Authors Response to Reviewer Comments

ECOSPHERE Manuscript ID (ECS23-0342) Tree regeneration in models of forest dynamics: a key priority for further research

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1 Internal instructions

- underlined comments are comments that still need attention
-

2 Journal formatting (ToDo list)

- Respond to the review comments in the space provided. You can use this space to document any changes you make to the original manuscript. In order to expedite the processing of the resubmitted manuscript, please be as specific as possible in your response to the review comments. If you disagree with a point, please explain why. Please note that the field in ScholarOne does not retain type formats such as italics, boldface, or colors, so please format the responses accordingly. We suggest you upload a separate file for your "Author's Response to Reviewer Comments" document and use our template: https://www.esa.org/wp-content/uploads/2021/04/Author-Response-to-Reviewers-Template.docx.
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- DEADLINE: We encourage you to submit your revised manuscript within three weeks from today's date. The final due date for submitting your manuscript with the same manuscript number is 14-Dec-2023.
- If you are unable to meet the final deadline, you can request an extension by contacting the the journal's editorial staff (esajournals@esa.org). Please note that we can only consider extensions of a few weeks. If you cannot submit by the final due date, you must create a new submission for your manuscript. If creating a new submission, be sure to note the previous manuscript ID (ECS23-0342) in the online submission form and include an "Author's Response to Reviewer Comments" document (using the template linked to earlier in this message) in the file list.
- Editorial staff note: In addition to revisions according to the review comments below, please make revisions to your paper to conform to the journal style at this stage, especially the tables, figures, and supporting information, anticipating the possibility that your paper may be accepted for publication.
- Please provide the main manuscript file composed in Word, taking care to use the Table function for the tables. However, if you created your manuscript in LaTex, please provide only the .tex file of the main manuscript, a .pdf file of the main manuscript (that is the exact same in content as the .tex file), and a .bib file.
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- Table and figure references: Please be sure that all tables and all figures have in-text citations in the main body of the manuscript, and that tables and figures are called out in numerical order (i.e., Figure 1 is called out before Figure 2).
- Figures: Each figure should be provided in an individual, complete file (all panels in one image, identified by figure number in the file name), preferably as a high-resolution (300-600 dpi) image file or high-quality PDF. Preferred file formats include TIF, EPS, PDF, or AI at 600 ppi, while JPEG, PPT/PPTX, or DOC/DOCX are acceptable if the resolution is sufficient. Only one version of each figure should be provided. Please delete figure images from the main manuscript file. Please check for misspellings and be sure that all parts, including all lettering, symbols, labels, and scale numbers, are discernible, clear, and readable when the figures are presented at the maximum allowable size (18 cm wide by 22 cm tall) in the typeset and paged PDF version of the article. See additional instructions for preparation in the Manuscript Preparation Guide.
- Figure captions: Please be sure to include a list of figure captions in the main manuscript file and ensure that any abbreviation that appears in a figure is identified in the caption.

- Supporting Information: Each appendix must be assembled exactly as you intend it to appear online. (Appendices are posted "as is"; ESA and Wiley staff do not copy edit or assemble appendices.) Note also that the Ecosphere naming convention for appendices is of the style "Appendix S1," "Appendix S2," etc., and for tables and figures within appendices is "Table S1," "Table S2," etc. or "Fig. S1," "Fig. S2," etc., and requires that the numbering begins at "S1" in each appendix (and revise references to material in other appendices as necessary). Please be sure to eliminate line numbering and to include the title of the journal, the title of the article, and all of the authors' names on the first page of each appendix. In addition, if there are literature references within an appendix, the appendix should include a list of literature cited.
- If the journal style is not followed at submission of the revision, we may return the manuscript to you for further revision before sending it along to the Subject-matter Editor. Closely following our manuscript preparation guide at this stage would expedite the production of your paper for publication, should it be accepted. You can download our guide here: https://www.esa.org/wp-content/uploads/2022/05/ESA-Manuscript-Preparation-Guide.pdf

3 Response to the Editor

3.1 General Comments

Dear Dr. Díaz-Yáñez:

Thank you very much for submitting your manuscript "Tree regeneration in models of forest dynamics: a key priority for further research" for review by Ecosphere. The reviewers and I appreciate the work you have accomplished. I am willing to consider a revised version for publication in the journal, assuming that you are able to modify the manuscript according to the reviewers' extensive recommendations. Your revisions should address the specific points made in the review comments. Please note that Reviewer #2 made extensive comments directly on the manuscript.

