Conference Volume | 5th Symposium for Research in Protected Areas 10 to 12 June 2013, Mittersill | pages 571 - 575

Soil Crust InterNational (SCIN) – Understanding and valuing biological soil protection of disturbed and open land surfaces

Thomas Peer, Lingjuan Zheng, Burkhard Büdel

Abstract

The international SCIN-project aims to achieve both better appreciation of the functioning and importance of biological soil crusts (BSCs) in Europe including four different sites in Spain, Germany, Austria, and Sweden, and to transfer scientific output to local authorities and stakeholders in order to ensure a better territorial protection. The project lasts 3 years (2011 – 2014) and is integrated within the pan-European BiodivERsA – a network of national funding organisations (www.biodiversa.org/). Six research groups and over 15 scientists from the Universities of Madrid (Spain), Salzburg and Graz (Austria), Kaiserslautern and Kiel (Germany), and the Natural History Museum of Stockholm (Sweden) participate in this project. Coordinator is prof. Burkhard Büdel from the University of Kaiserslautern (buedel@rhrk.uni-kl.de). After one year, first results have been achieved from all research groups, and in this paper comparison of soil physiochemical properties and vegetation differences between the four sites are reported. The results illustrate the unique situation of the alpine Hochtor site (Hohe Tauern, Grossglockner, Austria) relative to the other climatically different sites in Spain, Germany and Sweden.

Keywords

Biological soil crusts, SCIN-project, soil properties, vegetation, Hochtor, Austria

Introduction

BSCs are the biologically modified soil surface that form naturally in open areas. They are typically composed of cyanobacteria, algae, micro fungi, lichens, and bryophytes in varying amounts and can be the only vegetation cover in arid and semi-arid regions such as hot and cold deserts or xerothermic steppe vegetation. They are also the first colonizers of disturbed soils and have major impacts on the soil properties through stabilization, erosion limitation, better water infiltration and facilitation of colonization by higher plants (Eldridge & Greene 1994; Belnap et al. 2001; Belnap & Lange 2003).

The SCIN-project will provide a much improved understanding of BSC functionality from the severest deserts to the alpine ecosystems. Functional studies will be backed by detailed biodiversity assessments that aim to reveal the key organisms in BSC functioning over a wide latitudinal, altitudinal and climatic range. Information transfer to stakeholders will be achieved through a series of consultations and reports including highly visual material supporting their work. Key questions of the project are: How is their taxonomic composition and how diverse are the BSCs itself? How is diversity and productivity linked? What is their role in the referring ecosystems as carbon and nitrogen sequestration agent, soil stabiliser, and for enhancement of soil and vegetation succession? How unique are the key species and what is their role in BSC functioning over a wide latitudinal, altitudinal and climatic range? (see the project homepage: www.soil-crust-international.org/).

