Response to the comments of referee 2 on Sakschewski et al. 2020: Variable tree rooting strategies improve tropical productivity and evapotranspiration in a dynamic global vegetation model

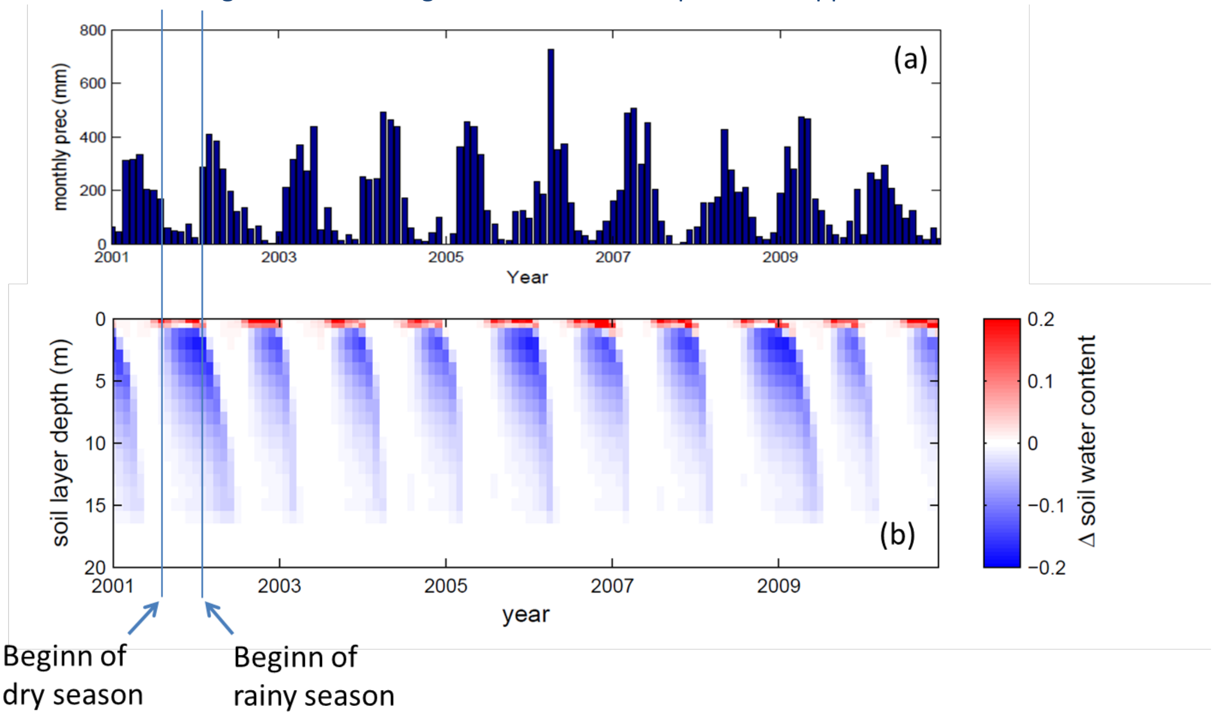
I like many aspects of this paper. In particular I appreciate the approach of carefully examining the behaviour of the model across a range of climate scenarios,
Overall I think this paper and model variant have great potential. The new scheme is clever and I have little to critique in its design. The various analyses do suggest the new model is providing a better match to available data. But I am yet to be convinced this improved match is for the reasons the authors claim (better handling of soil water & rooting).

Dear Daniel Falster,

Thank you very much for your positive evaluation of our approach.

The biggest concern I have is that despite all the results presented, these mostly for aggregate outputs at largish spatial scales. Almost no evidence is presented to show the effect of the new scheme on the actual water balance in the soil. Moreover, we don't even know how water is modelled in the different versions. Sure, the soil and root depth is changed, but what does this mean for water balance at different soil depths? Surely this is key to assessing why the model behaves differently. This is important, as the changes in rooting will also change the way carbon is allocated within the model (e.g. deeper roots divert carbon away from leaves). Are the model improvements due to changes in hydraulics, or changes in carbon allocated between leaves and roots?

