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Development of biological soil crusts in initial ecosystems in Lusatia, Germany

Roland Spröte[1], Maik Veste[2], Thomas Fischer[3], Philipp Lange[2], Oliver Bens[4], Thomas Raab[1], Reinhard F. Hüttl[1,4]

Introduction

At mobile inland dunes vegetation cover is sparse, but the space between tussock (e. g. *Corynephorus canescens*) and shrubs is often covered by biological soil crusts (BSCs) build up by cyanobacteria, green algae, mosses, and in later stages by lichens. These cryptogams are the first colonizers of sand dunes and play a major role for the further vegetation pattern and the ecosystem development. The BSCs change the physico-chemical conditions and influence various ecosystem processes, e. g. soil hydrology (VESTE et al. 2001). Cryptogams excrete exopolysaccharides that bind the fine-grained particles of the substrate on the surface.
We studied the development of BSCs on former substrate in the recultivated area of the open-cast lignite mining area near Welzow (Brandenburg, Germany) (KENDZIA et al. 2008). An artificial dune was constructed in 2001 at the artificial water catchment ´Neuer Lugteich´ (Fig. 1, LEMMNITZ et al. 2008). Chlorophyll a + b, soil organic matter, pH, texture and water repellency indices were determined along vegetation density reflecting plots to classify various soil crust types. At the plot without vegetation we expected that cyanobacteria are the first colonizers followed by green algae in the sparse vegetation areas of the Quaternary substrate. In zones with dense vegetation, in flat and moist areas, mosses dominate the soil crusts. Due to lack of soil organic matter in the sandy substrate, photoautotrophic organisms like cyanobacteria and green algae are important for soil organic matter accumulation in the first millimetre of the topsoil.

Key words: biological soil crusts (BSCs), cyanobacteria, green algae, initial ecosystem development, soil formation

[1)] *Brandenburg University of Technology (BTU) Cottbus, Chair of Soil Protection and Recultivation, P. O. Box 101344, 03013 Cottbus*
[2)] *BTU Cottbus, Research Center Landscape Development and Mining Landscapes, P. O. Box 101344, 03013 Cottbus*
[3)] *BTU Cottbus, Central Analytical Laboratory, P. O. Box 101344, 03013 Cottbus*
[4)] *German Research Centre for Geosciences GFZ, Telegrafenberg, 14473 Potsdam*

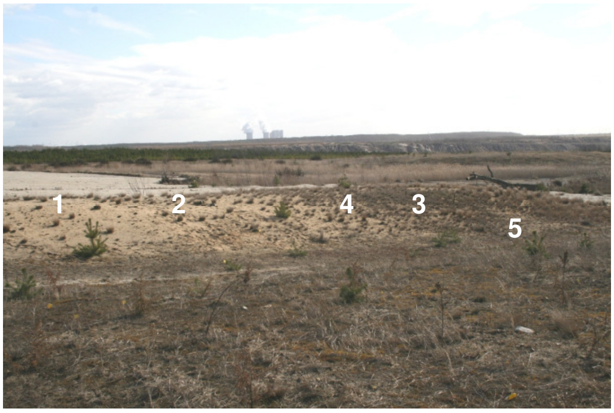

Fig. 1: Artificial dune of the artificial water catchment ´Neuer Lugteich´, Brandenburg, Germany with five development stages (see text and Fig. 2)

Material and methods

On the artificial dune we defined five development stages (St) of vegetation (Fig. 2): (a) no vegetation on the surface (St 1), (b) sparse vegetation with *Corynephorus canescens* (St 2), (c) dense vegetation (St 3), (d) slope with dense vegetation (St 4) and (e) foot vegetation (St 5). At each development phase six samples of topsoil and Quaternary substrate underlaying the topsoil were