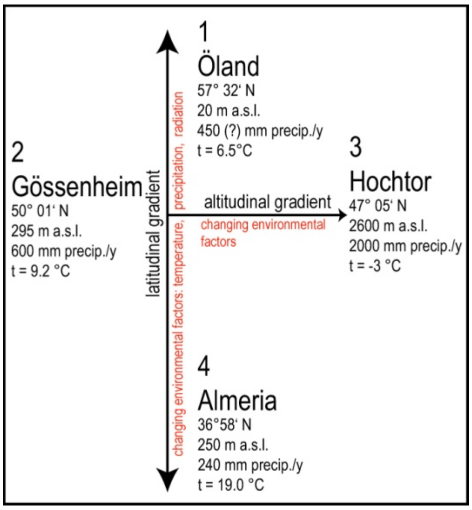

Figure 1: Coordinates, altitude, and climate of the four research sites

Material and methods

Along a latitudinal and altitudinal gradient across Europe, four sites were selected for our study (Fig. 1): i) Spain, Almeria, Tabernas basin, BSC in Mediterranean semi-arid steppe vegetation, ii) Germany, Gössenheim, nature reserve "Ruine Homburg", BSC in xerothermic steppe vegetation, iii) Austria, Hohe Tauern, Grossglockner, Hochtor, BSC in high alpine pioneer vegetation, and iv) Sweden, Island of Öland, Nature Reserve Gynge Alvar, BSC in xerothermic steppe vegetation. At each site, an area of 40 m × 40 m was defined, and equipped with a climate station to gain data about wind conditions, precipitation, air humidity, air and soil temperatures, PAR and UV-radiation, as well as the photosynthetic efficiency of some typical lichens (Moni-Da system). In these defined areas, crust types and vegetation cover were recorded in 150 randomly selected plots, using a 25 cm × 25 cm grid. At every fifth or tenth plot, 20 crust and 20 underlying soil samples were collected for analysis of soil properties. In addition, 10 control and 10 treatment plots (80 cm × 80 cm) were established for restoration experiments at each site. In treatment plots, the upper soil layer with BSC was removed. After 6, 12, 18, 24, and 30 months the speed and successional pattern of BSC recovery will be proved through species composition and alteration of relevant soil parameters.

Five work packages (WP1 to WP 5) were developed in our project. WP 1 works on identification of BSC component organisms like cyanobacteria, algae, fungi, lichens and bryophytes by means of classical and molecular methods. Primers for specific organismal groups (i.e. algae, cyanobacteria, fungi) will be used to extract DNA, and fingerprinting techniques (SSCP) will be used to assess and visualize variation among samples. To localize microorganisms in crust, light and confocal microscope technique will be applied. WP 2 looks at net carbon gain of BSCs, obtained from a model linking 3 sets of measurements: i) chlorophyll *a* fluorescence monitoring of activity at least one year data from each site (2 preferred), ii) CO_2-exchange of BSCs in the field using portable gas exchange fluorescence system (Walz GFS-3000) and Klapp-cuvette at least 14 days continuous record from each site, and iii) response of net CO_2-exchange of BSCs to environmental factors in the lab under controlled conditions. In this part, particular focus is given on lichenized fungal species and cyanobacteria, which represent key ecological indicators of soil crusts. Description of soil components (e. g. particle size distribution, pH, exchangeable nutrients, aggregate stability) and hydrological parameters (e. g. water drop penetration time test, water repellence, water infiltration) are included in WP3. Methods are described in CANTON et al. (2003), LI et al. (2005), HUBER et al. (2007), CONTRERAS et al. (2008), and PEER et al. (2010). In addition, contents of organic C, total N, $\delta^{15}N$ and $\delta\ ^{13}C$ in crust and underlying soil will be analyzed by elemental analyzer isotope ratio mass spectrometry (EA-IRMS) to provide insight into the N- and C-turnover. Moreover, the biological nitrogen fixation will also be investigated. WP4 focuses on vegetation analysis and recovery of BSCs. We differentiated between BSCs light, BSCs dark (represent successional development of BSC from a species-poor, light-coloured cyanobacterial BSC to a species-rich BSC community dominated by late successional lichens and dark cyanobacteria, BELNAP & ELDRIDGE 2003), cynolichens, chlorolichens, bryophytes, vascular plants, litter, open soil, stones and gravel. In WP5, crust lichens of the same species from all four sites are sampled to test whether they have the same photosynthetic CO_2-uptake properties, or they show a climatic-specific acclimation and have local photobiont populations. For further information see the project homepage (www.soil-crust-international.org/). A separate work package (WP 6, Delivery Package) should transform the science outputs into a form that is more easily understood by stakeholders and endusers, and most important, assure the awareness and appreciation of BSCs as an important component of the landscape.

Table 1: Chemical soil properties (n = 40) in crust and underlying soil at the four research sites. Values in the table represent mean values±SE.

	pH		P (ppm)		Mg (ppm)		K (ppm)		Ca (ppm)		Na (ppm)	
	Crust	Soil	Crust	Soil	Crust	Soil	Crust	Soil	Crust	Soil	Crust	Soil
Spain	7.0±0.02	7.4±0.01	89±8	60±2	127±4	93±3	259±8	216±5	2316±65	2005±67	13.7±2.3	9.6±2.1
Sweden	7.3±0.01	7.4±0.02	15±1	8±1	40±3	30±1	109±5	59±3	6129±281	4959±223	13.9±0.6	13.4±0.5
Germany	7.3±0.01	7.4±0.03	20±1	9±1	63±6	41±4	142±5	113±4	5623±353	4293±298	14.8±0.8	12.9±0.7
Austria	7.3±0.01	7.4±0.04	11±1	6±1	352±34	300±41	29±2	8±1	2189±188	1796±239	2.6±0.3	3.4±0.4

