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Interactive comment on "Species composition and forest structure explain the temperature sensitivity patterns of productivity in temperate forests" *by* Friedrich J. Bohn et al.

Friedrich J. Bohn et al.

friedrich.bohn@ufz.de

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Comments of reviewer 1 in blue, reply in black. Note, there is an online supplement including Appendix R.

I am sorry for being late. The manuscript uses an innovative modelling approach to assess the temperature sensitivity of above ground wood production. It is generally well written but there are quite a number of minor fixed that still need to be carried out.

Thank you very much for your detailed and helpful comments. We will include your recommendations carefully.

I have two major concerns that can be addressed in a thorough minor revision: 1) I think your "climate scenarios" are actually rather a "climate sensitivity test". Even though many things can be scenarios in the wider sense in the narrow sense, a scenario usually refers to an internally consistent projection while your scenarios systematically explore change temperature but do not adjust precip and radiation accordingly. This may lead to physically inconsistent "climates" because under a given temperature pathway it might be impossible to get a certain precip or radiation behavior.

Thanks for this comment. We agree. We will replace "climate scenarios" by "climate sensitivity test" or "climate time series" depending on the context. For instance, P1L9: For each stand we estimate annual above-ground wood production and perform a climate sensitivity test based on 320 different climate time series (of one year length).

Related to that, you should possibly also discuss that your approach basically ignores transient responses and time lags longer than a year that influence forests. So i think this "sensitivity test" aspect should be carved out more clearly. The title actually is fine but some of the other sections give the impression this is rather a scenario study.

This is a good point. Thank you. We will present the study more as a "sensitivity test". For instance, we will replace the sentences between P15L12 and P15L15 with the following text:

. . .This RCP scenario predicts only small changes of annual precipitation levels for many temperate regions. However, our approach analyzes only impacts of change in temperature. For instance, we do not simulate the effect of changing CO2 in combination with an increase of temperature. This might be critical for analysis of strong temperature changes (e.g. RCP 8.5), which will result in an increase of droughts and changes in the annual temperature cycles. Such more complex scenarios should be analyzed in future studies. Further, we neglect the effect of time lags (e.g. the bud building in the autumn in the previous year). However, it is possible to enlarge the used time series to analyze the behavior of the forest over longer time periods and study not

only productivity, but also effects on regeneration or mortality.

2) I think, even though referring to central European, temperate forests, you are not putting enough emphasis on the interpretation of the results from a forest management perspective. However, your target variable "above ground wood production" as well as the stand densities, species choices etc. are subject to forest management and species mixing etc. are important elements of EU silvicultural strategies. I think the discussion of the influence of forest management on your results and their implications for forest management should be strengthened. We agree that our result might be important for forest management strategies.

We therefore will add a new section "4.4. Implications for forest management" in the Discussion section (see Appendix R 2).

Thank you for these detailed smaller points.

P1L1: Either "Observational studies discovered that" or "Observations show that..."

P1L4: "increase productivity the most"

P1L8: "cover a wide range of possible"

We will reformulate the phrases.

P1L6: unclear: "within the forest structure" ==> don't you simply mean "within the forest given the environmental conditions of each..."?

We will write: ... how well species are distributed over the different forest layers regarding...

P1L11 and also L14: "increasing OmegaAWP" it sounds weird that an optimum can be increased or have "large values". Maybe I am too picky and I do not have a good alternative... maybe ask a native speaker...

We will introduce a new term forΩ_{AWP}: "species distribution index" but keep the acronym Ω_{AWP}.

P1L15: "heterogenity is associated with a positive"

We will reformulate the sentence, following your suggestion.

P1L14-16: This sounds like quite a contradiction: for young forests low diversity and low height spread make the forest react positively to temperature while for older forests this is not the case. Could you add one sentence of explanation here and discuss potential implications for forest management in the discussion? This would mean foresters should go for even aged, mono-species stands during establishment and then bring in other species later? or keep the canopy closed with one species while having other species in the undergrowth for some time?

We recommend paying attention to young forests with low diversity and even-aged structure. A mixture of climax species should be planted below the main canopy. Later those climax species will replace the pioneer species in the canopy and build the mature forest with heterogeneous tree sizes.

We will add a new section regarding the implications on forest management (Appendix R1).

P1L19: I have the feeling you are using "forest growth", "wood production" and "forest productivity" interchangeably. While this can be correct in some instances I wonder whether all the references you cite here actually refer to forest growth or rather productivity.

