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Multifaceted impacts of moss-dominated biocrusts on dryland soils: From soil pore structure to aeration and water infiltration

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ABSTRACT

Biocrusts are a crucial living cover of dryland soils that alter near-surface soil structure and properties. To date, it is still unclear how biocrusts affect soil pore structure, and subsequently alter gas and water transport processes. In this study, we investigated aeolian sand and loess soil colonized with moss-dominated biocrusts and in bare state of the Chinese Loess Plateau. X-ray computed tomography (CT) was used to quantify and visualize the pore characteristics for all considered scenarios. In addition, the soil air permeabilities and relative gas diffusivities were measured together with infiltration rates. CT imaging and reconstruction showed 102–107%, 56–87%, and 72–203% higher macroporosities, surface area densities, and mean pore volumes, respectively, for soils colonized with biocrusts when compared to their bare counterparts. The biocrusts also increased the ratio of connected and isolated porosities as well as pore node densities, while decreasing Euler numbers and tortuosity when compared to the bare soils. This suggests that the pore networks in biocrust-colonized soils exhibit higher continuity and less tortuosity. In addition, the biocrusts increased air permeability by 277–301% and relative gas diffusivity by 47–59%, which is attributable to more air-filled pores and better pore connectivity. However, when compared with bare soils, the biocrusts reduced steady state infiltration rates by 41–50% and the 60 min cumulative infiltration amount by 33–54%. The decrease in infiltrability is attributable to the higher fine particle content and the enhanced water holding capacity of biocrusts. In summary, the biocrusts improved soil pore structure and soil aeration, and reduced infiltrability when compared to bare soils. This implies that biocrusts play a multifaceted and complex role in the transport of gases and water, and as a consequence significantly impact near-surface hydrological and biochemical processes, such as soil evaporation and respiration in drylands.

1. Introduction

Drylands make up 41% of the Earth's terrestrial surface and support more than 38% of the world's population in subhumid, semiarid, arid, and hyperarid climate regions (Reynolds et al., 2007; Huang et al., 2015). They are characterized by sparse vegetation with low annual net productivity and are especially vulnerable to climate change and land desertification and degradation. It is predicted that the increasing aridity in the late twenty-first century will globally increase the total area of drylands and exacerbate their desiccation and degradation (Dai, 2013; Huang et al., 2017). This will have negative consequences for multiple structural and functional attributes of dryland ecosystems, such as soil structure, nutrient cycling, plant productivity, and microbial community richness (Berdugo et al., 2020). Biocrusts that are also known as biological soil crusts are particularly prevalent in vegetation interspaces of drylands due to their specific adaptation mechanisms, which allow them to cope with insolation, limited precipitation, and severe drought. As a crucial layer between soil and atmosphere, biocrusts cover about 12% of the global terrestrial surface, about 14% of China's dryland soil, and about 30% of dryland soils (Rodríguez-

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