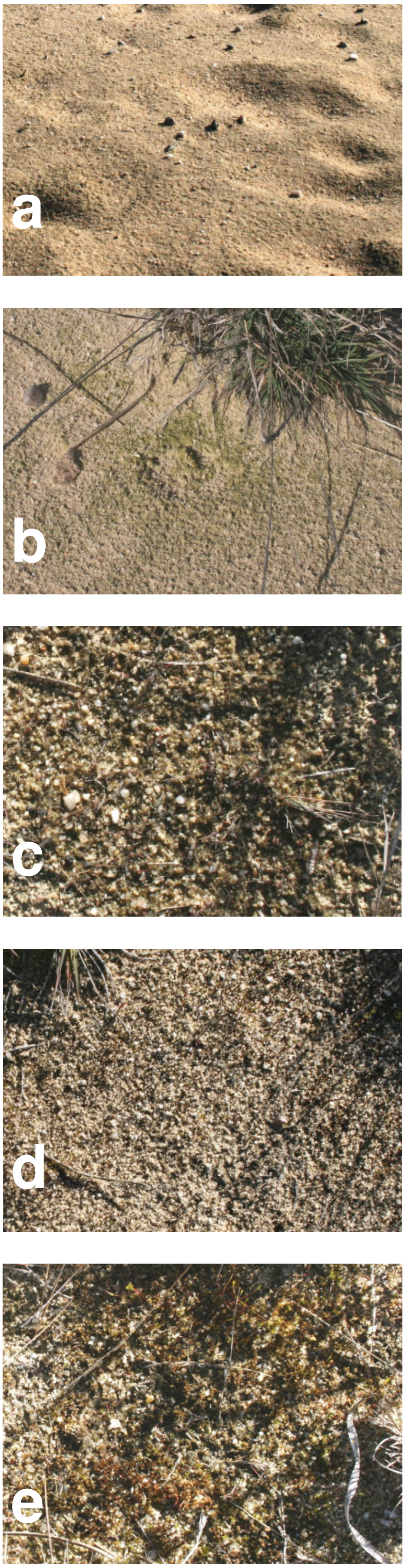

Fig. 2: Five stages (St) with
a – no vegetation surface (St 1), b – BSC in sparse vegetation (St 2), c – BSC with mosses in dense vegetation (St 3), d – slope vegetation (St 4), e – foot vegetation (St 5)

sampled separately. For analysing contents of chlorophyll BSCs were sampled on an area basis related with small soil sample rings (12 mm, diameter 26,6 mm), thoroughly stirred in a mortar, sonicated, extracted with acetone (80%) and determined with a photometer PERKIN ELMER Lambda 2. Furthermore, undisturbed BSCs with substrate were collected with petri dishes (0-180 mm, 850 mm diameter) from the topsoil for measuring the water repellency indices according to HALLETT & YOUNG (1999). On each sample with BSC soil pH was measured in water suspension (soil:H_2O = 1:2.5) and content of soil organic carbon was determined by dry combustion. Texture was analysed by wet seaving and fractionation after DIN 19683-2 (pipette method) on samples with BSC and on substrate samples from below the BSC.

Results and discussion

In the plot with no vegetation (a) the pH values are low and with advance of the development pH is increasing. At the foot, the pH is lower than at the slope of the artificial dune. However, the pH of the crusts is with values ranging from 4.9 to 5.2 strong to moderate acidic (Tab. 1).

With the development of the vegetation cover, BSCs grow on the substrate surface and the content of chlorophyll is rising (Fig. 3). Low filamentous cyanobacteria are developed in the pore space of the sandy substrate and bind the particles together. The range of variation is rising (Fig. 3, St 2). Cyanobacteria and green algae form patches between the higher plants here, hence, the variability at this stage is highest. At St 3 mosses are sporadic and at St 4 to St 5 dominant. This corresponds

Tab. 1: Mean values of pH by six measurements per St at the different development stages

Development stage	pH
St 1	4.95
St 2	5.14
St 3	5.19
St 4	5.25
St 5	5.20

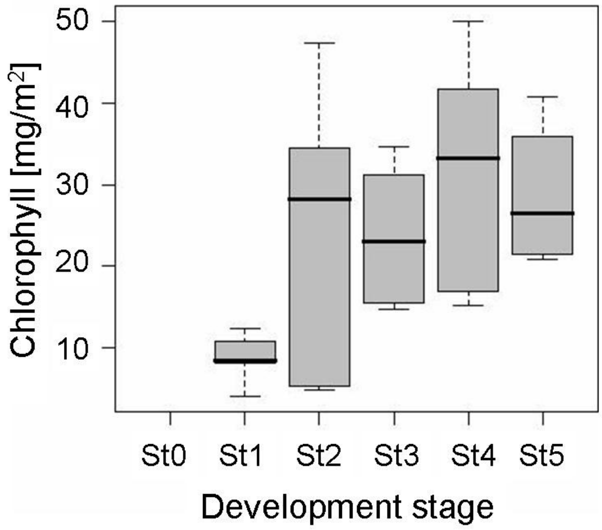

Fig. 3: Content of chlorophyll a + b

St0	= substrate
St1 to St5	= BSC (see Fig. 2)