Preliminarily results on soil and vegetation

Although no conclusive results can be expected after one year of research, however, initial indications show that each research site has its own specifics based on differences in geography, climate, geology, soil, and land use. In contrast to the Hochtor, which is the unique site with a high alpine climate, means 8 to 9 months snow cover, low annual temperatures, and high precipitation (AUER et al. 2002), the climate of the other sites is generally dry (< 600 mm.y^{-1}) and more than 10 ^{0}C warmer on their mean annual temperatures than the Hochtor site. From the analyses of soil parameters and site comparison, the following first preliminarily results can be derived (Tab. 1 and 2): i) Plant available nutrients like Ca, Mg, K, Na, and P are generally higher in crust than in underlying soil ($p<0.05$); the Hochtor site exhibits the lowest K-, Ca- , Na- and P- amounts but the highest Mg-amount of all studied sites. ii) The pH values are generally above 7 because of the calcareous parent material at all sites - although it is of different edge and mineral composition. Crusts generally show slightly lower pH values than underlying soil. iii) The Hochtor site has the lowest amount of clay (< 3 %) in comparison to the other sites (8 – 12 %), but the highest soil penetration resistance and water storage capacity (Tab. 2). The loosest crust is found in the Alvar (Öland, Sweden). The data vary over a wide range in all study sites (high standard errors), indicating great inhomogeneity of soil at each site. Moreover, the alteration of soil parameters within the recovery plots is difficult to assess as well. After taking samples for the 2nd time, 6 months later, we couldn't find any clear indications of change in soil parameters within the treatment plots so far (data not shown); possibly the time interval of sampling was still too short.

Table 2: Soil compaction (n = 40), soil texture in crust (n=20) and water storage capacity (n=20) at the four research sites. Values in table represent mean values±SE.

	Soil compaction kg.cm^{-2}	Sand (%) in crust	Clay (%) in crust	Water storage capacity gH_2O / 100g dry weight
Spain	2.51±0.1	22.5±0.7	11.4±0.4	32.7±0.5
Sweden	1.72±0.1	55.1±1.7	8.3±0.5	39.6±1.9
Germany	3.16±0.1	20.3±0.9	10±0.6	45.6±6.9
Austria	3.84±0.1	58±1.3	2.8±0.3	48.1±5.4

Investigation of crust type, vegetation composition, and cover degree, which were done by Laura Williams and Katarina Schneider (University of Kaiserslautern), reveal that the Hochtor site has by far the highest average percentage of cyanobacteria (BSC light and BSC dark), chlorlichens and also a high proportion of vascular plants (Fig. 2). At the other sites (Gössenheim, Öland and Tabernas basin), bryophytes (mainly mosses) dominate, and Gössenheim owns the highest degree of mosses with more than 40 %.

