Associate Editor: Miriam Muñoz-Rojas

Associate Editor: The reviewers are generally positive about the manuscript by Brancalion et al. but also raised some issues that need to be addressed before being considered before publication. I recommend clarifying some points about the experimental design. Also, I recommend the authors revise the sentence 'To the best of our knowledge, this is the first study to conduct such a comprehensive assessment of soil restoration in mining sites'. There have been several comprehensive studies addressing soil restoration in post-mine sites.

Authors: Thank you for the opportunity to prepare a revision, we made our best to clarify the points raised by reviewers. We deleted the aforementioned sentence, as we agree that it is not precise and oversells our study.

Associate Editor: Also, as noted by Reviewer 1, the MS does not present a detailed view of how to perform soil health monitoring (within the context of the UN SDGs) and maybe this is something that could be added to the discussion.

Authors: We agree, and added a specific sentence at the end of the discussion to address this point.

Associate Editor: The title could be more specific highlighting main findings.

Authors: We revised the title and added more details to it, as follows: "Multifunctional soil recovery during the restoration of Brazil's Atlantic Forest after bauxite mining".

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Reviewer 1

Reviewer 1: The MS JAPPL-2021-00156 "Soil recovery by tropical forest restoration after bauxite mining" presents information on a set of soil attributes that are of great importance in assessing the restoration process in mining areas. The authors particularize, the recovery of wooded areas after the exploitation by bauxite. The MS evaluates parameters that have traditionally been studied in this class of reports (e.g. physical and chemical soil fertility parameters, soil respiration); however, they introduce the modality of a more comprehensive study in terms of bacterial communities through PCR tests, which have been less studied in this type of trial. The MS advocates a more holistic assessment of forest recovery trials affected by mining activity within the UN Decade on Ecosystem Restauration program, however the MS does not present a more detailed view of how to perform soil health monitoring. Therefore, assertions such as: "To the best of our knowledge, this is the first study to conduct such a comprehensive assessment of soil restoration in mining sites" should be reviewed.

Authors: Thank you for the positive assessment and invaluable contributions to improve our study, we implemented all of your suggestions. We deleted the sentence "To the best of our knowledge…", as we

agree that it is not precise and oversells our study. We have also added a new sentence, right before the last sentence of the Discussion section (Ln 417-422), to better describe our vision on how soil health should be ideally assessed in restoration contexts: “In this context, soil health evaluation should be based on a multifunctional perspective, in which traditional attributes evaluated in soil assessments are complemented by soil biodiversity analysis in a comprehensive and integrated way, considering soils as a living and complex component of ecosystems that governs multiple ecological processes of critical importance for restoration success and ecosystem services provisioning.”

Minor comments

Reviewer 1: Soil collection. Since three different land use types were studied, and within them, six sites were chosen. It is not clear the final number of subsamples in each area!

Authors: We complemented the sentence describing soil sampling to clarify this issue (Ln 148-151), as follows:

“In each of the 18 sites (six per land use), 15 soil sub-samples were collected from randomly distributed points at four depths (0-5, 5-10, 10-20, and 20-40 cm; totaling 60 sub-samples per site), and mixed to form a composite sample for each depth class to integrate spatial variability.”

Reviewer 1: Line 309. The results concerning macro and micropores are not very conclusive. Microporosity was lower in restored areas (Fig. 1D), however soil density improved a little, in this area, compared with disturbed sites.

Authors: We fully agree with your comment. We have now added a new sentence in the Results section (Ln 245-248) and rewrote a whole paragraph in the Discussion (Ln 319-326) to clarify that restoration did not improve soil density and micropores, and that soil scarification was not enough to improve soil porosity and density. Thank you again for highlighting it.

Reviewer 1: Lines 326-328. This assertion “Within a few years, restoration interventions allowed for a successful recovery of soil microbial diversity, density, and activity, reaching similar levels to those observed in conserved forests” is much speculative, must be rewritten.

Authors: We rewrote this sentence to soften our argument on restoration success, thus expressly informing what was shown in figure 3 (Ln 337-339): “Within a few years, restoration interventions improved soil microbial diversity, density, and activity, reaching similar levels as those found in conserved forests.”

Reviewer 1: Lines 336-338. Please, revise the paragraph. It does not seem that Lima-Perim et al. (2016) worked with limestone mines in Spain!

Authors: Sorry for the confusion, you are right. We have excluded this sentence.

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Reviewer 2

Reviewer 2: This was a very well-written and easy to follow manuscript. A pleasure to read. Below are my comments, with some of the recommended changes being minor, and some involving major reassessment. However, I am still recommending "Acceptance After Minor Revision". That said, I really think the recommendations on the statistics and the deeper level taxonomic analyses need to be done.
Authors: We thank the reviewer for this positive comment. As suggested, we analyzed the data at a lower taxonomic level and we have responded to the comments on the data analyzes below.

Reviewer 2: Lines 134-150—How far apart were the different replicates of each habitat type? What size were the sample plots and how far apart were they?
Authors: We included a new supplementary figure (Figure S1) with the location of the study areas in a georeferenced map. We hope it is enough to address your comment.

