Biogeosciences Discuss., 9, C8015–C8021, 2013
www.biogeosciences-discuss.net/9/C8015/2013/


Biogeosciences Discussions



# *Interactive comment on* "Microstructure and hydraulic properties of biological soil crusts on sand dunes: a comparison between arid and temperate climates" *by* T. Fischer et al.

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Received and published: 7 February 2013

Comment #1 of Reviewer #3 a. The comparison is performed on 5-6 years old crusts in Lieberose (LIE), Germany and 25-30 years old crusts in Nizzana (NIZ), Israel, i.e., between crusts that did not reach maturity (LIE) and mature crusts (NIZ).

Response to comment #1: We did not make any statements on the age of the crusts in the original version of the article. The Lieberose site is located within a still restricted area of a former military training site, which was put out of operation during the early 1990ies, and which was left untouched since then. The Lieberose site could develop over a period of ∼17 years (Dümig et al., 2013). In Nizzana, the border between Egypt



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and Israel was closed in 1982, and there was much grazing and trampling on the dunes in Nizzana before (Tsoar et al. 1995, Tsoar 2008). The crusts could develop for at least 25 years under natural conditions. Hence, we believe that it is safe to assume that all BSC stages are in long-term equilibrium with their environment at both sites, and that the comparison between the sites is justified.

We added the age information to the manuscript.

Comment #2 of Reviewer #3 b. The authors try to reach significant conclusions regarding field processes in LIE and NIZ based on a comparison of the newly established crusts in LIE and the mature crusts in NIZ. While claiming that (hypothesis A) substrate wettability was reduced in LIE, attributing it to the most likely effect of a plant species (Zygogonium ericetorum), and claim that they impede water from their competitors in LIE, they also claim that (hypothesis B) moss hinder water infiltration and hence impede water from higher plants in NIZ. These are farreaching conclusions that should be backed up by adequate data, preferentially field data. Unfortunately, this was not the case.

Response to comment #2: Crust maturity: See comment #1 Zygogonium ericetorum is a green algae that has been reported to form water-repellent mats, so surface water repellency is generated by crust organisms themselves, but not by neighbouring higher plants. We further reported that water infiltration was dominated by soil texture, and that biotic elements had less influence on hydraulic properties in Nizzana. We also discussed literature findings that the high water holding capacity of mosses may prevent infiltration, which does not contradict our hypothesis that BSCs stabilize through capture of any available moisture under arid conditions.

Comment #3 of Reviewer #3 c. The authors based their conclusions on lab measurements. Yet, at least as far as NIZ is concerned, their data was based on a total of 5 Petri dishes taken from three habitats along one catena (two replicates from two habitats with cyanobacterial crusts and only one sample from the bottom slope with a



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moss-dominated crust). It implies that hypothesis B is based on one Petri dish sample. Looking at Fig. 8 and Fig. 9, the authors present higher extra WHC for the cyanobacterial crust at the midslope (Fig. 9), implying that the cyanobacterial crust there (and not the moss-dominated crust) has the most significant effect. Furthermore, given the differences in thickness (unfortunately, this essential data was not presented) the differences in WHC as presented in Fig. 8 are not high, and cannot convince the reader that large amounts of water is held by the crust to the extent that the shrub community will be severely affected

Response to comment #3: Number of replicates (see also response to comment #8 of reviewer #1): The low amount of replicates is often criticized in hydrological studies of geomorphological units. However, in practice it is almost impossible to find two identical study objects which may serve as real replicates. In such cases the selection of two or more replicates inevitably results is criticism of comparability.

Therefore, our approach was not based on a comparison of regions, but on a comparison of BSC types along two individual dune catenas under different climatic conditions. Based on this approach, we are well aware that we cannot give a comprehensive description of spatial heterogeneity of BSC types in two climatic regions – this would be a different task. In contrast, we propose mechanisms of crust stabilization on the two catenas studied.

On the scale of BSC habitats, the sampling size of a petri dish covers a variaty of surface structures, including BSC patches, within patch crevices and a between patch mineral surface interspace, offering the opportunity to perform replicate measurements when using appropriate, small-scale methods, like electron microspcopy, micro-infiltrometry etc. We are deeply convinced that spatial heterogeneity plays a crucial role for crust ecological functioning. In a previous study we used a geostatistical approach to characterize crust patches, and we found that the variogram range in Lieborose amounted to 4 mm or less (we refer to this publication in the manuscript: Fischer et al., 2012b), which is far bolow the size of the petri dishes used. Hence, a petri-dish sized sample covers all within patch spatial heterogeneity, and when talking about BSC stabilazation, we must be aware that in fact we talk about BSC patch stabilization.

