

# ***Interactive comment on “Leaf Area Index Changes Explain GPP Variation across an Amazon Drought Stress Gradient” by Sophie Flack-Prain et al.***

## **Anonymous Referee #1**

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## **Referee comments**

The authors investigate the importance of different drivers (LAI, leaf traits, climate) for GPP at both temporal and spatial scale across a drought stress gradient in the amazonian region using the Soil-Plant-Atmosphere (SPA) ecosystem model. The SPA model is applied at 7 sites, using sites specific parameters and is forced with LAI observed from hemispherical photographs. Simulation experiments and machine learning techniques are used to investigate their scientific questions. They find that indirect effects via plant traits and ecosystem structural changes, here expressed as LAI, are found to be the main driver of GPP across a spatial drought gradient, but the sensitivity of GPP to changes in these drivers varied with the gradient. On a sub-annual timescale climatic drivers were found to be more important for GPP. The authors discuss how these

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direct physiological and indirect mechanism affect GPP but fail to explain the added value of forcing their model with observed LAI and to explain in detail how this forced LAI propagates down the modelling structure of SPA. The manuscript is well written and well structured, however, with many repetitions that should be deleted to make space for more details on your methods. As explained in detail in the comments below, I would like the authors to consider my questions and comments, before I recommend the publication of this manuscript.

### General comments

- Throughout the manuscripts, your hypothesis/conclusions are repeated (abstract, introduction, discussion, and conclusion). This takes up a lot of space that could otherwise have been used elsewhere in the manuscript. Therefore, I urge you to delete several of these repeated paragraphs. Please see the specific comments below for my suggestions.
- The title *Leaf Area Index Changes Explain GPP variations across an Amazon Drought Stress Gradient* is not surprising as LAI generally scales well with GPP, and hence you would expect the changes to do so as well. Moreover, as also stated in the manuscript, the changes of LAI are affected by drought stress, and thus it is indirectly the drought stress that is causing the variation in GPP. Lastly, the title does not fully cover all three research questions made by the authors in the manuscript, although it points towards your most interesting finding. However, I would suggest that you reconsider the title.
- Several times you state that changes in LAI is an indirect structural effect from changes in soil moisture. From there, it follows that it is LAI which drives the GPP across the MCWD gradient. A strong emphasis is throughout the manuscript put on LAI and LAI as a driver of GPP, while LAI is strongly impacted by drought stress. However, the model is forced with LAI from hemispherical photographs,

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but the authors do not explain how the forced LAI is linked to and impact the simulated soil moisture content. From Fig. 2 it follows that LAI impacts the foliage carbon pool, and this pool together with carbon pool of fine roots and soil moisture impacts GPP, but the link between the forced LAI and soil moisture is not well explained for your model setup. Please clarify this in the manuscript.

- Several times you briefly mention the C allocation (line 232 to 241, Fig. 2 and Supplement material). In the text you state that allocation to  $NPP_{leaf}$  occurs first. Normally NPP is considered a flux, and normally you would allocate to a pool. Thus, do you mean that allocation to the foliar stock occurs first? If assimilation does not provide the C need for allocation to support the LAI, you take from the labile/non-structural carbon pool. However, in the supplement material in the last three equations, you state that if the labile pool has been depleted you allocate from the total NPP. Surely this must only be the case when you have enough NPP to sustain the foliar stock as required by the LAI. Please clarify this in the manuscript.

### Specific comments:

Line 88 can be read as if you say LAI is a trait. Conventionally, LAI is not considered a trait (you could use max LAI), but rather relates to the ecosystem structure. Thus, for clarification could you please consider rephrasing the sentence to e.g.: *Changes to both ecosystem structure and traits, such as LAI, rooting depth and carboxylation capacity, are expected to be more longstanding (Meir et al., 2015a).*

Line 142-162 As the introduction is already very long, and much of your hypothesis is repeated later in the manuscript, I would highly recommend deleting these paragraphs.

Line 175-181 These lines are almost identical to your scientific research questions listed in the introduction. Please consider deleting one or the other.

Line 232-234 You state that the mapping of canopy dynamics is critical, and that

changes in canopy dynamics cause disparity between field observations and model predictions – how well is canopy dynamics simulated by SPA? How is the LAI forced over the canopy layers in SPA? Please elaborate on these aspects in the manuscript and explain how your study improve these shortcomings.

Line 232-237  $NPP_{Leaf}$  was calculated as the difference between the foliar C stock of the previous time step and that which would equate to field measured LAI. The field measured LAI has a monthly resolution. In principle you would have foliar C stock that could change at every model time step. But if the foliar C stock already equates to the field measured LAI, because the resolution of the forced LAI is monthly,  $NPP_{Leaf}$  would just be zero.

Line 239 This sentence is not clear.

Line 243 How was the SPA model calibration constraint by an upper and lower sample error of LAI? Please add clarification to the text.