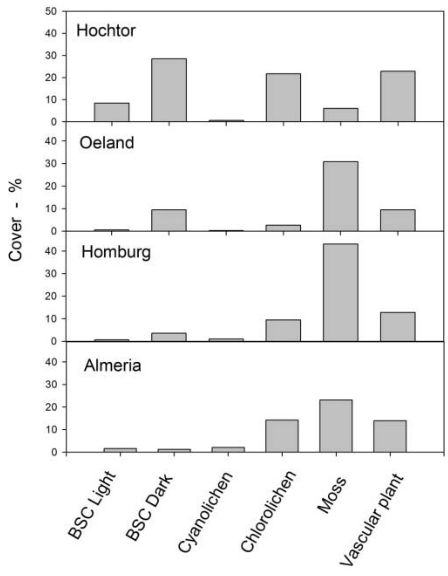

Figure 2: Mean cover degree for surveyed groups at the four research sites

Discussion

The special position of the Hochtor site was already mentioned in several papers (e. g. Huber et al. 2007; Peer et al. 2010). Our preliminary results verified it in comparison with other research sites of the SCIN-project. Soil properties like low amount of exchangeable nutrients and low clay content could be explained by low chemical weathering and leaching processes, which are typical for alpine climate with high precipitation (Bockheim & Koerner 1997; Egli et al. 2003). The high Mg amount probably originates from the dolomite within the Seidlwinkl Triassic formation. The high cover degree of dark crust and chlorolichens at the Hochtor site could be resulted from the humid climate and soil moisture through the whole year. Although this area is 8 to 9 months under snow cover, the conditions for growth of cyanobacteria and cynolichens seem to be excellent. The most common lichen species at the Hochtor site are *Toniniopsis obscura*, *Buellia elegans, Psora decipiens, Collema tenax, Catapyrenium cinereum, Fulgensia bracteata* ssp. *deformis,* and *Bilimbia lobulata* (R. Türk, personal communication). The lichens *Psora decipiens* and *Peltigera rufescens* occur at all four sites, and therefore they are important test organisms to study their symbiosis partners, as well as their physiological effectiveness and their adaptation and acclimation along latitudinal and altitudinal gradients. The humid climate at the Hochtor site promotes dark BSCs of 2-3 cm thickness, suggesting that the area has been undisturbed for a long time. Dark BSCs develop a relatively high surface compaction (indicated by soil penetration resistance). Therefore, they promote surface runoff (to see on small polygonal branched channels on the surface, filled with small stones), on the one hand, and they inhibit infiltration rate and establishment of seedlings (the latter has been controversially discussed, see Maestre et al. 2002, Belnap et al. 2003, Li et al. 2005, Langhans et al. 2009), on the other hand. Cultivation experiments with crust material from the Hochtor site will show how biological soil crusts effect germination and establishment of seedlings. However, the number of vascular plants is the highest at the Hochtor site! At the drier sites, the crust layer is considerably thinner and looser, and the cover degree of mosses is more than 20 % on average (maximum 43 % in Gössenheim). It is not yet possible to interpret this. However, we have to consider life strategy, life history, and life span of plants at each site. At Tabernas, for example, ephemeres might not have been visible at the end of February, when we were there. In Gössenheim, the vegetation was recorded at the end of September, and at this time spring time plants are already decomposed. The high proportion of mosses (mainly *Rhytidium rugosum*) may be interpreted with the high proportion of shadowing pine trees. In Öland, the vegetation period is optimal in May, but here the large limestone plains with thin or no soil limit the spread of higher plants. Also at the Hochtor site, the vegetation period was on its culmination point in July/August, but here the distribution scheme of plants is very irregular (clumped), depending on small scale site conditions. It might be that despite of the randomized survey of the vegetation, especially areas with abundant vegetation were recorded.

Conclusion

Unfortunately, it is not possible within the scope of this paper to present results of all working groups. However, the taxonomic/systematic scientists around of Martin Grube (Graz, Austria), Burkhard Büdel (Kaiserslautern, Germany), Mats Wedin (Stockholm, Sweden), and Roman Türk (Salzburg, Austria), as well as the ecophysiological scientists around of Allan Green (Madrid, Spain) and Burkhard Büdel (Kaiserslautern, Germany) have been deeply penetrated into the subject of the project. Objectives like comprehensive diversity assessment of photoautotrophs, as well as fungi and heterotrophic bacteria, net carbon gain of BSCs, N- and C-turnover, recovery experiments, infiltration coefficients and water repellence values for different crust and soil types, the level of adaptability of key species, the genetic diversity of local and continental-wide distributed species, and the uniqueness of key species at the four sites, all these studies are progressing well. 2013, data collection will be continued, and we hope to come to a comprehensive understanding of BSC functionality across Europe by the cooperation. Finally we hope that our research can also offer professional options for development of improved policies and actions in land protection.

Acknowledgments

The project is supported with around 1 Mio. € by national funding organisations. Our sincere thanks go therefore to the following institutions that supported the project financially:

- Deutsche Forschungsgemeinschaft (DFG), *Germany*
- Regierung von Unterfranken, Würzburg, *Germany*
- Fonds zur Förderung der Wissenschaftlichen Forschung (FWF), *Austria*
- Plan Nacional de I+D+i,*Spain*
- National Research Council (CSIC) - Arid Zones Research Station (EEZA), *Spain*
- Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, FORMAS, *Sweden*
- Länsstyrelsen Kalmar län, Naturvärdsenheten, *Sweden*

References

AUER, I., BÖHM, R., LEYMÜLLER, M. & W. SCHÖNER 2002. Das Klima des Sonnblicks – Klimaatlas und Klimatographie der GAW Station Sonnblick einschließlich der umgebenden Gebirgsregion. Österreichische Beträge zur Meteorologie und Geophysik 28: 408 pp. Zentralanstalt für Meteorologie und Geodynamik. Wien.

