

Geosci. Model Dev. Discuss., referee comment RC2  
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## **Comment on gmd-2021-287**

Anonymous Referee #2

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Referee comment on "Climate and parameter sensitivity and induced uncertainties in carbon stock projections for European forests (using LPJ-GUESS 4.0)" by Johannes Oberpriller et al., Geosci. Model Dev. Discuss.,  
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The study analyzed sensitivities and uncertainties of the LPJ-GUESS 4.0 model for climate change simulations of 200 sites across Europe for three tree species in pure and mixed-species stands. To this end, 11 general model parameters, 22 species-specific parameters and 5 environmental drivers were selected and varied within individually specified ranges. Sensitivities and uncertainties were calculated by multiple linear regressions for three model outputs relevant in the context of forests' role for carbon cycling (i.e., gross primary production, total standing biomass and net biome productivity). The results were analyzed for the whole of Europe, for environmental zones as well as along a temperature gradient.

Certainly, the results and insights of this study are relevant for simulation studies using LPJ-GUESS as well as other dynamic vegetation models and the manuscript fits well into Geoscientific Model Development. Yet, I have some remarks that should be addressed before publication.

### **General/major comments**

Overall: The study provides valuable findings. However, the focus on overall ecological theory is not convincing and the comparison with empirical data very vague. I suggest changing the focus on the LPJ-GUESS model itself, its further development and the meaning of the results for recent and upcoming studies applying this model, particularly for publication in Geoscientific Model Development. Moreover, the manuscript would benefit from a significantly improved discussion of the findings, particularly in the context of LPJ-Guess and other dynamic vegetation models.

1) The authors argue that one motivation for their study are substantial changes of the model structure, especially regarding nitrogen cycle and management modules, which have not been included in earlier SA/UA studies of LPJ-GUESS. While the process of nitrogen is mentioned and discussed, no insights are given regarding the management modules. An attentive reader can find out in Table 1 that two management-related parameters were considered in the analysis (cutinterval and thinning\_intensity), which are however not related to any sensitivity/uncertainty according to Fig. 1&2. Please extend on the changes in model structure and include and discuss the findings in the discussion section.

2) Drivers vs parameters: It is not at all surprising that the environmental drivers contributed most uncertainty and had the highest sum of interactions in a climate-sensitive dynamic vegetation model as LPJ-GUESS. These drivers are inputs to all important processes in the model (i.e., primary production/growth, plant biogeography, soil hydrology, C exchange, etc.). Moreover, the variation ranges deduced from the different climate change scenarios are considerable. Hence, all the climate change simulation studies with LPJ-GUESS build on the sensitivity of the model to the climatic drivers. I can see that the added value of this study is that the uncertainty contributions can be attributed to the individual climatic drivers and analyzed across a temperature gradient. Yet, I think the authors should make really clear that parameters and drivers have different roles in process-based models. At least to me, it appears a bit as if you are comparing apples and oranges. In view of the potential insights for the LPF-GUESS modelling community, a separate analysis of both would show patterns much better (right now, 'drivers' mask all other changes in parameters in Fig. 3, which is not really informative).

3) I find it surprising that there are hardly any differences of the relative uncertainties across the environmental zones in Fig. 3. For example, the different species do not seem to show species-specific uncertainties to water-related parameters across space. I would also expect that not all species are able to grow in all environmental zones, which should somehow become visible at range limits. In a subsequent analysis, the authors focused on the uncertainty contributions across a mean annual temperature gradient (Fig. 4). In line with Fig. 3, the changes in uncertainty contributions are rather small (e.g., approx. 11% for temp between a 5° and a 20° site; e.g. Southern Sweden vs. Southern Spain). I wonder, whether these changes are statistically significant. Could you please provide some details (e.g., plots of the linear regressions including simulated TSB and  $R^2$ ). Given these results, I got the impression that the authors oversold the results in this regard (L23-27; L371-380).

4) Discussion: The discussion section needs considerable improvement. Various topics are mentioned, but there is very little substance and added value to many of the raised points (e.g., often only one sentence mentions the importance of a process and refers to a study that found similar effects). A better selection of the critical points and an in-depth discussion of these issues would greatly improve the manuscript.

