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## Comment on bg-2021-215

Anonymous Referee #1

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Referee 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-RC1>, 2021

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The manuscript by Porwollik et al. presents a study using a new version of the land surface model LPJmL to simulate the effects of cover crops on soil C sequestration, nitrogen leaching and yields at global scale and for 4 crop types: wheat, maize, rice and soy beans. Cover crops are a promising element of conservation agriculture that may help to reduce climate and other environmental impacts of agriculture. Their impact on crop yield can be negative or positive, depending on climate and other land use practises (e.g. irrigation). Land surface models like LPJmL are a potentially valuable tool to assess the impact of these practises at global scale taking into account geographic differences in climate, soil properties and other land use management practises. While land surface models are regularly used to simulate the interactions between climate and biogeochemical cycles under various anthropogenic perturbations, the representation of land use management, including practises of conservation agriculture, is relatively novel or not yet well developed. Accordingly, the methodology presented in this paper is very promising, but will require future improvements. The study finds that cover crops have the potential to increase soil C sequestration and reduce nitrogen leaching substantially, but with large variations across different climate zones and between rain-fed and irrigated agriculture. Comparison to empirical studies reveals the reasonability of the overall range of simulation results, but also reveals persisting uncertainties and shortcoming with regard to the representation of additionally important processes.

I think this manuscript is very interesting and would fit very well into this journal. The MS is very well written, and I only have some comments requesting some clarifications and maybe a few more detailed analysis (in particular for the model result vs. literature comparison). I recommend publication after some moderate revisions.

Comments to the authors:

Abstract:

You should give a bit more information about the simulation set-up. For what period/condition did you run the spin-up? Did you do a transient run without cover crops before the 50 year period with cover crops? What does that 50 year simulation period represent, actually 50 years of the historical period to present day, 50 years of projection into the future, or do you simply loop over some years of climate forcing? Do your simulations account for changes in atmospheric CO<sub>2</sub> which would affect the soil C uptake as well? These are all important details that you should shortly mention in the abstract.

Introduction:

The introduction is overall quite well written. I miss however a bit the connection between the last paragraph of the introduction, which lists the specific objectives of the study, and the rest of the introduction section. It would be good if you could work out some existing research gaps that you could fill with your study, and maybe formulate at least one major, overarching research question. (I guess that research question will ask for a global scale, quantitative assessment of the potential of cover crops to increase C storage and reduce N leaching, for a certain number of globally important crops, accounting for differences in climate and soil.) In that context, it would also be good to summarize a bit the potential of land surface models to answer such a research question. In that context, you should also give the state of the art of the use of land surface models for this kind of research (in a broader sense: impact of agricultural land management on C and N cycles), and highlight what is new in your study compared to older studies applying land surface models, and in particular to studies (maybe also of your group) using older versions of LPJmL.

In the last paragraph with the specific objectives, you should also mention that you only do simulations for herbaceous cover crops.

Methods and data:

L93: "model skills" – you mean "model performance"?

L96-98: Why do you mention that? Did they do an evaluation of model performance that would support your study?

L106-109: I am not sure why you are mentioning that. Is that to show a limitation in existing models that you might want to overcome? This is not clear to me. It also seems that this could be put into the introduction section, where you should outline the state of the art for this kind of model approaches (see my comment on the Introduction).

L110-113: So you only use grass like cover crops? That should be mentioned already in the introduction. Do you use the three different grass types (tropical C4, temperate C3, and polar C3 grass) depending on the climate zone?

Section 2.2: Could you say something about your scenarios from fertilizer and manure application? Do you represent irrigation? Or is it all rain-fed agriculture?

L126-129: Did you do that spin-up for present day conditions, or for pre-industrial conditions (in particular with regard to atmospheric CO<sub>2</sub>)? That is not clear. Does atmospheric CO<sub>2</sub> levels impact vegetation-soil carbon dynamics in your model? Which climate forcings did you use? What years do they represent? These are important details and should be mentioned here.

L130-136: With that spin-up, did you bring the C and N stocks on cropland in steady state for conventional management practises? If so, I do not understand the sense of the first spin-up?

Results:

Table 1: You only start to discuss that table in the discussion section. I would suggest to move this table there, as it mainly serves comparison between simulation results and literature values. Why don't you also show the results for CCNT in this table? In the last subsection of the results section, you present the statistics applying as mask the map of areas where conservation agriculture was actually applied during 1974-2010. I guess it would make much sense to use that mask also for this table here and the comparison between model results and literature values, in particular for the impact of cover crops on yields.

L256-259: I guess this is because in drier regions, you simulate irrigation, as you mention below. But in fact, in drier regions where water is limited, you might want to abstain from planting cover crops if they lead to additional evapotranspiration losses. You should come back to that thought in the discussion section.

L274-278: Is that because under rain-fed conditions, cover crops increase the water limitation for the cash crops? What is the irrigation scenario: do you always fully irrigate or is there deficit-irrigation possible? Do you take into account the limited availability of irrigation water? Under irrigated conditions, are cover crops irrigated as well?

Discussion

L300-301: See my comment for table 1. It would make much more sense if you masked your results by the map of conservation agriculture. If you use the statistics including areas where conservation agriculture incl. cover crops is not yet applied (maybe because of water shortage that would be increased by cover crops), your simulation results are not comparable to empirical findings. Further, it would make more sense to also compare model results vs. observations per regions, and further distinguishing more clearly rain-fed and irrigated agriculture in that comparison. That seems very important as you have highlighted the huge spatial variations and a general difference between irrigated and rain-fed agriculture before.

L307-310: For that upscaling exercise, why would you use the median rate and not the mean rate? The latter would seem more appropriate. At least you should try to justify using the median.

Subsection 4.2: I wonder if you could disentangle the effects of increased N-uptake by vegetation vs. changes in runoff and drainage. You described before how cover crops increase the evapotranspiration, which should lead to a decrease in drainage and thus advective export of reactive N species. You mention that cover crops don't have a big effect on N leaching in dry regions. Might this be due to the fact that drainage is low in dry areas, and irrigation water is only applied to satisfy evapotranspiration requirements, with no excess water feeding additional drainage?

L384-386: Soybeans are also often irrigated, and would thus have no penalty from additional water consumption through cover crops. Could you investigate if that is the reason in your findings?