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Towards moss biocrust effects on surface soil water holding capacity: Soil water retention curve analysis and modeling

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ABSTRACT

As ecosystem engineers in drylands, biocrusts possibly generate great influences on surface soil water holding capacity and availability, but these effects have not yet been sufficiently investigated, especially through analyzing and modeling their soil water retention curve (SWRC). On the Loess Plateau of China, the naturally developed moss biocrusts and surface bare soil were sampled in five replicates on loess soil and aeolian sand respectively, and their SWRCs from saturation (soil water potential = 0 hPa) to dry (soil water potential = −15,000 hPa) were measured with a sandbox (low water potential range) in combination with a pressure plate (high water potential range). The measured SWRCs were compared to the van Genuchten (VG), Brooks and Corey (BC), and Log-Normal Distribution (LND) models, and the model with best performance was adopted to further determine the effects of biocrusts on surface soil water holding capacity and water availability through comparing the differences in soil water content (θ) at specific water potentials between the biocrusts and uncrusted soil. Our results showed that (i) the biocrusts always had higher θ as compared with the bare soil across the whole water potential range, and the increasing effects of the biocrusts was much stronger on aeolian sand (165%) in comparison to that on loess soil (15%). (ii) As compared with the bare soil, the saturated water content, field capacity, wilting point, and available water content of the aeolian sand increased by 52%, 256% (0.192 vs. 0.054 cm^3 cm^{-3}), 65%, and 1000% by the biocrusts, respectively; while that of the loess soil increased by 28%, 9% (0.240 vs.0.220 cm^3 cm^{-3}), 27%, and 8% by the biocrusts, respectively. (iii) The increased water holding capacity of the biocrusts was possibly attributed to their higher percentage (18% vs. 16%) of microscopic pores (0.3–5 μm) on the loess soil and their increasing (16% vs. 1%) microscopic pores and decreasing (18% vs. 50%) medium pores (30–75 μm) on the aeolian sand. (iv) The VG and LND models performed better ($R^2 > 0.98$, $RMSE \leq 0.019$ cm^3 cm^{-3}, $RE \leq 7.4\%$) than the BC model in simulating the SWRCs of the biocrusts and bare soil, and their fitting errors were mostly distributed in the high (−500 to −1000 hPa) and low (<−5000 hPa) water potential ranges. As indicated by SWRCs, we conclude that biocrusts greatly increase surface soil water holding capacity and water availability, leading in turn to a positive feedback mechanism of the biocrusted layer, which may affect surface hydropedological process (e.g., infiltration and evaporation) in drylands.

1. Introduction

As a critical component in regulating plant physiological changes, soil moisture has been widely explored in different soils and climate regions across multiple scales, especially in drylands which are characterized by limited precipitation (such as the Chinese Loess Plateau) (Chen et al., 2007; Heras et al., 2011). Due to the limited water resources, water availability has become a limiting factor in sustaining ecological processes and vegetation restoration in drylands (Zhang et al., 2016). Therefore, soil plays an important role in water retention under limited rainfall of arid and semi-arid climate areas (Shi et al., 2018). Soil water holding capacity (SWHC) is crucial for vascular plant growth, because it significantly influences soil water uptake by plant roots, especially in water-limited area (Ffolliott et al., 1995; Gao et al., 2002).

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