

Interactive comment on “Improving the representation of cropland sites in the Community Land Model (CLM) version 5.0” by Theresa Boas et al.

Anonymous Referee #2

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Overall: Boas et al. have done considerable work to modify and evaluate simulations of European agriculture in CLM. This work is very exciting and shows significant improvement in model parameterizations and capabilities to add cover crop and crop rotation management practices.

Despite the importance of this work, the text needs to be revised before it is suitable for publication. Some sections require reorganization for clarity, while others will benefit from streamlining to remove redundancies or adding necessary detail. Comments highlighting these sections are included below, as well as specific line comments.

Abstract. Line 25: Is cover cropping only common in humid and sub-humid regions?

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Perhaps it would be more informative to rephrase to something similar to: “. . . which is an agricultural management technique commonly used in the regions evaluated in this study.” Alternatively, you can say that it is a technique growing in popularity to improve soil health and carbon storage.

Line 26: Are you referring to the parameterization of new CFTs? Please clarify. Line 27: Please move the reference of RSME for LH and SH to just after the energy fluxes rather than after NEE. Line 31: When you refer to the “LAI curve”, is this the same as the season cycle of LAI? If so, please modify the wording to reflect this. Lines 31-33: It would be more impactful if you strengthened the last sentence in the abstract. Here is one suggestion: “Our modifications significantly improve model simulations and should therefore be used in future simulations to better understand large-scale impacts of agricultural management on carbon, water, and energy fluxes.”

Introduction: Overall, the introduction needs some reorganization. You need to more clearly highlight the role of management (make this a separate paragraph, include cover crops but also other types of management). The new representation of cover crops is a primary contribution to this paper and is barely mentioned here. The introduction also needs a broader overview of crops in LSMs (it currently only focuses on AgroIBIS and CLM). Last, most of the introduction emphasizes the global nature of models and that the variation in soils, plants, climate is important. When the reader finally gets to the end of the introduction, which highlights that you focus on a few sites in Europe (which some may argue has narrower variation in soils, plants, climate than if you were to compare to locations from other continents), it makes this study seem limited. It might help to instead describe that models are still limited by their ability to represent many crop types and important management practices, emphasizing the importance of your work adding these new capabilities, and also to highlight that Europe is a major agricultural hub for global food production.

Lines 44-49: The mention of cover crops here seems a bit out of place. The earlier part of this paragraph and the start of the next paragraph is focused on adaptation to

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climate change, whereas the description of cover crops here focuses on soil benefits and climate mitigation. I suggest reorganizing, moving the cover crop description to later in the introduction.

Lines 68-70: I'm not sure I entirely understand the point of this sentence. Is this just to highlight the evaluation of crops in CLM4.5?

Lines 73-76: You should also reference the CLM5 crop overview paper here, which evaluates global crop yields: Lombardozzi, D. L., Y. Lu, P. J. Lawrence, D. M. Lawrence, S. Swenson, K. W. Oleson, W. R. Wieder, and E. A. Ainsworth (2020), Simulating Agriculture in the Community Land Model Version 5, *J Geophys Res-Biogeophys*, 125(8), 927–19, doi:10.1029/2019JG005529.

Lines 77-84: This paragraph seems too detailed for the introduction. I suggest summarizing and merging with the previous paragraph. For example: “The few studies that have evaluated CLM5 suggest inaccurate phenology and overestimated crop yields (Sheng et al. 2018).” However, you'll probably want to change/update this to also incorporate results from the Lombardozzi et al. CLM5 paper mentioned above.

Methods Overall: The methods section needs to be tidied up. There are redundancies in the first section, and a lack of detail in the cover crop description. Please pay careful attention to providing enough detail that the reader isn't left wondering how something was done, but keep the text succinct.

You reference Lawrence et al. 2018 in several places throughout the text. However, I believe this paper was published in 2019 (not 2018). Please double-check.

Section 2.1:

When describing the crop model, please also cite Lombardozzi et al. (2020), as this has much more detailed information about the crop model updates than Lawrence et al. 2019.

The methods should be streamlined to avoid repetition. For example, allocation is

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mentioned in lines 134-138, and then again in the paragraph starting at line 153.

When referring to C allocation, you state that it varies throughout the growing season (e.g., line 156), whereas the reference to N allocation states that it uses two different C/N ratios (lines 161-162). However, these are treated the same way in the model. Please update for consistency.

I suggest switching the order of Eq. 1 and Eq. 2.

Line 114: Please define “CFT” the first time you use this term.

Line 115: land units are not separated by fertilizer, only by irrigation. Please update.

Lines 204-206: This is a bit confusing and could use clarification. Does the vernalization factor always range from 0-1? Is it applied to GDD for air and soil temperatures (e.g., does it affect all phenological phases)? If it is only applied to grain C allocation, where does the remaining C get allocated?

Section 2.2.1

It would be helpful to start with an overview of how winter cereal representation differs from other crops. I suggest a high level overview of why it’s important to include both vernalization and cold tolerance before diving into the details of each.

