydrology2019.wordpress.com).

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