Lower water holdng capacity at dune slope in Nizzana: We added the crust thicknesses to the manuscript. The text now readls like: "Undisturbed samples of dry biological soil crusts were collected in 2 replicates by gently "coring" the surface with 10 cm diameter petri dishes and carefully padded with cotton wool to avoid rupture near the crest (crust thickness 1-2 mm), at the slope (crust thickness 2-4 mm) and at the base (crust thickness 4-6 mm) of a carbonate-free, siliceous east-facing dune (lee side, slope angle 9.2°) in May 2010 and in July 2011."

and

"Undisturbed samples of dry biological soil crusts were collected in 2 replicates (1 replicate only available for the dune base) near the crest (crust thickness ca. 1 mm), at the slope (crust thickness ca. 2 mm) and at the base (crust thickness 2-3 mm) of a carbonate-containing, siliceous north facing dune (lee side, slope angle 17.1°) in September 2009 following the same procedure as described for Lieberose."

As described above, we attribute the hydrological properties of the BSCs in Nizzana more to soil texture. We added Table 1 to the revised version of the manuscript now, where it becomes evident that the WHC follows the pattern of silt and clay contents in Nizzana. Shrubs are not located in the direct vicinity of our sampling points. We hypothesize that BSCs could develop in Nizzana due to relative high WHC of the fine-textured substrate (also meaning that the WHC of a sandy substrate like in Lieberose would be too little to support BSC development under arid cnditions). We further stress that "water supply to higher plants was limited due to alteration of physico-chemical surface properties under temperate conditions", which explicitely does not apply to the Nizzana site.

Comment #4 of Reviewer #3 d. In support of hypotheses A, the wettability or repellency



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of the crusts was monitored. Admitting that the use of the water drop penetration time (WDPT) test "was not applicable. . .because drop penetration was too rapid on all crusts" (p. 12716; l 14-16), the authors adopted another method that shows very slight and unconvincing differences between the samples. Since WDPT is examined under field conditions and since the authors try to convince the readers that crust under field conditions are water repellent, the failure to show it with WDPT calls for attention. Furthermore, no supportive evidence was provided for the proposed mechanism that "water supply to higher plants was limited" (p. 12712; l 21). Contrarily, according to Figure 6, LIE is characterized by high infiltration.

Response to comment #4: It was one of the main results that water repellency was practically absent at Nizzana. Crusts developing water repellency under arid conditions would commit "ecological suicide“, because they would lose urgently needed moisture. The "repellency index“ expresses surface energy and is applicable for conditions where contact angles are too little to support resting of water droplets on the surface. Hence, it still can be used to describe wettability, meaning that high values of the repellency index express slow wetting of the surface.

Infiltration undergoes changes over time, and values are low at the onset of wetting due to inhibited wettebility. Once wetted, infiltration increases, but drops subsequently due to swelling of EPS. In the manuscript we state that "...the decrease of surface polarity along the catena was also reflected by impaired initial infiltration rates at the dune slope (t-test, p=0.08) and base in Lieberose (t-test, p=0.03), where maximum values were reached 10 minutes after the onset of rewetting (Figure 6).”

and

“Decreasing infiltration along the catena at Nizzana may possibly be determined by both biotic elements and by accumulated fine material. However, decreasing infiltration 10 minutes after rewetting at the dune slope and base in Lieberose and at the dune slope in Nizzana, as well as immediately after rewetting at the dune base in Nizzana, point to clogging of matrix pores by swelling of microbial mucilage, thereby possibly promoting surface run-off at the dune slopes (Verrecchia et al., 1995, Yair, 2001) and reducing infiltration losses at the dune bases (Figure 6)."

This mechanism is more pronounced in Lieberose, because the hydrological properties are influenced mainly by biogenic components in Lieberose. The maximum infiltration is determined by the sandy substrate in Lieberose, which is in full agreemant with our finding that infiltration is lower in Nizzana due to finer soil texture.

We rewrote the manuscript to "... water supply to higher plants may be limited....“

Comment #5 of Reviewer #3 e. No reference was made to the repellent crusts reported from the Dutch coast (Jungerius, Pluis) and to field measurements published by Kidron and co-authors regarding rain-runoff-erosion relationship in NIZ, despite the relevance of these papers to the data/hypotheses presented. Thus for instance, when referring to water repellency in LIE or to erosional processes in NIZ, the relevant publications should also be cited.

Response to comment #5: Pluis (1994) also found that dry Zygogonium crusts were water repellent. We added this reference to the manuscript. Witter et al. (1991) reported that "a major effect on runoff . . . is exerted by water repellency of soils, which results in impeded infiltration of dune soils when dry.“ We added this reference to our discussion section. Having in total 6 citations of Kidron and Yair in our reference list, we believe that we cite all the relevant literature on runoff-generation in Nizzana.

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Interactive comment on Biogeosciences Discuss., 9, 12711, 2012.