I should note that personally I can hardly disagree with your basic conclusion that models of forest dynamics need to do a good job of capturing regeneration and recruitment processes. I have devoted most of my research over the past 40 years to developing the field methods to allow incorporation of accurate seedling, sapling and canopy recruitment in the models SORTIE and SORTIE-ND, in systems ranging from the tropics to boreal forests. The specific ecological processes incorporated in those models depended on the goals of the modeling and the ecology of the system, and included processes such as masting cycles, effects of disturbance on seedbed substrate dynamics, seed and seedling predation by small mammals, browsing by ungulates, Janzen-Connell effects, and, of course, detailed analyses of shading and neighborhood competition. More recently, this includes developing statistical models of seedling recruitment from the US forest inventory network that have been directly incorporated in the model for forests

of the entire eastern US. To my mind, the difficulties the models you reviewed encountered in capturing canopy recruitment speak more to the limitations of the approaches used in model development than in any inherent difficulties in capturing regeneration and recruitment in models of forest dynamics.

Sincerely,

Dr. Charles Canham Subject-matter Editor, Ecosphere

3.2 Response to editors comments

Dear Charles,

Thank you very much for taking the time to review our manuscript and for your insightful thoughts on our findings.

We totally agree with your comments. Our main take away from this manuscript it is not that it would be impossible to calibrate all 15 models against e.g. the EuFoRIa data, but the issue is - as you wrote - that this needs to be bound to the goals of the study. And when the goal is to provide extrapolation into a future climate, then calibration against data under current climate may be unreliable. This is why we belive it is fundamentally valuable to test model performance "out of the box", as we have done here.

In this revised version we have modify the manuscript according to the reviewers' recommendations and we have addressed each of the specific points made in the review comments. We believe the manuscript has significantly improved based on this changes.

4 Response to reviewer 1

4.1 General Comments

The manuscript compares how regeneration and recruitment is simulated in 15 forest models, using a large network of forest reserves in Europe as the observed data. I want to start by saying there are many strengths of the paper. I was impressed with the comparison of 15 models, that the observed data was not used to parameterize or fine-tune the models, and the high quality of the writing. The introduction and discussion were easy and enjoyable to read, and the topic is critical and relevant. Some of the details about the models and methods were placed in the very substantial appendix, and I agree with their choices. However, the manuscript is still quite long with lots of multi-paneled figures. If the journal does not have a page limit, then this is not an issue. If there is a page limit, then some tough choices will have to be made for which figures to keep. Figures 2, 3, 6 and 7 are the most important (in my opinion).

I have a few major comments. One of which requires a different statistical analysis – which is why I do not consider this a 'minor revision'. However, there are no fatal flaws, and all of my comments are fixable. I hope they serve to improve the manuscript.

4.1.0.1 Our general comments to reviewer 1:

4.2 Major comments

4.2.1 COMMENT 1

'regeneration' versus 'recruitment'. I personally have had this conversation multiple times over the years, so I understand that there is variation in the definitions and uses. However, the authors do define these terms in the methods (L167-171) and I completely agree with them. Regeneration is for flowers, seeds, and seedlings while recruitment is for reaching a certain size threshold. However, the entire manuscript refers to regeneration as "passing of trees across a specific diameter threshold ("ingrowth") (L142), either reaching a size of 7 or 10 cm DBH. This is recruitment. Since this is the response variable for the manuscript, I would suggest replacing 'regeneration' with 'recruitment' throughout the manuscript.

4.2.1.1 Response to comment 1:

Thank you for pointing

4.2.2 COMMENT 2

The difference between 7 cm and 10 cm DBH in the observed data. From the methods, there is one dataset that has sites where recruitment was defined as 7 cm DBH, and then another where recruitment was somewhere between 7 – 10 cm DBH. It was not clear how these were treated and compared in the results. I assume that the models simulated all 200 sites, but then the recruitment results were compared like-to-like. So, if a site defined recruitment as DBH = 8.0 cm, then all 15 models would compare simulated recruitment at that site only at 8 cm. Since the data are boxplots, I am not able to tell. For example, Figure 2 – there should be 165 points for all of the 7 cm bars (observed and simulated) and 35 data points for the 10 cm bars (observed and simulated). If true, then please clarify. If not true, then please explain. Also, how was the data analysis performed when looking at the change in mortality and species diversity between 7 to 10 cm? I assume only the 165 stands were used. Please clarify.

