

# ***Interactive comment on* “Disturbances of Biological Soil Crust by fossorial birds increase plant diversity in a Peruvian desert” by María Cristina Rengifo and Cesar Arana**

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We thank gratefully the comments given, which we found constructive and improved tremendously the quality of this manuscript. We agree with most of the comments. We have revised the manuscript in the light of the comments. Below the separated specific comments we indicate our responses and we attached a new version of the manuscript in the supplement.

Comments by S. Chamizo

This manuscript analyses the effect of biopedturbations on soil properties and plant

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abundance and diversity compared to BSCs, which is a very uncommon topic in the scientific literature regarding BSC and which makes the content of the manuscript interesting and novel. However, I have some concerns about the design of the experiment and discussion of the results obtained, especially regarding the effect of BSC on plant diversity and abundance.

I have three main points to highlight: First, different plots have been set up and samples have been collected from different places for soil moisture, chemical properties and seedling analyses, so it makes difficult to establish direct relationships between soil properties and abundance and diversity of plants in BSCs and biopedturbations. Nevertheless, if results about soil properties and seed bank and seedlings are presented, authors should make an effort to discuss these results in an integrated way, trying to link, to some extent, the effects on soil moisture and chemical properties in BSCs and biopedturbations with the results obtained regarding plant abundance and diversity. As written now, the Discussion looks like different paragraphs addressing independent results and without linking one result with others.

RE: We agree and improved the Discussion to create a better linked between the results.

Second, for the chemical properties, seed bank and seedling emergence experiments (it is not clear to me if also for the soil moisture), it has been compared BSC and the removed soil by biopedturbation (which is on top of a BSC), but not undisturbed soil devoid of BSC (or bare soil). This is important to really understand the effect of BSC on soil properties and plant establishment, as compared to bare soils.

RE: We agree, but it was not possible to compare BSC to actual bare soil, because in the study area the biological soil crust has a total cover of the soil surface. Which greatly differs from other parts of the world where biocrust grows in the interspaces. We add a better description of the area to explain this issue.

Third, it is said that BSCs have a negative effect on plants, but this conclusion is not

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clear to me from the experiments conducted and the results obtained as, on one hand, there is no comparison of the BSC with bare soil to clearly understand the effect of the BSC and, on the other hand, the disturbed soil (by biopedturbation) lies on the BSC and thus, the BSC might have indirect effects on seedling emergence by contributing with longer moisture retention and higher nutrient release to the mound of sand. The authors should discuss these points adequately in the manuscript.

RE: We briefly increase the discussion on this issue and remarked that we are basing many of our assumptions in literature only, since no further studies had been done in biocrust in this ecosystem.

As a general comment, the language of the manuscript should be thoroughly revised by an English native speaker.

RE: Done

More detailed comments are: Page 4, MM. Were samples for soil moisture, chemical properties and seedlings determination taken in areas next to each other? RE: We add the extension of the sampled area. All measurements and sampling were done in the 1.4 square km. Nevertheless, because we target biopedturbations in the area the sampling depends on the distribution of the biopedturbations, and because of that we used paired sampling in each section of the methods.

Also, indicate the period in which soil sampling was done (dry or wet season). Page 4, P10: What does “experimental plot” (after “the bare soil plot”) mean? Please, explain the meaning of “active” and “inactive” biopedturbations.

RE: Done. We add the definition of active and inactive biopedturbations both in the Introduction and in the third paragraph of the 2.1 Method section.