Moreover, the discussion should be better embedded in the existing body of literature, both regarding model-based and empirical/physiological studies, especially if the authors keep the comparison with empirical results as one of the four main objectives of this study

(L102-103). Thereby, please make clear whether the reference you refer to is a model-based study or a field study.

Also, please be careful with the wording, e.g., a positive or negative effect of a parameter or driver can be explained by the fact that a certain ecological effect (which has been found by empirical studies) is integrated in the model formulation. Such an effect can be 'in line with empirical studies' but it cannot prove an effect as LPJ-GUESS is just a model.

Please also discuss processes, which turned out to be related to low sensitivities/uncertainties according to your simulation setup (e.g., establishment, management). Currently the discussion only considers the processes that turned out to be important, but it lacks an explanation why these patterns occur. For instance, no effect was found for management. This definitely needs explanation. Or, only small effects were found for establishment. Can this be explained by the spin-up and what are the implications for other simulation setups?

Given the motivation the authors outline in the introduction, it would be worth to cover the following points: How are your findings relevant for recent and upcoming studies using the LPJ-GUESS model? What does your results imply with regard to further model development efforts? How could the robustness and reliability of the model projections be increased?

## **Minor comments**

### *Abstract*

L23-27: The conclusions are strongly focusing on the stress-gradient hypothesis, which was not the main focus of this study. I am convinced that there are other, more general conclusions you could make. For example: How are your findings relevant for recent and upcoming studies using the LPJ-GUESS model? What are conclusions that also consider your findings regarding the model parameters? What does your results imply for further model development?

### *Introduction*

L58: please provide a reference for local sensitivity/uncertainty analysis

L83: no comma after 'model'

L86-88: difficult to follow as you introduce another aspect (ecological principles). Please split the sentence and explain better how the aspect of ecological principles can be evaluated by SA/UA and why this is interesting (and give references)

L92: how did you make sure that the 200 sites you selected were forest sites? Else, please do not refer to 'European forests' here.

L95: which processes were not considered? Could be added in the section 63-75.

L95-99: long sentence, consider splitting; why do you run simulations for pure and mixed stands? Please explain and mention relevant references. Are mixtures of these three species common in Europe (or do they stand for different life-history strategies)?

L98: 'and' not in italic

L101: introduce the environmental zones before and give a reference to the classification system you applied

### *Methods*

L108: add space after '2014).'

L117: please give model version in this section

L117: is fire relevant in this study. If yes, please explain the BLAZE model briefly.

L119: are these key parameters according to a previous SA/UA or key parameters because they are first in the modeling routine?

L122: please move 'at regular intervals (here: 1 year)' to after 'are established'

L123: add 'is' after 'floor'

L126: please add 'net primary productivity' before NPP

L137: is there missing something after 'for'?

L144: please remove the comma after 'competition'

L148: does population stand for cohort or all trees of the respective species on the forest patch?

L150: how are these wildfires linked to climatic conditions? Which trees are killed by fires (i.e., I guess not all as there are additional patch-destroying disturbances)?

L151: please give examples for the patch-destroying disturbances

L168-173: please add some references to previous LPJ-GUESS publications introducing this process

L177: please give a reference to the method applied and a reference to the climate data you used

L179: replace 'und' by 'and'

L189: please add a point before 'We'.

L189: What type of data did you use to derive CO<sub>2</sub> values for the transient and future simulation runs?

L196: which fraction of all parameters are covered by these 11 and 22 parameters?

L208-209: please add references for carbon cycling and forest owners.

L211-228: does your approach correspond to a global or local SA/UA? Please clarify. Are there other SA/UA that followed the same approach/method as you?

L217-236: well explained

L230: replace 'are' with 'is'

L230: very good explanation for sensitivities. Please add such an explanation for uncertainties too.