4.2.2.1 Response to comment 2:

Thank you for highlighting that we didn not managed to appropriately communicate our diameter thresholds approach correctly in the manuscript. The explanation is that the observed data

In this revised version we have revised the explanation in L XX

4.2.3 COMMENT 3

The t-tests. The results in Table S2 and S3 (comparing at 7 cm and 10 cm DBH) should be at least by paired t-tests not two-sided t-tests (L319), where you are comparing the difference within the same stand at 7 and 10 cm. The results Table S5 and S6 should not be a t-test at all. Performing 15 individual t-tests is a classic Type-1 error situation (technically this applies to Tables S2 and S3 as well, a comment on that below). For Tables S5 and S6, I would suggest a general linear mixed effects model. You can take the difference between the observed, and the simulated output and make this the response variable (Y). Then, include model complexity, feedback, model type and scale as fixed explanatory variables. And include the stand ID as the random effect. This will more accurately answer your question about if any of these fixed explanatory variables can predict over or under representation of recruitment. For Tables S2 and S3, you could do the same thing (i.e., calculate the difference between the observed and the simulated output for each model) and make this your response variable. But the only fixed effect would be the actual model, and then you could do an ANOVA (again, stand ID as the random effect) and then a post-hoc test to see which models were or were not different from observed. If you do want to keep the 15 paired t-tests, then you need to account for Type I error rates and adjust your p-values accordingly.

4.2.3.1 Response to comment 3:

Based on the comments from Reviewer 1, we have re-analyse some of the results. More specifically we

4.3 Minor comments:

4.3.1 COMMENT 4

The abstract is not clear if the models do a good or poor job in simulating regeneration (L59, that they match observed ranges, and then L66, considerable mismatch between simulations and observed data, but that they do capture tree regeneration). Please clarify the main message in the abstract.

4.3.1.1 Response to comment 4:

4.3.2 COMMENT 5

L123-138: this paragraph has a lot of "on the other hand" type of statements, and it does not lead nicely into the next paragraph about the current study. It was a bit of a surprise (i.e., I did not expect the main purpose of the study when I started to read the following paragraph). It seems like the main issue is that we just don't know how uncertain regeneration and recruitment methods are, because we lack the comparison across models and a comprehensive empirical recruitment data set that we can use to compare. And that is what your study is doing.

4.3.2.1 Response to comment 5:

4.3.3 COMMENT 6

Table 1. Please clarify what the letters are for (a, b, c and d in the table headers). For models that start from saplings or ingrowth, please add in the size as well (i.e., start from saplings with DBH = 1.0). Could also add in the classification scheme mentioned in the methods (L168, regeneration or recruitment) to Table 1.

4.3.3.1 Response to comment 6:

4.3.4 COMMENT 7

L218 – do I understand this correctly, that regeneration rates are a mean of 56 trees per ha per decade? This seems really low (assuming that this is for >10 cm DBH).

4.3.4.1 Response to comment 7:

4.3.5 COMMENT 8

L264 – 274: how will this be accounted for later, that not all models simulated the same set of species?

4.3.5.1 Response to comment 8:

4.3.6 COMMENT 9

L340: “regeneration basal area of that species” is mentioned twice, please delete the second one.

4.3.6.1 Response to comment 9:

4.3.7 COMMENT 10

L364: so please remove the 4C model from the figure as it is not comparable. Do you need to also remove other models that don’t simulate the same number of species too?

4.3.7.1 Response to comment 10:

4.3.8 COMMENT 11

Table S2 and S3: What are the 3 columns for p-values? Please report just the one you used. No need to have a column to state ‘t-test’ – just move this to the table caption. Then add in a column for df, the test statistic (t) and the effect size (was it higher or lower and by how much?). NOTE, this comment may become irrelevant if you change the statistical analyses.

4.3.8.1 Response to comment 11:

4.3.9 COMMENT 12

Figure S1 and S2 – I can’t tell the difference between observed and simulated. Are they different colours? The legend should be larger. What is the black line for?