Thank you very much for raising this point. Indeed we did not explicitly explain how the water perculation scheme and water balance of LPJmL works. We inserted a new description of this part of the model in line XX-YY. We agree that we do not present results of how the new scheme affects the water balance in the soil. However, we compare the results of our new scheme (LPJmL4.0-VR) to a baseline model (LPJmL4.0-VR-base). LPJmL4.0-VR-base differs from LPJmL4.0-VR only in the amount of tree rooting strategies present. Both models have the same soil depth information. Hence, soil hydraulics are the same as well and differences in evapotranspiration, net primary productivity, biomass and PFT distribution only arise from the absence/presence of different tree rooting strategies. Deeper roots clearly correlate with higher evapotranspiration and productivity during dry seasons. When shallow roots lead to decreasing evapotranspiration in dry seasons, then the water used for evapotranspiration by deep rooted sub-PFTs must come from deeper soil layers. Regardless of knowing the exact soil water balance we argue that this evidence is presented. The fact that deep rooted sub-PFTs are selected for in regions with deep soils and a dry season, even though deeper roots are more costly than shallow roots, proves that diverting carbon away from the leaves into a deeper root system can be beneficial for the overall carbon balance. Therefore, the differences in the results between LPJmL4.0-VR and LPJmL4.0-VR-base must be related to the new rooting scheme and not to soil hydraulics. Nevertheless, we prepared a new potential supplementary figure (SF X) which we pasted right under this specific response. It shows the difference in monthly relative soil water saturation between LPJmL4.0-VR-base and LPJmL4.0-VR at STM KM67, for 2001-2010, for all 23 soil layers (so LPJmL4.0-VR-base minus LPJmL4.0-VR). Here blue colors depict a lower soil water content in LPJmL4.0-VR compared to LPJmL4.0-VR-base. The figure clearly shows how deep water is extracted by deep roots in the dry season and how the soil water balance changes over the year. With regard of your general suggestion to shorten the manuscript and to reduce the amount of figures we hope not to include this figure or further figures in the manuscript or the supplement.



Supplementary Figure X: Difference in soil water reaction to seasonal precipitation between LPJmL4.0-VR-base and LPJmL4.0-VR at Fluxnet site STM KM67 a) Mean monthly precipitation input from CRU for 2001-2010. b) Difference in relative soil water content between LPJmL4.0-VR-base and LPJmL4.0-VR forced with CRU climate for 2001-2010. The underlying model output variable "soil water content" of each model version is a number between 0 and 1 depicting the relative water saturation of the soil. Blue colors denote a lower soil water content in LPJmL4.0-VR and red colors a lower soil water content in LPJmL4.0-VR-base.

Second, I feel the authors need to come up with a stronger story and reduced set of results. The paper is currently very long and dense. The authors have made many comparisons using a variety of datasets. Consequently, there is a large number of figures (15) and tables (8). This makes it hard for us to know where to put our attention.

Thank you very much for this suggestion. Indeed the manuscript is very long as variable roots changed a variety of model results for the better. We agree that a clearer story helps to convey the most important messages. We now formulated a clearer research question "What is the role of diverse tree rooting strategies for productivity and evapotranspiration in tropical South America?" and highlight it in the introduction now in line XX. We will shorten the manuscript according to this question and transfer several figures and tables to the supplement.

Finally, more work is needed to make the different results accessible and easy to interpret. I found that each figure required a fair bit of work to interpret what is going on. Some simple changes could make it much easier for the reader, then we could spend less time deciphering your results and more time thinking about the science!

Thank you for raising this very important point. We will check every figure, insert more information like labels into the figures and simplify the captions and labels.

As examples,

Thank you very much for pointing out all these examples.

- In Fig 1: confusing caption. Simplify labels in legend.
We now simplified the caption and reduced the complexity of the legend labels.

- In Fig 6: label panels with dataset name, so that we don't need to refer to legend as much
We now label each panel as suggested.

- In Fig 9, uses different colours in the map and traces, otherwise these are easily confused. Label each subplot with site name.
We decided to use no colors for the location markers instead using a different symbol for each location. We inserted the site name in each panel as suggested. We applied the same approach in Fig. 10.

- In Fig 12, put labels on the columns (evergreen, deciduous) and rows (models), so that we can easily see what the different panels are without constantly referring to the caption.
We labelled all panels according to the suggestions.

Some minor issues
- Some line breaks between paragraphs would make the text much easier to read
Thank you for raising this point. During shortening of the manuscript and strengthening the story line we will insert more line breaks.

- Eq 8: I've looked over this a few times and wonder if the n_est_tree at the end should be removed?
Thank you for this question. Yes this is true. The 2 times occurring n_est_tree can be cancelled from this equation. We kept it in for an easy comparison to the original equation (Eq. 7). We think this makes it easier for model developers to copy our approach.

- ln 413 – It didn't make much sense to me to compare your results to a modelled product of rooting depth.
Thank you for raising this point. We completely understand this criticism. Since empirical data on rooting depth in this region is very sparse, we wanted at least evaluate our results in the context of a totally different modelling approach. With regard to shortening the manuscript we now moved the comparison to the supplement and avoid a detailed comparison of our results with Fan et al. (2017).

- I found the talk of offspring, saplings, and "growth" throughout the paper a bit misleading. My understanding of this version of LPJ is that each patch has a single functional type which has a density 'n' of average sized individuals. When new offspring are recruited, they don't grow from seed to adult, but rather enter fully formed at the average size (this occurs by increasing n, the number of individuals). The only time the individuals seemingly grow from small to large plants, is when starting from bare soil, i.e. during spin up. Yet, often the paper gave the impression that individuals could be born and grow.

Thank you very much for this criticism. We fully agree. Apparently, it is always a thin line between easy wording and correctness of model description. We now clarify "offspring", "saplings" and “growth” in the methods now in line XX and avoid any misleading formulations in the entire manuscript.