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Biological soil crust characteristics and their response to global change

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Biological soil crusts (referred to as biocrusts hereafter) represent communities of photoautotrophic bacteria, algae, lichens, and bryophytes, growing together with heterotrophic organisms like bacteria, archaea and fungi in varying proportions. They occur widely in dryland ecosystems, where vascular vegetation is quite sparse or even absent and wherever dry microclimatic conditions are met. According to the dominant photoautotrophic organism, biocrusts are divided into different types, i.e. cyanobacteria-, lichen-, and bryophyte-dominated biocrusts. These different types could also represent sequential stages of succession with lichen- and bryophyte-dominated biocrusts forming climax stages if water, nutrient, and other factors are not limiting their colonization. Biocrusts fulfill a broad range of highly important ecosystem services, being relevant in regional water cycling, soil stabilization, plant germination and growth, but also global carbon (C) and nitrogen (N) cycling.

The aim of the present project was to characterize the microbial composition and physiological properties of biocrusts and to analyze their response to global change (i.e., land use and climate change). We conducted qPCR and high-throughput 16S rRNA gene and fungal internal transcribed spacer region sequencing to investigate the microbial composition of the different biocrust types. The gas exchange properties of the different biocrust types were analyzed by means of CO_2 gas exchange and reactive N emission measurements. Finally, global biocrust distribution patterns and their expected response to global change were analyzed by environmental niche modeling.

Our results showed that the 16S and 18S rRNA gene copy numbers of bacteria and fungi increased from bare soil via cyanobacteria- and lichen- to bryophyte-dominated biocrusts. Bacterial community composition changed in a stepwise manner along with biocrust succession, while bare soil communities were completely different. The Shannon diversity index ranged between 8 and 11.2 for the different biocrust types, being in a similar range as the values observed for deciduous forest soils. CO_2 gas exchange measurements revealed characteristic adaptions of the different biocrust types to the environmental factors such as water, light, and temperature. Reactive nitrogen measurements also showed type-specific nitric oxide and nitrous acid emission patterns. Thus, the results suggest that the microbial composition (besides altered abiotic biocrust properties) accounts for the physiological characteristics of different biocrust types. In a global biocrust modeling approach, 18 independent environmental parameters were identified to control biocrust occurrence and growth. Based on these traits, a global map was created, suggesting that biocrusts cover a total area of $\sim$ 18 x 10^6km^2, corresponding to $\sim$ 12 % of the global terrestrial surface. Utilizing the climate and land-use forecasts obtained by the Climate Model Inter-Comparison Project (CMIP5), our model suggests that the biocrust cover will decline by $\sim$ 25%-40% until the year 2070, being caused by both land use and climate change to similar extents.

This biocrust loss is expected to be accompanied by a decrease of overall biocrust diversity and ecosystem services, as C-, N-, and water cycling. Due to their soil stabilizing properties, the biocrust decline will likely result in higher erosion values and increased dryland dust emissions with potential adverse effects on climate and human health.