4.3.9.1 Response to comment 12:

4.3.10 COMMENT 13

Figure 4 (and Figure S3) are interesting in that there are no patterns with overstory diversity, and that this was not explained by feedback with seed production. What happens if you colour the points, by those from models with the feedback? Do you address in the discussion why this feedback makes no difference to recruitment?

4.3.10.1 Response to comment 13:

4.3.11 COMMENT 14

All figures in the Appendix, please make the X and Y axis labels larger and centered. I actually thought labels were missing initially and it took a while to find them.

4.3.11.1 Response to comment 14:

4.3.12 COMMENT 15

L400 – 402: where is this conclusion about mixed species or monocultures coming from? I don't see that in the figures or the results.

4.3.12.1 Response to comment 15:

4.3.13 COMMENT 16

Figure 6 is excellent.

4.3.13.1 Response to comment 16:

4.3.14 COMMENT 17

Table S4: please clean up. No need to report 7 places after the decimal point. Please clarify in the table caption what the slope represents (maybe mention Figure S5 too, as I assume it is illustrating the slopes). Another suggestion, would be to make the slopes solid lines if significant, or dashed lines if not significant. Not sure if that would help, but if it does then it could eliminate the need for this table.

4.3.14.1 Response to comment 17:

4.3.15 COMMENT 18

Not sure both Figure 7 and Figure S7 are necessary (I admit I spent a few minutes going back and forth between them trying to understand how they differed). I would just keep Figure 7 and note that the scales differ.

4.3.15.1 Response to comment 18:

4.3.16 COMMENT 19

L547-548: predicting stand diversity, did I miss this? I don't believe Figure 4 shows this, as if you put all data points on the same panel it would just be a random scatter of points that covers the entire space (not necessarily closer to the 1:1 line).

4.3.16.1 Response to comment 19:

4.3.17 COMMENT 20

L575: that most models did not deviate exceedingly from observations seems in contrast to what the previous section was stating. What is this based on?

4.3.17.1 Response to comment 20:

4.3.18 COMMENT 21

L584: What does this mean, about degrees of freedom for modelling regeneration?

4.3.18.1 Response to comment 21:

4.3.19 COMMENT 22

L624: Missing the end of the sentence.

4.3.19.1 Response to comment 22:

4.3.20 COMMENT 23

L647: Completely agree that observed data is a snapshot of a stochastic and dynamic system and care should always be taken with comparing to simulation data, however I disagree about the following stamen (L648). The models should be able to capture broader patterns along climatic or environmental gradients.

4.3.20.1 Response to comment 23:

4.3.21 COMMENT 24

L655: But the landscape models generally did about the same (i.e., not consistently worse) then the rest, correct?

4.3.21.1 Response to comment 24:

4.3.22 COMMENT 25

L663: But in general, the models were more sensitive to water balance and the observed data did not have any real pattern. Why would this coarser representation of water balance in the model, cause it to be more sensitive?

4.3.22.1 Response to comment 25:

4.3.23 COMMENT 26

L675: what would a 'comprehensive regeneration dataset" look like? There are large data sets for seed production (MASTIF, MASTREE, etc.) and seedling data from national forest inventory programs. Does EuFoRIa (L677) have everything you need? Is it just a matter of expanding the spatial and temporal extent? Please explain what sort of data that the models would need (imagine an ideal world).

4.3.23.1 Response to comment 26:

5 Response to reviewer 2

5.1 General Comments

The paper evaluates whether forest dynamics models are successful at capturing the essence of regeneration processes, by comparing outputs from 15 simulation models with tree recruitment data obtained from 300 mature forests spread across central/eastern Europe. Specifically, the models predicted how many trees of different species recruited each year (i.e. grew larger than 7-cm or 10-cm stem diameter) and indices derived from these numbers were compared with analogous indices derived from repeat-measured forest inventory plots. Most of the

simulation models performed poorly for most of the indices examined. In particular, they tended to overestimate recruitment rates.

It is valuable to demonstrate that leading forest dynamics models are unable to characterise regeneration processes very well. I also thought the "blind trial" approach was clever. Huge effort must have gone into running 15 models under various starting conditions and synthesising the outputs into a coherent paper. Choices have been made about which details to include in the main body of the text vs supplementary information and I thought a good balance was struck, although I have made several suggestions on the pdf.