Page 4, P15. It is said that soil moisture was measured at three times, but what do days 0, 5 and 60 represent? If they are three independent measurements at three different times, it should be represented as time 1, time 2 and time 3 (or by the date) but not as

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a cumulative time since an initial time. In addition, the sentence “At day 0 the bare soil plot was sample with the undisturbed BSC layer, and immediately after the collection of the sample the BSC was removed” is not understandable. Was the bare soil plot soil devoid of BSC or soil with BSC in which the crust was removed? In the latter case, it is not measured soil moisture content in bare soil but in the soil underneath the crust. The soil below the BSC usually has better properties (higher EPS, N, aggregation: : :) than the bare soil and thus, soil moisture is likely higher in the soil beneath the crust than in adjacent soils devoid of BSC. If the BSC was removed from the soil and water content was measured in the underlying soil in day 0, what was measured after 5 and 60 days? Soil moisture in the scalped soil? Both measurements are not comparable because in day 0 the presence of the BSC conditions soil moisture in the underlying soil, while in the resting days, soil water content is measured in soil lacking the BSC. I think authors should show soil moisture data only for the days in which similar surface types are compared, and in the case of the bare soil, let clear that it consists of scalped soil where the top BSC was removed (which is not the same than bare soil).

RE: We addressed all of this points and (1) Reanalyzed the data and only consider the data set on the last moment in time, where all the surfaces were comparable, and (2) we changed the term ‘bare soil’ to ‘scalped soil’ because it fits the actual nature of the surface, as suggested.

Regarding the method, if moisture content is determined by weight, it is gravimetric water content (g H<sub>2</sub>O/kg soil), not volumetric water content.

RE: We apologize for the mistake made. We correct this to show the gravimetric water content in percentage, and we add the formula in the Methods.

Page 4, P20. Which soil depth was sampled for the analysis of chemical properties? Besides, the method used for the determination of each soil property should be explained. We add the depth of the soil sample for the chemical properties analysis. We specify that “. The routine soil analysis included the available phosphorus (P), ex-

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changeable potassium (K), calcium carbonate (CaCO<sub>3</sub>), soil organic matter (O.M.), pH and electrical conductivity (E.C.)”.

RE: We didn't find necessary to explain the method used for each chemical property, but we could add it briefly if it is need for a better construction of the article.

Page 4, P25. Please, homogenize the terminology for biopedturbation samples as different terms are used along the text (“biopedturbation plot”, “removed soil from the loose soil of the entrance of the burrows”, “disturbed soil”).

RE: Done

Page 5. It should be included a section of “data treatment” or “statistical analyses” to explain how statistical differences were analysed and also to explain the indices of plant abundance or diversity used. Done

Page 5. In general, description of the results is very poor and should be greatly improved. Authors should describe more in detail differences in the properties analysed between BSC and biopedturbations.

RE: We improved the Result section

Page 5, P5. Please, describe first differences in soil moisture among times (also explains what the different times represent), and then, differences among “bare soil” (see my comment above), BSC and types of biopedturbations. We eliminate the measurements of the first to moments in time. And in the results we first compare active biopedturbations with the 2 treatments and then did the same for the inactive biopedturbations  
Page 5, P10. Results of chemical properties should be better described by comparing the BSC with the underlying soil and both with the disturbed soil for all soil properties. For instance, it could be shown average values of the different properties in BSCs compared to disturbed soil,

RE: We improved the results of chemical properties and add some values.

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Pages 5-6. The Discussion should be substantially improved. Authors should make an effort to connect the different results obtained and, for instance, try to link the results of seed bank and seedlings with the results of soil moisture, organic matter and nutrients in BSC and biopedturbations.

RE: We separated the Discussion in sections, linked them, and extend the final paragraph to summarize and linked our conclusions

The manuscript should be also improved by comparing with other published studies that analyse the effect of biopertudbations on seedlings and by adequately explaining and discussing the positive and negative effects of BSC on seedling and plant establishment, and relating these effects with their effects on soil properties. I also recommend using more recent references in the Discussion as some of them are old and there is a large budget of articles recently published about the influence of BSC on soil properties (water content, nutrients).

RE: Done, we add literature about the effects of BSC on vegetation.