Reviewer 2: Lines 141-143—I think a Supplementary list of the different tree species used and their size at planting would be very useful and of great interest to those interested in restoration strategies.
Authors: We included a new supplementary table (Table S2) with the tree species sampled in restored areas.

Reviewer 2: Lines 153-157—Can the authors provide more information on soil sampling? In particular, were samples randomly collected, systematically collected, how far apart was each sample, was sterile technique used between samples and what type of sterile technique was used? Also, 2 mm sieving is very small, as 5 mm is more common. Is 2 mm a typo or is that accurate? Just curious.
Authors: We rewrote a sentence to better describing soil sampling (Ln 148-151). Soil samples were randomly distributed across the whole study areas, covering an area of ~2 ha (0.8 - 5.3 ha). We did not sterilize samples because they were also used for microbiological analysis, and did use a 2 mm sieve, which is the standard method used in soil analyses laboratories in Brazil (and may not have influenced the results).

Reviewer 2: Lines 225-226—I think the authors are saying here that you used ANOVA on the richness, diversity, etc., which is OK, but can they clarify here? Also, as these data were derived from the non-parametric, multivariate DNA NGS results, a more appropriate test would be using something like the Kruskal-Wallis non-parametric ANOVA, followed by the pairwise Mann-Whitney test. Also, using ANOVA on the differences in OTUs goes against the requirements of ANOVA, as the OTUs are not normally distributed, parametric data. These data should be analyzed by your PERMANOVA tests, or at minimum the nonparametric KW and MW tests.

Authors: Normality of all variables was checked using the Shapiro-Wilk test and if necessary, data was transformed prior to ANOVA analyses. We have specified in the material and methods section that this data validity test was done before variance analysis for a greater clarity (Ln 219). With regards to the statistical test used for the analysis of the NGS data presented in the NMDS, we agree with the reviewer and a PERMANOVA analysis was performed as indicated in the figure 3E and in the material and methods section (Ln 226-229).

Reviewer 2: Lines 231-232—It is unfortunate that the analyses were only done at the phyla level, especially as the authors presumably already have more detailed taxonomic data. Analyses at the phyla level does not really provide sufficient granularity to identify critical findings concerning changes in any of the functional activities occurring across the disturbance/recovery gradient. For example, there are many groups of Proteobacteria that are involved in amo activity, and many groups of different phyla that are involved in N-fixing activity by free-living soil bacteria. Also, all members of the Nitrospirae are amo bacteria, so they really should have been included. These types of deeper analyses would allow for much more detailed and robust discussions of how the different practices are influencing the N cycle.
Authors: The NMDS was presented at the phyla level because the bacterial communities found in the mined area are so different from the other two sites that the analysis of the data at the OTU level did not allow a satisfactory graphic resolution. However, a similar separation of the different sites as well as similar PERMANOVA results were obtained at all taxonomic levels. For a more detailed analysis, as suggested by the reviewer, we analyzed our data at a lower taxonomic level. As several variables did not pass the normality test and/or were represented by values equal to zero, a Kruskal Wallis test (non parametric test) followed by a pairwise comparison was used. The material and method section has been modified accordingly (Ln 226-229) as well as the results (Ln 277-289) and discussions sections (Ln 362-371). With regards to the Nitrospirae phyla mentioned by the reviewer, it was very poorly represented in our data (included in the category "Other" in Figure 3F) with no significant difference between treatments which explains why we did not mention it.

Reviewer 2: In addition, there are many groups bacteria within these phyla that are important complex organic C (i.e., poly aromatics, complex carbohydrates, hemicelluloses, chitin, etc.) decomposers and lignin degraders. As well, changes in different subgroups/genera of Acidobacteria have been associated with different soils undergoing restoration, or grasslands vs forests, etc. in the Amazon. So, information on how these C cycle-associated groups change, especially along with the changes in organic C and respiration would provide much more valuable information concerning how this restoration practice vs mining are influencing this aspect of the soil ecosystems. I strongly encourage the authors to conduct a more detailed examination of the different microbial groups at the lower taxa levels, and examine it with respect to the soil physicochemical findings.

Authors: As previously mentioned, our data was also analyzed at a lower taxonomic level, and correlations between microbial groups of interest and physicochemical parameters were assessed. Results were presented as a table in the supplementary data (Tables S5 and S6). The results and discussion sections have been completed to present new information (Ln 277-284 and Ln 347-351).

Reviewer 2: Lines 286-287—Seems as if there are some words missing here. Please clarify.
Authors: We have rephrased the sentence.

Reviewer 2: Lines 287-289—I disagree with this broad-sweeping statement. There are many articles that discuss how soils begin recovery of the C and N cycle activities almost immediately after such extreme climate events for the rapid recovery of both N and C in tropical soils of damaged habitats (i.e., deforestation, agriculture, logging roads, etc.) using both natural recovery and plantings. These should be discussed and compared to the mining situation.
Authors: We agree with your comment and deleted this sentence. We have also expanded the discussion on this topic to address your comment (Ln 349-371).