5.1.0.1 Our general comments to reviewer 2:

5.2 Major comments

5.2.1 COMMENT 1

Where the paper falls short, in my opinion, is in providing a clear path forward. It shows that the models are too simplistic to simulate regeneration processes accurately but provides few insights into how we can improve their performance. The paper reports that creating more complex models is not valuable in and of itself, but that's not to say that intelligent improvement of specific subcomponents may hold the key. For instance, deer browsing and competition with herb layer plants may well contribute to lower recruitment being observed than simulated, but how can we demonstrate that, and if the inadequate representation of these processes in the models is the problem, what should be done to improve the models? The review by Hanbury-Brown et al. (2022) on "future forests within Earth system models: regeneration processes critical to prediction" provides a good summary of current knowledge and future directions, including thoughts on 1. reproductive allocation and seed production; 2. dispersal; 3. seed survival, germination, and resprouting; and 4. seedling survival and growth. I would encourage the authors to frame their discussion in a similar way. Advanced statistical approaches that bring together simulation models and Approximate Bayesian Computation to estimate parameters of recruitment submodels may hold the key (e.g. https://onlinelibrary.wiley.com/doi/full/10.1111/ecog.04824). To me, a key question is how we can make better use of field measurements and statistical analyses to refine forest dynamics models, i.e. not only parameterise them but also to identify which submodels need refinement and the function that need inclusion.

5.2.1.1 Response to comment 1:

5.2.2 COMMENT 2

I felt the readability of the paper would be improved by introducing a "road mapping" paragraph at the end of the introduction or start of the methods section that sets out the approach in broad terms.

5.2.2.1 Response to comment 2:

5.2.3 COMMENT 3

The words "ingrowth", "regeneration" and "recruitment" are used interchangeably to describe the recruitment of new trees into the 7-cm diameter class. I would encourage the authors to use the term "ingrowth" or "recruitment" to this to describe this process, and keep "regeneration" as an overarching term describing the entire process of seed production, dispersal, early establishment, and onward growth.

5.2.3.1 Response to comment 3:

5.2.4 COMMENT 4

The article is written entirely by Europeans, unless I'm mistaken, and very much focused on the central/eastern European forestry literature. I would encourage a deeper dive into the relevant North American and Asian literature when introducing and discussing their work.

5.2.4.1 Response to comment 4:

5.3 Minor comments:

These comments have been extracted from the reviewer 2 comments on the PDF document of the manuscript.

5.3.1 COMMENT 5

L51-52 "However, an assessment of their ability to accurately represent tree regeneration is lacking." Not true.

5.3.1.1 Response to comment 5:

Based on the reviewers comments we have modified this sentence to: “However, there is a need to evaluate their capacity to accurately represent tree regeneration”

5.3.2 COMMENT 6

L56 “The results are evaluated against comprehensive data from unmanaged forests.” comprehensive?

5.3.2.1 Response to comment 6:

Following the reviewers comment we have changed the word “comprehensive” to “extensive” to express that we used a wide-range data that considers many important elements of regeneration.

5.3.3 COMMENT 7

L56 “Models simulating higher species diversity at the stand level do not feature higher regeneration diversity.” feature?

5.3.3.1 Response to comment 7:

Following the reviewers comments we have changed “feature” with “present”.

5.3.4 COMMENT 8

L76-78 “A wide range of models of forest dynamics were developed over the past decades considering the impacts of climate”

5.3.4.1 Response to comment 8:

Following the reviewers comment, we have changed the word “were” with “have been”.

5.3.5 COMMENT 9

L79 K. Vanclay and Skovsgaard 1997;

5.3.5.1 Response to comment 9:

Following the reviewers comment, we have corrected the reference style.

5.3.6 COMMENT 10

L83-84 “Which is a clear research gap in the context of climate-induced forest disturbances and forest resilience.” incomplete sentence

5.3.6.1 Response to comment 10:

Following the reviewers comment, we have changed this sentence to: “This presents an important research gap, particularly in the context of climate-induced forest disturbances and forest resilience.”

