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Reply on RC2

Vera Porwollik et al.

Author comment on "The role of cover crops for cropland soil carbon, nitrogen leaching, and agricultural yields – a global simulation study with LPJmL (V. 5.0-tillage-cc)" by Vera Porwollik et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-215-AC2, 2021

Dear referee#2, thank you very much for your comments and suggestion to improve our manuscript. Please find below the suggestions of referee#2 (**bold**), and our responses to the individual points (normal font):

Ref#2: My main comment is with the presentation/organization of the paper. There are three main model simulations: 1) cover crops, 2) no till, and 3) both. Yet, these three simulations could be presented in a more consistent way. For example, Table 1 describes the soil C sequestration of cover crops only. I was also expecting to see analogous tables for tillage and CCNT.

In the main text, we focus on the analysis of cover crops effects (CC) and their sensitivity to tillage and no-tillage (CCNT). The results for the no-till scenario (NT) are merely indented to support the interpretation of differences between the CC and CCNT scenarios. To improve the balance between CC and CCNT results in the paper, we will shift Figure S2.5 to the main text (as also requested below) and improve the presentation and discussion of CCNT results where needed. To address the request by referee#1 we will move Table 1 to the discussion as it solely provides a summary of CC results for comparison and evaluation of model results to literature estimates.

Since we lack corresponding literature values for CCNT we cannot provide an analogous table for CCNT results. However, for comprehensiveness we will add overview tables similar to Table 1 but without literature values for CCNT and NT to the supplement.

If similar literature estimates have already been provided in previous work on LPJml-tillage2, then perhaps the authors could refer to that, but CCNT is a new interaction that has not yet been modeled with LPJml, so I think that it merits a comparison to observed values.

Unfortunately, we were not able to find appropriate literature values to validate our CCNT results directly. Therefore, we have also provided the results for the no-tillage setting (NT scenario), which has been extensively validated in Lutz et al. (2019) for a previous LPJmL code version. Together with the here presented evaluation of the CC results obtained with the model, we assume this to be the best available option to support the interpretation of CCNT effects. We will clarify the role of the NT scenario in the revised manuscript and improve its utilization for the interpretation of CCNT results, especially regarding soil N and water effects.

Again, Figure 4 only shows productivity response to cover crops, while all of the other figures show all three model simulations.

As requested below we will move S2.5 to main text and will add the 4 maps for productivity impact of NT into the SI.

I would also be interested to know if LPJml predicts a similar total C stock (and maybe yield, veg C, GPP, NPP..) as LPJml-tillage2 from Herzfeld et al. (2021) or LPJml4 (Schaphoff et al. 2018b), basically to show if the model is indeed similar except for these new features.

LPJmL5 fundamentally differs from LPJmL4 in that it includes a mechanistic representation of the N-cycle. Resulting differences in model behavior are presented and discussed in von Bloh et al. (2018). Herzfeld et al. (2021) uses a very similar model code to ours, which differs mainly in the implementation of cover crops. However, the results presented in Herzfeld et al. (2021) are not entirely comparable to ours, because we use another simulation protocol. We will include the reference to von Bloh et al. (2018) in the revised manuscript and point out the similarity between model versions used in Herzfeld et al. (2021).

L54: A word is missing, maybe: "by this [method] may"

Yes, we will modify the text to '...and in this way may reduce fertilizer...' .

L67: Change "glass" to "grass"

We will rephrase the sentence, because here we refer to area covered with green houses made of 'glass' in contrast to bare soil or vegetated ground cover- it is the wording for categories used in the cited EUROSTAT statistics on 'soil cover'.

Mention somewhere in the methods that LPJml simulates all of the crops mentioned in TablS1.1 but that in this paper, you only focus on maize, rice, wheat and soybean. I think it is fine to focus on the four major crops, but it is worth highlighting to readers that there are others. It is also worth noting if they are included in any crop averages or totals reported in the paper.

We will improve Sect. 2, adding that we do model all crop types as indicated in the Table S1.1. Further, we add that we focus the productivity impact analysis on the four crop types because of their global relevance as staple crops for food security and their large shares on cropland. We will also clarify that results for soil C and N leaching always refer to the entire cropland within a grid cell.

Figure 5: It would be useful to know the number of grid cells (or whatever spatial unit is being used) in Figs 5, S2.4.1, and S2.4.2. From looking at the three graphs together, it looks as though most locations are rainfed rather than irrigated, and that the small response and variability of the irrigated locations could also be due to the lower sample size.

We will add the corresponding numbers of grid cells and area covered by each crop type (and per water regime) to the graphs in Fig 5 and Fig. S2.4.

