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Research papers

Direct evidence and mechanism for biocrusts-induced improvements in pore structure of dryland soil and the hydrological implications

Fuhai Sun [a,b], Bo Xiao [a,b,c,*], Shenglong Li [b], Xingxing Yu [c], Giora J. Kidron [d], Joshua Heitman [e]

[a] *Breeding Base for State Key Laboratory of Land Degradation and Ecological Restoration in Northwestern China/Key Laboratory of Restoration and Reconstruction of Degraded Ecosystems in Northwestern China of Ministry of Education, Ningxia University, Yinchuan 750021*

[b] *Key Laboratory of Arable Land Conservation in North China, Ministry of Agriculture and Rural Affairs/College of Land Science and Technology, China Agricultural University, Beijing 100193, China*

[c] *State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling, Shaanxi 712100, China*

[d] *Institute of Earth Sciences, The Hebrew University of Jerusalem, Givat Ram Campus, Jerusalem 91904, Israel*

[e] *Department of Crop and Soil Sciences, North Carolina State University, Raleigh, NC 27695, USA*

A R T I C L E I N F O

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A B S T R A C T

As a crucial living skin inhabiting the soil-atmosphere interface, biocrusts play a vital role in various soil properties and processes, especially surface soil pore structure and soil pore-related hydrological processes, such as infiltration and evaporation. However, it remains unclear how biocrusts affect pore structure in the micrometric point of view. In this study, X-ray computed tomography and image analysis were employed to quantify the differences in soil pore structure between bare soil and three types of biocrusts (cyanobacterial, cyanobacterial-moss mixed, and moss crusts) at 0–50 mm depth. Three-dimensional images were segmented and analyzed to assess morphological and geometrical properties, such as porosity, pore volume, degree of anisotropy, Euler number, pore shape, pore connectivity, and pore tortuosity. Our results showed that the porosity of three types of biocrusts was, on average, 100% higher than bare soil, and the porosity ranked in order of moss crusts > mixed crusts > cyanobacterial crusts > bare soil. In comparison to bare soil, pore surface area density, mean pore volume, and node density of biocrusts were increased by 45%, 422%, and 52% on average, respectively. Biocrusts had larger fractal dimensions but lower degrees of anisotropy, mean tortuosity, and Euler number, which indicates the pore structure of biocrust became more complex and stable with higher connectivity compared to bare soil. Additionally, elongated pores had the largest contribution to porosity, and these pore proportions were significantly higher in biocrusts than bare soil. More importantly, the pore network model and network analysis revealed that biocrusts have a higher connected porosity (17% vs. 4%), connected porosity/isolated porosity (11.7 vs. 0.6), average coordination number (8 vs. 5), and number of channels (14,480 vs. 807), but a lower average channel length (2.7 vs. 3.8 mm), which indicates that the physical and topological structures of pore network in biocrusts were reconfigured and exhibited a better pore network connectivity. Moreover, the biocrusts increased soil water holding capacity by 87% on average, but decreased saturated hydraulic conductivity by 55% as compared to bare soil. From the reshaped pore structure, improved soil water holding capacity, and decreased infiltrability of the biocrusts in comparison to bare soil, we conclude that biocrusts play a vital role in surface soil water balance, which subsequently affect surface hydrological processes (e.g., runoff generation and evaporation) in drylands.

1. Introduction

Drylands include subhumid, semiarid, arid, and hyperarid climate regions, which cover 41% of the Earth's terrestrial surface and support about 35% of the world's population (Reynolds et al., 2007). However, 10%–20% of dryland ecosystems have already been severely degraded due to intensive human activities and climate change (Huang et al., 2016; Mao et al., 2018). It is forecasted that in the late twenty-first

* Corresponding author at: Key Laboratory of Arable Land Conservation in North China, Ministry of Agriculture and Rural Affairs/College of Land Science and Technology, China Agricultural University, No. 2, Yuanmingyuan West Road, Haidian District, Beijing 100193, China.

E-mail address: xiaobo@cau.edu.cn (B. Xiao).

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