5.3.7 COMMENT 11

L85-86 “Tree regeneration arises from multiple processes such as pollination, fruit maturation, seed production, dispersal, germination, juvenile growth and survival” including

5.3.7.1 Response to comment 11:

Following the reviewers comment, we have changed “such as” with “including”

5.3.8 COMMENT 12

L85-86 “Tree regeneration arises from multiple processes such as pollination, fruit maturation, seed production, dispersal, germination, juvenile growth and survival” including

5.3.8.1 Response to comment 12:

Following the reviewers comment, we have changed “such as” with “including”

5.3.9 COMMENT 13

L90-92 “Currently, tree regeneration processes in dynamic forest models are handled in a multitude of ways (König et al. 2022; Bugmann and Seidl 2022): from 1) entirely ignoring it (as done in classical forest growth models, e.g., Pretzsch et al. 2002),” it.

5.3.9.1 Response to comment 13:

Following the reviewer's comment we have changed "it" with "them"

5.3.10 COMMENT 14

L96-98 Particularly given your conclusion that the models are poor at predicting regeneration processes, should we now return to statistical parameterisation afresh and find better ways of extrapolation/interpolation across space/time?

5.3.10.1 Response to comment 14:

It is indeed interesting to account with the increasing data vailablity to better understand tree regeneration processes. However, we believe that the main take away it is not that it would be impossible to calibrate all 15 models against e.g. the EuFoRIa data to better capture regeneration, but that the focus should be in the study goals. And when the goal is to provide extrapolation into a future climate, then calibration against data under current climate may be unreliable. With the approach we have followed in this study where we have asked the models to simulate forest dynamics and capture regeneration without statistical predetermination we can better assess their behavior and understand how their current model structures and inclusion of exclusion of certain ecological processes impact the outputs we are seeing.

Following this and other comments from the editor, we have tried to capture this better in the discussion/conclussions section.

5.3.11 COMMENT 15

L100-101 "Overall, models are needed to…(3) identify the most important processes that are shaping ecological patterns." doesn't that depend on what goes into the model?

5.3.11.1 Response to comment 15:

We are not complete sure of the reviewers point here. If the reviewer is referring to the fact that the most important processes will be those included in the model, it is true that you can only asses those processes included or how including or not another processes impact regeneration. This was also the idea with considering a large pool of models, that we could assess how their structural complexity, or the inclusion/exclusion of a certain process affects the results we are seeing. This also goes very much in line with our research recommendations presented in the discussion where we proposed that improvement of the regeneration modules is implemented as additional features that can be traced back, as done here for the variants of

ForClim and ForCEEPS, and that model complexity and structure must always be connected with modeling objectives.

5.3.12 COMMENT 16

L101-106 “Given the current strategies that are used in models of forest dynamics to represent tree regeneration, model behavior often is prone to problems, such as very high levels of tree regeneration that necessitate excess mortality at early stages of tree life to simulate correct stand structure and composition.” ref? tens of thousands of seeds...

5.3.12.1 Response to comment 16:

Following the reviewer’s comment we have added a reference

ToDo find a reference!

5.3.13 COMMENT 17

L112-114 “A related issue is the excessive reduction of species diversity due to positive feedback effects, such that eventually just single-species stands remain.” ref

5.3.13.1 Response to comment 17:

Following the reviewer’s comment we have added a reference

ToDo find a reference!

5.3.14 COMMENT 18

L127 I suggest making better use of the hanbury-brown 2022 review.

5.3.14.1 Response to comment 18:

We currently use the exciting Hanbury-brown 2022 review in several places across our manuscripts, following the reviewer’s comment here and the general comment 2 in Section 5.2.2 we have also get inspired by their structure by creating a road map to help the reader to navigate the manuscript content.

5.3.15 COMMENT 19

L145-147 “Due to the large variability in tree regeneration patterns in nature and the large number of factors driving this process including some that are not incorporated explicitly in most models, such as deer browsing—”

5.3.15.1 Response to comment 19:

We believe the reviewer highlighted the words “models, such as deer browsing” because they think this is not correct. From our sample pool only 4 models incorporated explicitly deer browsing.

5.3.16

COMMENT 20

L150 “regeneration niche of multiple species”

L154 “traits”

5.3.16.1 Response to comment 20:

We are unsure why the reviewer highlighted those words

5.3.17 COMMENT 21

L185 “(mean regeneration formulation complexity across all processes >0, Table 1).” Meaning

5.3.17.1 Response to comment 21:

This statement relates with the Bugmann and Seidl (2022) where complexity values were provided. The exact details of how we calculated this mean regeneration formulation are available in the software suplmentary materials to this paper: “‘figure.R“‘ line 706-750

6 Other changes made in the manuscript