Reviewer 2: Lines 289-290—Missing words?
Authors: We have rephrased the sentence.

Reviewer 2: Lines 301-305—make this into 2 separate sentences.
Authors: We have separated in 2 sentences as suggested.

Reviewer 2: Line 305—not sure what "partly conducted at the same sites" means. Please clarify.
Authors: We have rephrased the sentence.

Reviewer 2: Line 309—Shouldn't this say "damaged forest sites undergoing recovery"?
Authors: We have rephrased the sentence.

Reviewer 2: Line 341—Acidobacteria are also involved in decomposition of complex organic C and lignin, and also are important producers of NH4+--and, as stated above, different groups/genera in this phyla have been associated with habitats indifferent stages of damage and recovery in the Amazon.
Authors: We have completed with more information on the potential role of members of the phyla Acidobacteria (Ln 347-357).

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Reviewer 3

Reviewer 3: The restoration of mined land is a hot topic and an urgent filed for global ecological restoration. This is an interesting investigation. The presentation of this manuscript is very clear and logical. I was surprised by the satisfied restoration outcome in the study area at southeastern Brazil. I have the following 4 comments.

Authors: Thank you for the valuable comments and positive feedback on our study, we agree that it is a hot topic and expect we can make a valuable contribution to it. Your suggestions greatly improved the manuscript.

Reviewer 3: 1) The author can provide a group of photograph to show the mind sites, restored forest, and conserved forest. In addition, the location of study area should also be shown in a figure.

Authors: We included a photograph representing a mined site, restored forest, and conserved forest in Figure 1.

Reviewer 3: 2) This manuscript report that restoration allowed recovering crucial physical, chemical, and microbiological soil parameters down to 40 cm depth. From my experience in North China (semi-arid mining area) the depth of recovery only is limited in 0~10cm. I think the satisfied restoration outcome mostly could be attributed to the ~15 cm topsoil and initial fertilization.

Therefore, I think the author should focus on making comparison between 0~15cm and 15 cm- 40cm, so as to illustrate the role of ecological recovery process. In addition, the reason why the 15-40cm can gain a so satisfied recovery should also be discussed. In a short word, the author should discuss the recovery process, instead of only focuses on the description of data.

Authors: We agree that we overlooked the influence of more superficial soil processes in restoration processes and should focus on it in the discussion. Your insightful comment made us also realize that most of the positive results described in our study can be a simple and direct legacy effect of topsoil. We then added a new sentence to the Discussion to better explore these issues, as follows:

(Ln 376-386) “The most crucial soil improvement promoted by restoration in comparison to mined substrates, i.e. the increase in organic matter content at 0-10 cm depth and in phosphorous concentration at 0-5 cm depth, and the recovery of the activity, richness, diversity, and composition of soil bacterial communities, were found in the topsoil (Heneghan et al. 2008). Since a ~15 cm layer of forest topsoil was spread over mined substrates and the most positive results were found at 0-10 cm depth, we highlight that our findings may simply express a legacy effect of forest topsoil on restoration processes, and that the recovery of soil attributes from 10 cm depth downwards may take much longer or may never be achieved within the timeframe of restoration projects. Therefore, successfully restoring mined

areas relies on the availability of topsoil, as the aforementioned benefits could hardly be obtained with regular soil fertilization."

We further added a new sentence to highlight the fragility of relying on forest topsoil to restore mined areas:
(Ln 386-391): "It is worth emphasizing that the use of this technique is directly dependent on the legal destruction of another area of native vegetation, and the positive results described here should not be used as an argument to expand mining areas. In other words, the restoration of a mined area relies on the degradation of a conserved area, so although it may work at the local scale, this restoration approach is not effective at the landscape scale and may still result in net environmental losses.".

Reviewer 3: 3) In the part of discussion, there should be some sub-title. Otherwise, the discussion is too long to read.
Authors: We agree. We added four sub-titles to better organize the Discussion section, we hope it is easier to read now.

Reviewer 3: 4) Although the intensive management (Topsoil and fertilization) could quickly restore the soil. However, it costs. Therefore, the effect and cost of fertilization on the soil indicators also should be discussed. Is there any cheap methods to accelerate the soil recovery?
Authors: We agree that exploring the costs of intensive management would enrich the discussion and contribute to guide decisions, so we added a new sentence to address this issue, as follows:

(Ln 391-395) "A study performed at the same study area found that restoration implementation and maintenance costs increase by 35% when forest topsoil is used, and this difference would be even higher if topsoil transport and distribution costs were considered (Guimarães et al. 2013). Thus, traditional restoration approaches are cheaper, yet not as effective as those based on topsoil transfer (Guimarães et al. 2013)."

Reviewer 3: 5) The title is very plain, looks like a review. It did not present the key findings.
Authors: We revised the title and added more details to it, as follows: "Multifunctional soil recovery during the restoration of Brazil's Atlantic Forest after bauxite mining".