### *Results*

General comments:

- It is helpful, if you mention the process groups when referring to individual parameters. Sometimes you do this, but not throughout.
- It would also be helpful to mention process groups that were not important too (e.g., establishment and nitrogen for 3.1)

L250-252: The sensitivities of the three species are quite different from each other for some parameters (also different directions possible; not only for bioclimatic limits and environmental drivers). Please be more precise here.

L263: please give numbers for the 'substantial' nitrogen-related uncertainty.

L270-271/284-286/L300-304: this should be part of the Method section. Please add the reference to Metzger et al. in the text.

L273: replace 'tree' by 'three'

L274: what does 'on average' mean? Averaged across three individual species and one mixture (if so, would it make sense to give the same weight to the individual-species simulations as to the mixture)? Please clarify.

L296: no comma before 'decreased'

L301: what do you mean by full dataset (in contrast to data used for Fig. 3 with at least 5 sites per environmental zone)? Please clarify.

L269: Does this analysis refer to TSB only? If so, please state clearly at the beginning and directly mention Appendix A1.4.

L303: you summed the **absolute** individual interaction indices, right? What do you mean by 'other processes'? E.g., for CO<sub>2</sub>, did you only took the sum of the interaction indices with parameters from other processes (i.e., without the other parameters from drivers, such as prec, temp, insol, ndep)? Please clarify.

L307-309: similar to what?

### *Discussion*

General comment 1: Please make sure to be clear about which findings have been previously found for LPJ-GUESS and which for other DVMs.

General comment 2: The processes the authors discuss in a bit more detail seem to be picked rather randomly (e.g., in L344-351: some details about nitrogen, but nothing about water).

L322-326: The two sentences do state the same, right (deduced from two different figures)? This could be simplified as it seems confusing when reading through it. Consider skipping the sentence referring to Fig. 3, as this result can hardly be seen.

L328: consider deleting the interpretation here ('considering that ...'), as you give a summary of all results but an interpretation only for the very last one.

L330-351: Please extend a bit on your findings, otherwise these two sections are just a repetition of the introduction and your results. E.g., have you used similar parameter ranges as the previous LPJ-GUESS SA/UA studies? What do you think why have previous studies not found high sensitivities to water-related parameters (sites, species, parameter ranges, changes in model structure, ...)?

L330-342: Do I understand correctly that for the mixed simulations, you did not change the values of a species-specific parameter simultaneously for all three species? But for the averaging, simulations for which the value of just one species has been changed for a specific parameter, where then averaged? Please clarify in the method section.

L344-345: Please explain what is the difference to Petter et al. 2020.

L345: you did not mention nitrogen-related parameter as being important in the summary at the beginning of the discussion.

L353: refer to the Figs via 'Figs. 2-5'

L356-357: the positive CO<sub>2</sub> effect could be explained by the assumed CO<sub>2</sub> fertilization effect, which is integrated as an assumption in the LPJ-GUESS model. This does not necessarily mean that this is what happens 'in the real world', as various empirical studies questioned this effect (e.g. Körner and colleagues).

L361: replace 'is' by 'could be'. I am not at all sure that this is true. Could your finding be related to the averaging effect across sites (e.g., Beech growing better across large areas of Europe due to northward spreads related to increasing temperature)? Please extend this point and explain your argument with empirical studies.

L363-369: this paragraph is difficult to follow.

L371-380: please consider major comment 4

L382-400: well written

*Figures and Tables*



Table 1: Could you order the parameters by Group for better readability?

Fig. 1: The species result symbols are very small, please improve. The sensitivities of the three species are quite different from each other for some parameters (also different directions occur!). Please use the same y-axis for better comparability between the three outputs (also for Fig. 2).

Fig. 3: I agree with reviewer 1.

Fig. 5: panel a x-axis label: change 'Parameter' to 'parameter'; the shared y-axis labels for a) and b) is a bit confusing, particularly, since the axis labels are missing in a)

### **Technical corrections**

Please add a comma: L73: after 'uncertainties'; L142: after 'period' and please add 'or' after 'PFT,'; L153: before 'which'; L158: after 'tissue'; L173: after 'coefficient'; L185: after 'data set'; L188: after 'data'; L227: after 'thereby'; L278: after 'zone'; L345: before 'especially'