Page 6, P5-10. In this paragraph it is said that in the biopedturbation, the mound of sand is on top of the BSC. If the BSC acts as a seal on the soil surface limiting water infiltration into deeper soil, it could have a positive effect retaining moisture at the surface and keeping moisture longer in the sand above it, indirectly favouring seedling in the mound of sand. Page 6. Soil moisture, chemical properties and seedlings in biopedturbations and BSC are discussed separately, and no relationships and interactions between these properties have been discussed. For instance, higher organic matter and nutrients in BSC could be the reason for higher plant abundance. In contrast, lower moisture could be the reason for lower diversity, as only certain species better adapted to drier conditions could be competitive for growing in soils covered by BSCs, while others with more water requirements would grow better in biopedturbation-disturbed soils.

RE: We made a better linked between the parts of the study. It's hard to address the

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last point in the discussion because all 13 species are native and well adapted to the environment

Page 6, P25-40- An important point to discuss is the different results found in the seedling greenhouse experiment and the field experiment. Such differences could be related to differences in water availability between both experiments that could strongly condition species diversity and abundance in the BSC under greenhouse and field conditions. In the greenhouse, samples were irrigated frequently and in this case, higher abundance of the seed bank was found in the BSC compared to biopedturbations, while in the field, with limited water availability, opposite results were found. Water, thus, appears to be a major driver for seedling abundance. This should be discussed in the Discussion.

RE: Done. We expand the discussion.

Page 6, P30-35. Together with moisture availability, I really think that the reduction in seedling emergence in BSC is greatly associated to a physical impediment: the seal created by the crust impedes seed penetration and leaves the seed more exposed (and less protected) to hostile environmental factors, at the same time that facilitates seed removal by wind. Page 7, P5-10. This paragraph is confusing and mix different ideas about BSC and plant interactions. The authors should explain along the Discussion the contrasting effects of BSC on vegetation, and why they can have positive and negative effects on vegetation. The sentence “At the same time, vegetation provides a positive effect to the BSC (Bowker, 2007), and because photosynthetic organisms compete to each other for resources, a negative effect is also expected” is not understandable and contradictory as it suggests a simultaneous positive and negative effect of vegetation on BSC. I do not think plants and BSC compete for water and nutrient resources, but that BSCs grow in the areas where water and nutrients are not available enough to allow plant establishment.

RE: We improved the discussion. We eliminate the statement that ‘photosynthetic

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organisms compete to each other for resources’

The sentence “and at a landscape scale the presence of ecosystem engineer would result in an increase of the species richness, along with the Competitive exclusion principle of Gause (Palmer, 1994) coexistence is allowed, and as a result vegetation increases its abundance and richness in an indirect way.” is very abstract and not understandable in this context. Please, either rewrite it or delete this sentence.

RE: Done, we delete the sentence.

Page 7, P20. What do the authors mean by “relationships of a high order interaction”? It is not clear that BSCs have a negative effect on the plant community and that “biope-  
durbations attenuate the negative effect of BSC to the plant community”. Likely, BSCs could have an indirect effect on the disturbed soil by maintaining soil moisture longer and by contributing nutrients to the mound of sands.

RE: We deleted the sentences involving the high order interaction, since our findings are not strong enough to support it.

In addition, it has not been analysed seedling abundance and diversity in BSCs compared to bare soil.

RE: This was not possible in our study area, because areas without biocrust are very distant. We add a better description of the study area to remarked the full cover of biocrust in the landscape

Some editing comments: Is the term “biopedturbation” more commonly used than “bio-  
turbation”? The second one is more familiar to me.

RE: We used the term biopedturbation as a more specific term for the disturbances of animals to soil.

Page 5, P15. “: where the BSC samples had a higher abundance of germinated seeds than active and inactive biopedturbations.” Figure 2. Include the units for soil moisture

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in axis Y. In addition, units in the legend seem to be wrong (gH<sub>2</sub>O/kg soil, not RE: Our soil moisture data is in percentage as shows in the formula used.

Maria Cristina Rengifo

Please also note the supplement to this comment:

<https://www.biogeosciences-discuss.net/bg-2017-376/bg-2017-376-AC3-supplement.pdf>

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Interactive comment on Biogeosciences Discuss., <https://doi.org/10.5194/bg-2017-376>, 2017.

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