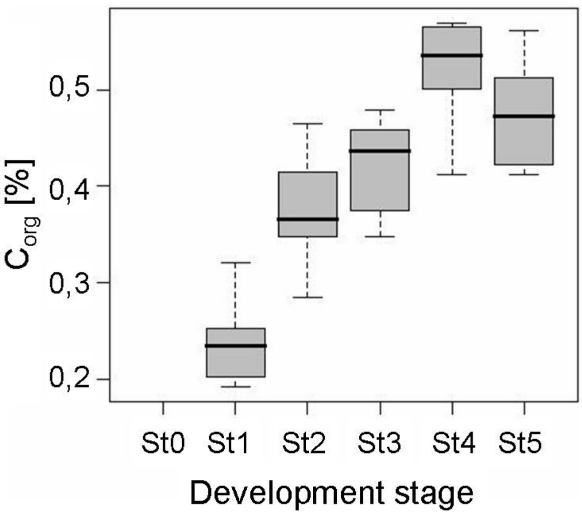

Fig. 4: Content of soil organic matter

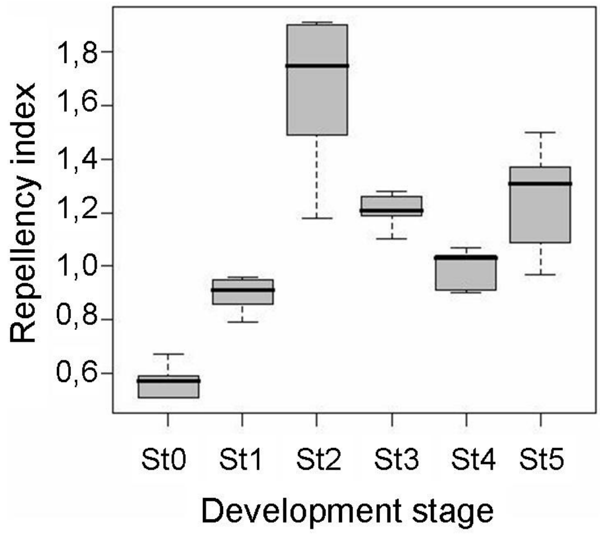

Fig. 5: Water repellency index

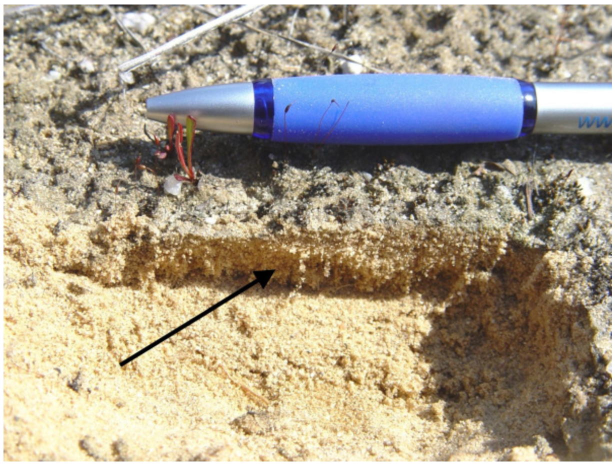

Fig. 6: Rhizoids of mosses loosen the substrate and exopolysaccharides stick together the sand particles (see arrow).

with the increasing concentrations of soil organic matter (Fig. 4) and with the general increase of biomass production and the chlorophyll content.

On sandy substrate the water repellency index is low, but with the development of the BSCs water repellency is increasing (Fig. 5, St 1 to 2). At St 3 influenced by mosses the water repellency index is reduced again. This demonstrates that rhizoids of the mosses (Fig. 6) alter the polarity of surfaces in the crust, which corresponds to findings reported by FISCHER et al. (2009). In addition, they loosen the substrate and water infiltration is promoted. On the slope (St 4) of the artificial dune the water repellency index is

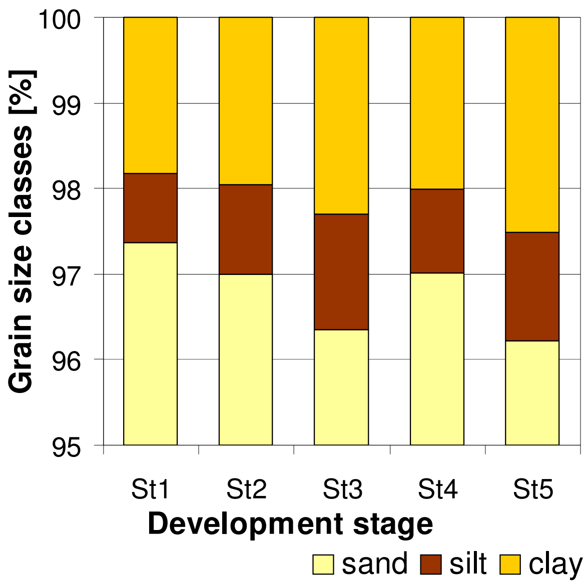

Fig. 7: Grain size classes

lower than in the foot area (St 5) of the artificial dune.

The particle size analyses were conducted separately according for crust and substrate. The BSCs contain predominantly coarse to medium sized sand particles. At St 1 (Fig. 7) the contents of silt and clay in the crust are low (2.64%) and at St 2 (3.00%) and St 3 (3.65%) the contents are increasing. More dense BSCs keep the fine particles.

On the slope the content of fine material is lower than at the foot of the artificial dune. This shows the process of displacement of fine material downward from the slope and the accumulation of this material at the foot of the dune.

Conclusion

BSCs are an important factor for the beginning of accumulation of organic matter in the first millimetres on the surface of a substrate in an initial ecosystem. The content of chlorophyll and of organic matter is rising continuously with the development stages. Filamentous cyanobacteria and green algae develop in the pore space of sandy particles and bind them together. BSCs stabilise sandy particles at the surface and reduce element transport caused by wind erosion.

With the development of the vegetation mosses keep the fine particles, rhizoids loosen the substrate and water repellency is decreasing again. By that, BSCs influence the hydrological properties of a substrate already in the initial stage of soil development and have an effect on the formation of an ecological system.

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