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Towards the effects of moss-dominated biocrusts on surface soil aeration in drylands: Air permeability analysis and modeling

Fuhai Sun [a], Bo Xiao [b,c,*], Giora J. Kidron [d], Markus Tuller [e]

[a] 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
[b] 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
[c] 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, China
[d] Institute of Earth Sciences, The Hebrew University of Jerusalem, Givat Ram Campus, Jerusalem 91904, Israel
[e] Department of Environmental Science, The University of Arizona, Tucson, AZ 85721, USA

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ABSTRACT

Soil aeration is an important factor influencing soil biological and biochemical processes because it directly affects soil microbial activity and respiration. As an important living skin of the soil, biocrusts strongly impact various soil properties and play a vital role in maintaining surface soil structure and multifunctionality. Although there are several studies concerning the effects of biocrusts on soil respiration processes, it is still not well understood how biocrusts affect air permeability (K_a) and soil aeration in drylands. In a semiarid climate region of the northern Chinese Loess Plateau, the K_a and air-filled porosity (ε_a) of moss-dominated biocrusts established on aeolian sand and loess soil were measured as a function of soil water content under laboratory and *in situ* conditions and compared to measurements of bare soils. The relative air permeability (K_{ra}) of biocrusts and bare soils was further analyzed and estimated with commonly applied K_{ra} models that are based on the soil water retention curve (SWRC), and the performance of these models was specifically assessed for biocrusts. The *in situ* measurements yielded a 51.8% and 76.7% higher K_a for the biocrust-colonized aeolian sand and loess soil, respectively, when compared to the bare soils. Correspondingly, in comparison to the bare soils, the ε_a of the biocrusts also increased by 38.0% for the aeolian sand and by 52.4% for the loess soil. The laboratory measurements showed an 8.5%–9.3% increase of K_a for the biocrust-colonized soils from wet to dry conditions when compared to their bare counterparts, which was mainly attributed to their higher fine particle and organic matter contents as well as to the moss rhizoids. Moreover, a positive linear relationship ($R^2 > 0.43$) was found between the log K_a and log ε_a for both biocrusts and bare soils. Additionally, the biocrusts exhibited higher water content at almost all matric potentials in comparison to the bare soils. The K_{ra} of biocrusts was 22.0% higher for aeolian sand and 42.1% higher for loess soil when compared to the bare soils. The van Genuchten-Burdine and Brooks and Corey-Burdine models performed best with regard to the estimation of K_{ra} (RMSE $\leq$ 0.100, bias $\leq$ 0.018). In general, biocrusts may greatly increase surface soil aeration due to their higher K_a and ε_a, and the soil aeration status of biocrusts can be indirectly assessed through their effective degree of soil water saturation. Our findings suggest that biocrusts should be carefully considered in further studies of soil aeration related to biological processes and gas and vapor transport in dryland ecosystems.

1. Introduction

Soil air permeability (K_a), defined as the ability of soil to transmit air through interconnected air-filled pores under an imposed air pressure gradient, governs soil gas transport (Poulsen et al., 2007). Generally, K_a is affected by various soil-pore structural characteristics, such as soil bulk density, pore size distribution, and total porosity (Roseberg and McCoy, 1990), and structured soils usually have higher K_a than

* Corresponding author at: 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, No. 26, Xinong Road, Yangling, Shaanxi 712100, China.
E-mail address: xiaobo@cau.edu.cn (B. Xiao).

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