Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2017-139-RC2, 2017

Biogeosciences Discussions
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EGU

Interactive comment on "Development of bacterial communities in biological soil crusts along a revegetation chronosequence in the Tengger Desert, northwest China" *by* Lichao Liu et al.

Anonymous Referee #2

Received and published: 11 June 2017

This manuscript presents the "Development of bacterial communities in biological soil crusts along a revegetation chronosequence in the Tengger Desert, northwest China". The major findings show that over 60 years, bacterial richness and abundance reached their peak after 15 years of BSC establishment. The results suggested that changes in the bacterial community structure may be an important indicator of the biogeochemical nutrient storage in early successional stages. Overall, I found the information about the bacterial component of BSC presented in the context of succession very interesting and the results in this paper to be sound and well presented. There are very few reports on the bacterial composition of BSC yet their function is equally important to the bigger organisms such as lichens, mosses and cyanobacteria. I commend the authors

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for their work and presenting complex data derived from sequencing in a clear manner. There are some suggestions I would recommend to improve the manuscript and to add to depth. General comments Introduction The introduction needs strengthening in terms of explaining the roles of BSC in succession both on the landscape scale and on the micro-scale. Some BSC remain in an early successional state due to the harsh environments that they occupy. This needs to be expanded on. The first paragraph of the introduction was a little repetitive (i.e. saying the same thing twice in a slightly different way) and needs tightening. The last two sentences mention succession in a general sense but then leaps into the role of bacteria in BSC (second paragraph). There have been some very good studies on succession in BSC. If these were brought into the introduction at this point it could help to define the terms of the research more clearly. These studies could highlight the gaps in understanding the role of bacteria in BSC. There are also some relevant points in the first paragraph of the discussion that could be better placed here (see comments in Discussion section). On rereading the paper some points mentioned below are scattered throughout however they need to be brought together to provide a clearer insight into the importance of BSC bacteria and microprocesses in succession. For example: Bowker (2007) examines the role of BSC in primary succession (vs secondary succession) where their role may exist during a time when resources are made available (e.g. light) however they fade into the background once higher vegetation takes over. On the other hand, in some environments of high abiotic stress (e.g. deserts) BSC play a role in succession yet exist as a permanent component. Bowker's review and discussion is supported by work carried out in southern Africa (Büdel et al. 2009) where different successional BSC are described. How do the Tengger Desert BSC differ from the southern African crusts in terms of successional stage? This can be further examined in the discussion of the results in relation to BSC succession and the bacterial component. Büdel et al. (2009) also describes in detail crust types that were representative of successional stages. Do these compare well with your study? This can be further elaborated in the discussion of your results. In Germany, Langhans et al 2009 studies succession at a shorter time scale

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with some interesting results. Castillo-Monroy et al (2011) showed few BSC effects on ecosystem function could be ascribed to bacteria. Other literature of interest could include Baran et al (2015) that describes resource partitioning where BSC primary producers (e.g. cyanobacteria) produce an array of metabolites that influence bacterial composition. The hypothesis states that: '. . .bacteria are the key species in C accumulation and soil improvement in the early stages of BSC succession'. In the preceding paragraph N-fixation by heterotrophic bacteria is mentioned yet until the hypothesis C is not discussed. There is no mention of the role of cyanobacteria, cyano-lichens and bacteria and their various roles in C and N fixation or micro-processes (e.g. their role in producing metabolites that are resources for bacteria). These are needed to place this study in the full context of BSC succession and establishment. The key questions may be further developed around: Do bacteria follow the same successional patterns as described in other BSC research? What are the drivers of bacterial composition over time? What are the micro-processes that drive bacterial composition and function? Do bacteria drive changes to soil physicochemical properties or alternatively do the larger BSC organisms drive these changes which in turn has a direct influence on bacterial composition and function? Materials and Methods This section is relatively clear aside from some minor corrections (below). What was the depth of the samples extracted? Line 89 needs further explanation of what 'plantation in floating sand' means. Section 2.2 repeats some descriptions that are also in Figure 1C. This section may be more clearly presented as a table? Results A minor concern with the results is that there is no follow-up description of the key species of the BSC. Section 3.4 touches on the two main groups where the first group is mainly physical and cyanobacterial crusts and the second group is more diverse with algae, lichens and mosses. It would be interesting to have some basic information concerning these organisms in terms of diversity and function so bacterial communities are viewed in that context. This also appears important in terms of succession (also see Büdel, Langhans and Castillo-Monroy papers mentioned and others). You infer that BSC development is associated with bacterial diversity however these results do not identify which crust organisms are drivers of soil