We will focus on (above-ground) wood production in the whole manuscript. Barber et al. 2000 analyzed the change in radial growth of white spruce under climate change. We will replace the references of Cao and Woodard 1998 (as it refers more to carbon fluxes of ecosystem in general and not explicit wood production) by Reyer et al. 2013. The other two refer to the effect of climate change on photosynthesis or respiration of

trees (Luo 2007) or plants (Penuelas and Filella 2009).

P1L21-P2L2: I think this sentence is imprecise. the observed changes in productivity are not the primary reason for discussing the compensation of co2. it is rather the overall high carbon stocks and sequestration rates (even without changes) that matter for this discussion. I see what you want to say but I think it is a bit too condensed here....

We will reformulate the sentences:

Changes in forest productivity have been observed in past decades all over the world (Nemani et al., 2003; Boisvenue and Running, 2006; Seddon et al., 2016). The carbon stock of forests and their role as carbon sink are therefore in danger. These findings stimulated discussions about whether forest management strategies can be adapted to reduce forest vulnerability to climate change, to support recovery after extreme events and foster the carbon sink function of forests.

P2L3-9: I think this section should also mention the influence of other factors, at least briefly... Especially since you say that "productivity is influenced by several factors" in the first sentence of this paragraph...

We will add the following sentences: . . . in addition to other climate variables (Barford et al. 2001). For instance, increasing CO2 increases water use efficiency of forests (Keenan et al. 2013), which could compensate negative effects of climate change on European forest growth (whereas, with constant CO2 at 350ppm, forest growth declines on several sites due to climate change - Reyer et al. 2014). Another important often investigated process is the fertilization effect of nitrogen (De Vries et al., 2006, 2009). For instance due to depositions in the second half of the last century, wood production had increased in European forests (Solberg et al. 2009). In case of temperature change, photosynthesis, respiration and growth rates are modified. . .

P2L18/19: "rarely include properties related to both species composition...

P2L22: "forests stands were available, it would"

P2L23.: "option to such field experiments is"

P2L26: "simulating 30 year time slices of a range of different future climates for 135..."

P2L27: "analyzed"

P2L29: "a large number"

P2L30: "species compositions"

Figure 1: I would delete the "..." in each box as your study does not cover more climate variables nor more stand structural or composition related variables. In the caption, I would precise: "overview of drivers influencing forest forest productivity in this study" and also clearly state that only temperature is varied in a "temperature sensitivity analysis" or so.

P3L3: "2017). The forest factory generates 370,170...and allows to estimate"

We will realize all these suggestions. Thank you.

P4L2: How to get from the 15 stem size distributions and 256 mixtures to the 370,170 stands?

The forest factory creates forest patches which are based on 15 different stem size distributions and 256 species mixtures. 100 forests patches of each combination are built (in total 15*256*100 = 384,000 forests). In a few cases not all species of the mixture could be placed within a patch by the algorithm, so these forests are rejected. We end up with 370,170 forest stands. We will reformulate section 2.2 of the Method section to clarify these points.

P4L3/4: At some point you should give the latin names of the species to allow international readers to check which species you mean...

Good point. We will add the Latin names in the section 2.2.

P4L6: I wonder how you can actually represent complex mixtures on a 400m2 plot. This could be covered by one large beech tree? I think you need to discuss the implications of choosing this patch size. Or do you upscale to the ha or so?

Within an area of 400m^2 the trees compete for light as large trees shade the smaller ones. This is the typical plot size used in forest gap models. You are right, a very large tree could cover such a plot but below its crown there is space for smaller trees of other species. However, there are indeed a few combinations of species mixtures and stem size distribution that could not be represented within a plot because of limited space. Thus, these forests do not exist in the collection of forests generated by the forest factory. We will reformulate the text in section 2.2. to clarifying these points.

P4L6: "space limits"

We will reformulate the text.

P4L8: You should discuss in detail why you think the year 2007 in Hainich is representative of temperate climatic conditions! I think you make two dangerous assumptions: 1) Hainich is somehow representative for "temperate climates" (it certainly is but only to a certain degree and 2) the 2007 climate is somehow representative of the overall Hainich climate

We agree. We use this year as an example of a temperate climate. (In principle, it is possible to use climate data of every other location). We will reformulate the text in section 2.2.

