ADVANCING EARTH AND SPACE SCIENCES

Water Resources Research

RESEARCH ARTICLE
10.1029/2023WR036520

Biocrusts Critical Regulation of Soil Water Vapor Transport (Diffusion, Sorption, and Late-Stage Evaporation) in Drylands

Fuhai Sun[1], **Bo Xiao**[1,2,3], **Giora J. Kidron**[4], **and Joshua Heitman**[5]

[1]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, China, [2]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, China, [3]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, China, [4]Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel, [5]Department of Crop and Soil Sciences, North Carolina State University, Raleigh, NC, USA

Key Points:

- Biocrusts increase water vapor diffusion properties, water vapor adsorption amount, and cumulative evaporation amount
- Modified soil properties of biocrust are a key factor influencing water vapor flux
- Reshaped vapor transport properties of biocrust control soil water and energy balance

Supporting Information:

Supporting Information may be found in the online version of this article.

Correspondence to:

B. Xiao,
xiaobo@cau.edu.cn

Citation:

Sun, F., Xiao, B., Kidron, G. J., & Heitman, J. (2024). Biocrusts critical regulation of soil water vapor transport (diffusion, sorption, and late-stage evaporation) in drylands. *Water Resources Research*, *60*, e2023WR036520. https://doi.org/10.1029/2023WR036520

Received 26 OCT 2023
Accepted 14 JUN 2024

Author Contributions:

Conceptualization: Fuhai Sun
Formal analysis: Fuhai Sun, Bo Xiao
Funding acquisition: Bo Xiao
Investigation: Fuhai Sun
Methodology: Fuhai Sun
Project administration: Bo Xiao
Resources: Fuhai Sun
Supervision: Bo Xiao
Writing – original draft: Fuhai Sun, Bo Xiao
Writing – review & editing: Bo Xiao, Giora J. Kidron, Joshua Heitman

Abstract

Soil surface cover is one of the most critical factors affecting soil water vapor transport, especially in drylands where water is limited, and the water movement occurs predominantly in the form of vapor instead of liquid. Biocrusts are an important living ground cover of dryland soils and play a vital role in modifying near-surface soil properties and maintaining soil structure. The role of biocrusts in mediating soil water vapor transport during daytime water evaporation and nighttime condensation remains unclear. We investigated the differences in vapor diffusion properties, vapor adsorption capacity, and water evaporation between bare soil and three types of biocrusts (cyanobacterial, cyanobacterial-moss mixed, and moss crusts) in the Chinese Loess Plateau. Our results showed that the three types of biocrusts had 5%–39% higher vapor diffusivity than bare soil. At the same level of ambient relative humidity and temperature, the initial vapor adsorption rates and cumulative adsorption amounts of the biocrusts were 10%–70% and 11%–85% higher than those of bare soil, respectively. Additionally, the late-stage evaporation rate of cyanobacterial-, cyanobacterial-moss mixed-, and moss-biocrusts were 31%–217%, 79%–492%, and 146%–775% higher than that of bare soil, respectively. The effect of biocrusts on increasing vapor transport properties was attributed to the higher soil porosity, clay content, and specific surface area induced by the biocrust layer. All of these modifications caused by biocrusts on surface soil vapor transport properties suggest that biocrusts play a vital role in reshaping surface soil water and energy balance in drylands.

1. Introduction

Drylands encompassing hyper-arid, arid, semi-arid, and dry sub-humid regions, collectively occupy ∼41% of the Earth's land surface, sustaining ∼38% of world's population, and holding ∼25% of global soil organic carbon (J. F. Reynolds et al., 2007). Due to the sparse vegetation, limited precipitation, and intense evaporation, dryland ecosystems are fragile and sensitive to global climate change and desertification (Mao et al., 2018). In drylands, soils have relatively low moisture, and water transport occurs predominantly in vapor form instead of liquid (Huang et al., 2016). Soil vapor transport plays a critical role in water and energy balances of near-surface soil layers, and therefore has a substantial impact on multiple processes directly related to ecosystem structure and functioning, such as biological activity, plant productivity, and nutrient concentration (Berdugo et al., 2020). Most notably, climate projections indicate that ongoing global warming will cause drylands to become hotter and drier in the late twenty-first century, which in turn may enhance soil vapor transport (IPCC, 2021). Consequently, it is essential to investigate soil vapor transport properties for further understanding the exchange of water and energy in dryland ecosystems. Soil vapor transport is influenced by the combination of soil texture, porosity, structure, and especially surface cover (Arthur et al., 2015), and biocrusts directly impact each of these factors. Thus, biocrusts are also likely to play a major role in impacting soil ecohydrological processes (S. L. Li et al., 2022a).

Biocrusts are complex communities of living organisms dwelling on or within the uppermost few millimeters (or even centimeters) of the soil surface, and are widely distributed in the interspaces between sparse vegetation,