BELNAP, J. & O. L. LANGE (eds.) 2003. Biological soil crusts: structure, function, and management. Ecol. Stud. 150: 503 pp. Berlin.

BELNAP, J., ELDRIDGE, D., KALTENECKER, J. H., LEONARD, S., ROSENTRETER, R. & J. WILLIAMS 2001. Biological soil crusts: Ecology and Management.Technical Reference 1730–2. U.S. Department of the Interior. Available at: http:// www.soilcrust. org/crust.pdf (date: 03/10/06).

BELNAP, J. & D. J. ELDRIDGE 2003. Disturbance and recovery of biological soil crusts. In: BELNAP, J. & O.L. LANGE (Eds.). Biological soil crusts: structure, function, and management Ecol. Stud. 150: 363-383. Berlin.

BELNAP, J., PRASSE, R. & K. T. HARPER 2003. Influence of biological soil crusts on soil environments and vascular plants. In: BELNAP, J. & O.L. LANGE (Eds.). Biological Soil Crusts: Structure, Function, and Management. Ecol. Stud. 150: 281-300. Berlin.

BOCKHEIM, J. G. & D. KOERNER 1997. Pedogenesis in alpine ecosystems of the eastern Uinta Mountains, Utah, U.S.A. Arct. Alp. Res. 29: 164-172. Colorado.

CANTON, Y., SOLÉ-BENET, A. & R. LÁZARO 2003. Soil-geomorphology relations in gypsiferous materials of the Tabernas desert (Almeria, SE Spain). Geoderma 115:193-222. Elsevier.

CONTRERAS, S., CANTÓN, Y. & A. SOLÉ-BENET 2008. Sieving crust and macrofaunal activity control soil water repellency in semiarid environments: Evidences from SE Spain. Geoderma 145: 252-258. Elsevier.

EGLI, M., MIRABELLA, A., SARTORI, G. & P. FITZE 2003. Weathering rates as a function of climate: results from a climatesequence of the Val Genova (Trentino, Italian Alps). Geoderma 111: 99-121. Elsevier.

ELDRIDGE, D. J. & R. S. B. GREENE 1994. Microbiotic soil crusts – a review of their roles in soil and ecological processes in the rangelands of Australia. Aust. J. Soil Res. 32: 389-415. CSIRO.

HUBER, K., PEER, T., TSCHAIKNER, A., TÜRK, R. & J. P. GRUBER 2007. Characteristics and function of soil crusts in different successional stages in alpine environments, outlined on alpine lime scree in the Grossglockner region. Mitt. Österr. Bodenkdl. Ges. 74: 111-125. Wien.

LANGHANS, T. M., STORM, C. & A. SCHWABE 2009. Biological soil crusts and their microenvironment: Impact on emergence, survival and establishment of seedlings. Flora 204: 157-168. Elsevier.

LI, X-Y., GONZÁLES, A. & A. SOLÉ-BENET 2005. Laboratory methods for the estimation of infiltration rate of soil crusts in the Tabernas desert badlands. Catena 60: 255-266. Elsevier.

LI, X.R., JIA, X.H., LONG, L.Q. & S. ZERBE 2005. Effects of biological soil crusts on seed bank, germination and establishment of two annual plant species in the Tengger Desert (N China). Plant Soil 277: 375-385. Springer Netherlands.

MAESTRE, F. T., HUESCA, M., ZAADY, E., BAUTISTAA, S., & J. CORTINA 2002. Infiltration, penetration resistance and microphytic crust composition in contrasted microsites within a Mediterranean semi-arid steppe. Soil Biol. Chem. 34: 895-898. Elsevier.

PEER, T., TÜRK, R., GRUBER, J. P. & A. TSCHAIKNER 2010. Species composition and pedological characteristics of biological soil crusts in a high alpine ecosystem, Hohe Tauern, Austria. eco. mont 2: 5-12. Innsbruck.

Contact

Thomas Peer
Thomas.peer@sbg.ac.at

Dr. Lingjuan Zheng
lingjuan.zheng@sbg.ac.at

University of Salzburg
Hellbrunnerstrasse 34
5020 Salzburg
Austria

Univ. Prof. Dr. Burkhard Büdel
buedel@rhk.uni-kl.de

University of Kaiserslautern
Erwin-Schrödingerstrasse 13
67663 Kaiserslautern
Germany