P4L11-22: This is from FORMIND, right? You could say that

We will add the following sentence at the beginning of the paragraph: The calculation of wood production of trees is based on algorithms of the model FORMIND (Fischer et al. 2016,).

P4L10: "2.2 Forest productivity..."

P4L15: "by the photosynthesis-limiting..."

We will use your suggestions.

P4L17/18: I read this as if Rm was both maintenance respiration and allocation to non-woody tissues?

This is correct.

P4L23: I would introduce a new subheading here about the "climate sensitivity"

We will add it.

P4L25: "separated" The methods description should be in the past tense

We will change the tense.

Figure2: You should explain once more all the variables shown on the plots in the caption, AWP and MAT are not explained currently.

Good point. We will modify the caption of Figure 2.

P5L1: unclear: do you include co2 and nitrogen in the model but keep them constant or are they not included at all? You should discuss that co2 will matter in a 2 $^\circ C$ warmer world...

They are not included at all. We will modify the sentence. See also the reply to your first major comment above.

P6L6: Do you have any reference or argumentation to support using BA as a proxy for LAI? I could imagine this only works until canopy closure?

In the forest factory dataset LAI and basal area correlate quite well (R^2=0.74). A high correlation between leaf area and basal area (R^2>0.92) has been found for instance also by Levi and Jarvis 1999.

P6L13: "maximum forest height"

We will replace the phrase.

P7L1-2: Is "10.2015" the right citation format?

No. We will correct the citation format to "2015".

P7L5: Why Gaussian? Any deeper reasons or simply because it is the default?

It is the default setting. We will modify the sentence: ... assuming a Gaussian error structure (default setting).

P7L8: the heading is unclear. "benefit the most" ==>from what?

We will add: ... the most from increasing temperatures.

P7L18-19: I wonder if the mean is the appropriate measure here given that the distributions are so skewed (figure b1)?

Figure B1 shows the distribution of the SI values. The shown SI values do not represent mean values; they are the slope of linear models, which relate temperature changes with AWP changes divided by the average AWP of the forest (see equation 2, 3 4). We will modify the sentence: We than quantified the changes in productivity due to changes in mean annual temperature (SI_{MAT}) and amplitude of inter-annual temperature (SI_{Q95}).

P7L28: This has to be carefully discussed. It seems to be obvious that the species choice will have the strongest influence.

Thanks for this point. We will modify the sentences at P11 L16ff: ... If species have an unfavorably distribution within the forest (low Ω_{AWP}), the wood production (AWP) of the forest is low. Note, Ω_{AWP} is the ratio between current AWP and the highest possible AWP of the forest which can be reached due to shuffling of species identities. If AWP is low the forest will suffer from increasing temperatures, which results in negative slopes (ΔAWP / ΔT). These values are than divided by low AWP values (Equation 4), which results in large negative values of SI_{MAT} and SI_{Q95}. (See Appendix B5).

Figure 3: maybe explain somewhere (can be in the main text) how to interpret the scale from 0-1 of the Ω_{AWP}.

We will add an explanation in the caption of figure 3.

P8L12: "analysed how"

We will reformulate the phrases.

P8L12: Maybe recap here that AWP is your expression of productivity.

We will replace forest productivity by (above-ground) wood production. See also reply to your comment P1 L19.

P9L1: "specific value combination of forest properties" ==> rephrase

We will write: ...with a specific set of forest properties which...

P9L5/6 12-14: Certainly analyzing all possible combinations of species and structures etc as done in the Forest Factory approach is valuable but this approach will also generate a huge number of stands which are highly unrealistic and that will never be found in reality. So the discussion could be more balanced here highlighting that you also produce quite a lot of "non-sense" forests as well.

This is an important point of the forest factory approach. All forest patches could exist in reality, as every tree has a positive productivity and enough space for its crown. It is not possible that "non-sense" forests are generated as the used method prevents that a light demanding species occurs below a closed canopy or that forests are overcrowded. We will revise the text to makes this clearer (see Appendix R 5.6).

P9L10: "FORMIND"

We will replace the phrase.

P10L2-3: This sentence needs to be rewritten for clarity

We will remove this sentence.

P10L11: RCP2.6

We will correct this.

P10L15-28: I had the feeling this section needs to be rewritten for clarity and logical connection to the preceding sections.