Line 301-302 These lines are repetitions, and not needed. Please consider deleting.

Line 308 There is something wrong with the structure of this sentence.

Line 320-325 The correlation between GEM estimated and SPA simulation GPP are non-significant and moderate. As GPP is imperative for your analysis, have you considered the impact it might have on you results? Have you investigated how the GEM estimated GPP relates to the LAI form the hemispherical photographs?

Line 326 Please explain why the  $GPP_{SPA}$  variance is calculated under the LAI standard error.

Line 401-410 This paragraph sounds like a conclusion, and since you have a Conclusion section, where this is also stated, I would suggest you delete this paragraph.

Line 437-449 You mention how changes in LAI is a response to precipitations regimes, and even call it a key response mechanism. Then, one could infer that it is just as

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much changes in precipitation that explains the changes in GPP as it is LAI. You state that changes in LAI is an indirect effect from climate — although the impact might be somewhat delayed, but did you investigate lagged correlations and variances between precipitation and GPP?

Line 452 You do not have a forest at steady state, if it is changing and experiencing trends. Please explain what you mean by a steady state forest – is it continuous cover, constant number of trees etc.? Or better yet refrain from using the term.

Line 465-468 With the SPA model you are not able to quantify the impact of soil nutrient on the GPP-MCWD interactions because you lack nutrient cycling in the SPA model. However, according to Table 1 there is a huge P gradient across your sites, therefore please discuss how this could possible affect your results.

Line 477 It is unclear which analysis this sentence is referring to. Your analysis or the work by Quesada et al 2012 mentioned in the previous sentence? Please clarify and elaborate on this statement.

Line 515 What do you mean by GPP is demand limited across spatial scale? Is it the atmospheric transpirational demand? And how does this relate to your already conducted analysis of you results? According to your own analysis, LAI is explaining most of the variation across the spatial scale (sec. 3.5.1, sec. 3.5.2, and 4.2). You must elaborate on the statement.

Line 517 In this section, or possible add another section to the discussion, you will also have to address the uncertainties from the intrinsic model behaviour. You recognised already in line 245 that the model uncertainty is underestimated due to the lack of intrinsic model error. However, during your discussion this is not assessed at all. Please assess these uncertainties in particular in relation to the moisture stress and how the plant hydraulics is modelled in SPA and acknowledge its limitations.

Line 544-546 Something is wrong with this part of sentences. Please rephrase.

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Line 549-551 I agree. And to my knowledge, some models already do so.

Line 576 According to the manuscript preparation guidelines for authors for Biogeoscience, Journal names are to be abbreviated according to the Journal Title Abbreviations by Caltech Library

(see [https://www.biogeosciences.net/for\\_authors/manuscript\\_preparation.html](https://www.biogeosciences.net/for_authors/manuscript_preparation.html)).

Line 1010 Table 2, delete 'subsequently allowed to fluctuate'. This is already implied by being initial conditions.

Line 1095 Figure 1,  $NPP_{Leaf}$  does not classify as a trait. Please correct the figure accordingly.

Supplement Material:

Please use accurate mathematical expression (e.g. then; should be  $\Rightarrow$ ) and make sure the equations are not in italic.

Please consider numerating your equations

If the LAI is forced using monthly time series, then how does the LAI change between the daily time steps in the calculations for  $NPP_{Leafi}$ ? Is it because you nudge the LAI, and hence not force it at every time step? Please clarify.

As mentioned already, the three latter equations are confusing. If the labile pool is depleted ( $NSC_i < NSC_{i-1}$ ) then you allocate from the total NPP pool to the labile pool. I assume that this is only the case when  $NPP_{Leafi}$  is met by the daily assimilation? Please clarify and complete your sets of equations for all cases.

### Technical corrections:

In general, Please reconsider the usage of the word whilst – it reads a little pretentious.

Line 32 Abbreviate GPP in line 32, not line 34

Line 88 Abbreviate LAI in line 88, not line 90

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Line 100 Please change p50 to  $\psi$ 50

Line 195 Please Abbreviate NPP here

Line 307 Add a space between the two sentences.

Line 473-774 Add *they* to the sentence: . . . so they may be acclimated. . .

Line 716 Please change CO2 to CO<sub>2</sub>

Line 716 Please change CO 2 to CO<sub>2</sub>

Line 929 Please change CO 2 to CO<sub>2</sub>

Line 981 Please change CO2 to CO<sub>2</sub>

Line 996-999 Table 1: Please include the abbreviation of RAINFOR in the Table 1 text. Should RAINFOR be above the second horizontal line? Is there no site code for Tanguro? Please use correct degree symbol for the unit of Mean annual air temperature. Would it be possible to add species composition or just dominant species at each site to the table?

Line 1095 Please delete the single parenthesis in this line.

Line 1112 Please correct nodule to module.

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