L315: Here the authors mention that there is a time lag in response of soil C sequestration rates, and while perhaps one could detect a change in soil C using a model, I would not expect field measurements to reflect soil C changes for at least a few years, due to the relatively small signal in such a large pool.

We agree. Also the authors cited in that paragraph, e.g. (Blanco-Canqui et al., 2015; Laborde et al., 2020; West and Six, 2007) in their reviews and meta-analysis do find delayed responses on soil C and yields after switching to cover crop or generally to another soil management practice. We will mention the challenge to detect changes in soil C and other variables in the first years after switching to another soil management practice in field experiments.

L335: Could be useful to know how you define equilibrium.

Our assumption on 'equilibrium' as effect detected in our alternative management simulations are based on Poeplau and Don (2015), who defined "the new steady state to be reached after the annual change in SOC stock fell below 0.01 Mg ha-1 yr-1.". We will add this definition in the revised manuscript.

L463: I would say "model prediction" instead of "quantification" here. In general, it would be good to use language recognizing that these are model predictions and not measurements.

Thanks for hinting to this, we will improve the wording in the entire MS to make clearer and harmonize for model 'projections' or 'simulation' results.

L484: Perhaps "conclude" instead of "resume"?

We will improve for 'conclude' instead of 'resume'.

Table S2.1: It is interesting that yields tend to increase with CC for specific crops, but in non-legume averages, yield losses tend to be larger than the modeled losses. Why do you think the meta-analyses disagree with the national statistics?

We will add to the discussion for model evaluation that values derived at field scale measurements under highly controlled conditions may reflect local conditions rather than covering the variance of environmental and socio-economic conditions captured with the global model set-up applied here.

Figure S2.5: I know there are already a lot of figures in the main manuscript, but this one seems as important as cover crops to the paper's main conclusions.

We will move the Fig. S2.5 to the main text.

Optional, just a thought: It would be interesting to see if the C that is "lost" as a result of a reduction in yield is proportional to the C gained in the soil. It seems for example, that land management practices with less yield loss (like NT) also have less soil C gain.

Cover crops have a stronger impact on water, carbon and nutrient cycles than no-tillage alone, which leads to smaller effects, in general. Yield changes in the CC and CCNT scenarios are very heterogeneous across crop and do not appear linked directly to changes in soil C. Nevertheless, we will investigate these aspects in our analysis if appropriate. Soil carbon dynamics are additionally determined by the spatial pattern of the crop type, the crop specific growing season length, fertilizer (Fig S1.2b), and other crop management modeled at the grid scale, which we will emphasize more in the discussion.

References

Blanco-Canqui, H., Shaver, T. M., Lindquist, J. L., Shapiro, C. A., Elmore, R. W., Francis,

C. A., and Hergert, G. W.: Cover Crops and Ecosystem Services: Insights from Studies in Temperate Soils, Agronomy Journal, 107, 2449-2474, doi: https://doi.org/10.2134/agronj15.0086, 2015.

Herzfeld, T., Heinke, J., Rolinski, S., and Müller, C.: Soil organic carbon dynamics from agricultural management practices under climate change, Earth System Dynamics, 12, 1037-1055, doi: 10.5194/esd-12-1037-2021, 2021.

Laborde, J. P., Wortmann, C. S., Blanco-Canqui, H., Baigorria, G. A., and Lindquist, J. L.: Identifying the drivers and predicting the outcome of conservation agriculture globally, Agricultural Systems, 177, 102692, doi: https://doi.org/10.1016/j.agsy.2019.102692, 2020.

Lutz, F., Herzfeld, T., Heinke, J., Rolinski, S., Schaphoff, S., Von Bloh, W., Stoorvogel, J., and Müller, C.: Simulating the effect of tillage practices with the global ecosystem model LPJmL (version 5.0-tillage), Geoscientific Model Development, 12, 2419-2440, doi: https://doi.org/10.5194/gmd-12-2419-2019, 2019.

Poeplau, C. and Don, A.: Carbon sequestration in agricultural soils via cultivation of cover crops – A meta-analysis, Agriculture, Ecosystems and Environment, 200, 33-41, doi: https://doi.org/10.1016/j.agee.2014.10.024, 2015.

von Bloh, W., Schaphoff, S., Müller, C., Rolinski, S., Waha, K., and Zaehle, S.: Implementing the nitrogen cycle into the dynamic global vegetation, hydrology, and crop growth model LPJmL (version 5.0), Geoscientific Model Development 11, 2789-2812, doi: https://doi.org/10.5194/gmd-11-2789-2018, 2018.

West, T. O. and Six, J.: Considering the influence of sequestration duration and carbon saturation on estimates of soil carbon capacity, Climatic Change, 80, 25-41, doi: https://doi.org/10.1007/s10584-006-9173-8, 2007.