Thanks for this comment. We will reformulate the section in the following way: To characterize the annual cycles of temperature we select two variables: mean annual temperature (MAT) and inter annual temperature amplitude (Q95). Both variables can be varied independently. In case of higher MAT we observe an elongation of the vegetation period. This leads to higher forest productivity, if other resources are sufficiently available (Luo, 2007). This explains why SI_{MAT} is often positive. However, warmer summer temperatures can also lead to a decline in wood production due to an increase in respiration. In case of increasing Q95, more days with extreme temperatures will occur in a year. Thus, an increase of one $^{\circ}C$ of Q95 will increase respiration more strongly compared to an increase of one $^{\circ}C$ of MAT. Hence, the increase of Q95 has normally negative effects on the productivity (negative SI values).

P11L3-12: Also here maybe some rewriting is needed to better link the paragraph to the rest of the discussion.

We will modify the two paragraphs of section 4.2.

P13L5: I find the conclusions too short and too close to the results. The conclusion in my view should clarify: Why do your results matter? What do we learn?

We will extent the conclusion and include implications of our study for future forest modelling and forest management. (See also Appendix R3: new conclusion)

P13L12: I find the supporting material organized in a complicated way. Can you not provide the text plus the associated figures and then another piece of text etc. The online material is not meant to be read as one text but one should find things quickly.

We will rearrange the text and figures as suggested.

Figure A2: I am pretty sure you are showing the annual precipitation sum and not the "mean" here.

Correct. We will revise the sentence.

P15L4/5: I do not understand this: it seems mean (1.5%) is outside of the interquartile range?

The unit is $\%^{\circ}C^{-1}$. This means that on average forest increase their productivity by one % if temperature increases by $^{\circ}C$. The interquantile range of 95% (Q95) is used only to quantify the interannual temperature variability. We will modify the sentences to make this clearer:

Figure A3: hec should be ha

P16l5: "the first plot" ==>not very precise. Do you mean plot 3a)? Then also include small letters in the plots!

We will follow your suggestions.

P16L6: I would always refer to âĎęAWP and not introduce any other terms such as suitability etc. it is getting too complicated...

We will modify text and figure.

Figure A4: To me it looks like You are overestimating SIMAT quite systematically but you never really discuss this?

Good point. It is quite difficult to evaluate the theoretical analysis by using field data, as a huge number of similar forest plots are needed, which cover a temperature gradient. In case of the German forest inventory only a few forest plots can be used for such an analysis. For spruce and beach monocultures we were able to select enough similar plots. Further, these inventory plots provide no direct measurements of climate or

LAI, which would be needed for an appropriate evaluation. We therefore used altitude as proxy for temperature (although other environmental variables like precipitation or soil attributes could change as well with altitude) and basal area as proxy for LAI. The reason for the overestimates of SI_{MAT} is not clear, but might be a result of the differences between SI_{MAT}-calculations based on field data and the calculation of SI_{MAT} based on the forest factory approach. We will add some sentences regarding this point to the Appendix.

P17L6: sentence misses a verb

We will revise the sentence.

Figure b3: I wonder why there are so distinct patterns of values with y=0 and also x=-100 in panel a and y=-8 (or so) and x=-100. Is this an artifact?

The vertical dots occur as all forests with SI values smaller than -100% $°C^{-1}$ where set to -100% $°C^{-1}$ for this graphic. To be consistent, we will remove them, also as they were removed for the final analysis, which is presented in the paper. See page 6, line 4 of the manuscript: . . .In our analysis we exclude all forests stands for which AWP turns negative if the temperature rises by 1 $°C$ (2% of all stands). I assume the horizontal structure is an artifact of the boosted regression tree algorithm. We will reformulate the corresponding sentences.

P18L2: "in some simulated"

P18L7: "we calculate a mean..."

Figure B5: panel "b)" is missing the "b)"

We will reformulate these phrases and add the "b)".

Figure B6: The layout of this figure makes it very hard to see which color overlays the other ... so do most "brownish" species rather follow the green line or the dark blue for the left-side of the bell-shaped lines in panel a)?

We will revise the figure based on a modified color-palette and enlarge the graphic.

Figure B7: Is nowhere referred to in the text. What is the unit of the y-axis?

It will be referred in the text and the text will be reformulated and we will revise the figure.

Figure B8: The SIMAT values are so small, is that correct?

We forgot conversion into % (multiplication by 100, as done in all the other graphics). We will also add the unit to the y-axes.

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2017-335/bg-2017-335-AC3-supplement.pdf

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