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physicochemical properties. The phototrophic organisms of BSC are key C fixers and many also N-fixers. Even though the focus is bacteria the stratification of the processes down the profile is an important part of understanding the role of bacteria and drivers of their diversity. The conclusion that soil physicochemical factors are the driving influence in bacterial diversity and function needs to be qualified especially as the data was used from a much earlier study. With the key changes occurring over the first 15 years it would have been more robust to have run tests. Please be sure that each time algae or algal crusts are mentioned that they are algae and not cyanobacteria as sometimes these terms are interchanged accidently. As with cyanobacteria, lichens and mosses, it would also be good to understand where algae stand in terms of BSC succession in the Tengger Desert. Discussion The first paragraph of the discussion is part introduction material and part discussion that could be better incorporated into discussing with the results. In line 266 algal crusts are referred to – were there algae at the site too? It would be good to be able to refer to some names of the various organisms where applicable. Which lichens and moss appear? Were the lichens N-fixers (cyano-lichens or chloro-lichens). Further down you mention the importance of microbial biomass in terms of succession and their role in conversion rates of organic matter. This information really needs to be in the introduction then discussed in more depth in the results illustrating how your results support this and compares to other studies. I would like to see section 4.1 separated into two paragraphs where the discussion changes between bacteria and cyanobacteria as they differ in their key points (and perhaps other sections looked at too). Here, the knowledge that cyanobacterial crusts are often the permanent state in high stress environments could explain the results (Bowker 2007). The last sentence supports this argument in that these species are well-adapted to drought conditions. Section 4.3 needs depth with a slightly broader discussion where other literature on this topic is referred to in more detail especially in the first part. It is important to clarify how bacteria fit in the BSC picture and why the authors can state that these bacteria are the most likely major contributing microbes in soil physicochemical properties. When describing the recovery phase one would expect the overall diver-

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sity of BSC is a crucial factor as well as the influence of the revegetation (secondary succession) that would also provide stability. This is finally mentioned in the last sentence which is too long and loses its impact. Ultimately, it would be good to understand more of the factors that influenced the composition and function after 15 years. Had the vegetation matured? Were abiotic factors (climate) an influence? Had the BSC community composition reached its peak and just ebbed and flowed from this point according to resource availability? These are just some questions that are brought to mind, some of which may have answers and others that need further research in the future. Conclusion The conclusion needs rewriting to summarise the strengths of this manuscript. There are several very interesting results that could be neatly wrapped up including separating out the importance between BSC succession and vegetation succession. On a landscape scale and in high stress environments the role of diversity hot spots of BSC microbes is crucial to establishing stability, regulating moisture and nutrient cycling. Additionally, bacteria are the conduits between the larger BSC organisms and plants facilitating micro-processes. These types of statements will support your final statement that the significant biomass points to bacteria as key contributors to the BSC primary succession process and no doubt in terms of secondary succession as well. I would prefer to see the support of your hypothesis and statements of key findings summarised (as per last paragraph in introduction) in the first paragraph of the discussion. Minor corrections Abstract Line 19 compositional Line 25 bacterial Line 29 Changes. . ..structure Introduction Line 35 BSC or BSCs? Many authors now drop the 's' for Biological Soil Crusts acronym to read BSC even for plural. This sentence needs recasting and perhaps split into two sentences: BSC composition and function. Line 40 missing word – '..landscape xxxx' Line 43 They provide ecological services. . . Line 45 BSC generally exhibit primary successional stages. . .. Line 49 define more clearly 'most abundant' Materials and Methods Line 79/80 natural. . .with a vegetation cover of less than 1%. Line 85 burial. . .dust hazards. . .. Delete 'Also. . .' start sentence with 'The. . ..' Line 87 change to 'fixed sand..' Line 89 delete 's' off literature Line 91 'The BSC could. . ..' Line 94 add (MS) after sand for first mention of

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abbreviation Line 99 ‘In each revegetation site. . .’ add depth of cores Results Line 226 remove space between 31 and % Line 232 delete ‘this’ Line 245 changed composed to comprised Line 250 change testified to verified Discussion Line 305 ‘. . .that display good adaptation to drought conditions together with important roles. . .’ Line 309 More recent information. . .. Line 344 ‘properties were. . .’

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