Equation 4: You specify that T_{crown} is slightly higher than the freezing temperature when covered by snow. I see that snow height is used in the calculation, but where is the plant height? Without including the plant height, how do you know whether the plant is covered by snow?

Line 213: The text describes what the accumulative parameters are, but what about the previous time step is used? It would also be useful to include a brief description of how some of the accumulative parameters accumulate (e.g., are these all based on some aspect of accumulated temperature?)

Equation 6: Please define the “alpha-surv” and the “t” variables in this equation.

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Equation 7: I am confused by this, partly because it's not clear what the equation is taking the max of. Also, can T_{crown} be negative? That seems to be the only way the solution to this equation isn't 0. Please update to clarify. Also, I think 'fsurf' should in fact be 'fsurv'.

Paragraph starting at line 227: I find the description here a little confusing. Can you revise this to more clearly articulate the difference between survival probability and WDD? Is survival probability just a step function, where any value <1 causes the same amount of damage (simulated as part of the C and N pools being transferred to litter)? Should I be thinking of survival probability as the proportion of the plant that survives, or the probability that the whole plant survives? Also, part of my confusion is that this is the first place that a frost damage function is mentioned.

Table 1: This is a useful summary, but I'm not sure it adds much information to the main text.

Section 2.2.2:

Since you use a pre-existing winter wheat parameterization, it would be helpful to include some information about what you changed in the parameterization and why.

Section 2.2.3: How do you determine when the cover crops (or rotations) are planted and the subsequent phenology phases? Is it based on GDD? Did you have to modify GDD parameters or add new ones? Did you add new CFTs to accomplish this? How is allocation determined? This section needs more detail about how modifications were made, as it is the bulk of the development work in this paper.

Lines 267-270: It's great to hear that you introduced a flag to use the cover crop option, but I'm not sure you need to include that description here.

Lines 276-277: How are you predefining a rotation scheme?

Line 283: "catch crop" – this is the first time you mention it. Are you using this interchangeably with cover crop (which is how you described this in the previous sentence),

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or are you using a new phrase to distinguish this from cover crop? Please be clear and consistent with word choices.

Line 283: You mention plowing the crop into the soil. However, CLM does not represent plowing. How did you accomplish this. Do you assume that the plant biomass is transferred to the litter pool? Also, how did you decide when this happens?

Section 2.3:

I think it would help to describe the sites before the validation data, and/or mention whether you run CLM simulations at these sites. This section starts by describing validation data, but does not mention what is being validated.

Table 2: Useful information about the sites, but I think the map describes the locations quite well, and most of the other information included in the table is not used in the simulation. Therefore, I'm not sure that this table is necessary in the main text.

Lines 318-319: You mention winter wheat twice here.

Lines 341-342: CLM's default time step is 30 minutes.

Section 3.1: Throughout this section, the differences in model version versus parameter set seem to be conflated. Please make this much clearer throughout, explaining what each of the model versions includes and what the default versus modified parameter sets include.

Table 3: Which simulations include the potato and sugar beet parameterization? It looks like it's the CLM_WW simulation, but this needs to be explicitly mentioned in the table description.

Lines 364-366: This text is confusing: It is not clear what the difference is between the default model and the modified model. I assumed the "default" model did not include winter wheat, but this text suggests that it does. How, then, is the default model run with the modified winter wheat parameters different from the winter wheat model with

the modified parameters?

Lines 369-370: What are the default parameterizations of sugar beet and potatoes? These aren't included in CLM, so is there a "default"?

Section 4

In general, I find the use of CLM_D, CLM_WW, and CLM_WW_CC to be confusing, as the changes included in each are not clearly described. Additionally, it seems that sugar beet and potato parameterizations are added to CLM_WW. It might be more helpful to instead refer to CLM_D as "control" or "default" and then refer to updated parameterization (e.g., "improvements to winter wheat" rather than "CLM_WW" in Section 4.1 and "new potato" or "new sugar beet" parameterization in Section 4.2).

Additionally, throughout this section, figures should include estimates of uncertainty.

Section 4.1: Throughout this section, the text could be streamlined to avoid repeating the description of trends for each site (see note below about Figs. 2-5). Additionally, the trends in energy fluxes are barely mentioned, leaving the reader wondering why you show these in Fig. 2-5, particularly since their mention focuses on cumulated monthly sums (which aren't shown). Also, yields are discussed frequently throughout the text in this section. Is it worth making a bar chart of yields to more clearly illustrate their evaluation? I realize that a bar chart may look busy, but perhaps averaging across years for the sites with multiple years and including standard deviations will work. Related, how are you calculating yields from CLM simulations? It's important to use the peak daily grain carbon value for the entire growth cycle rather than averaging this over some period of time.

I suggest reorganizing the text (and figures) have 4 paragraphs, focusing on the descriptions of: 1) LAI ; 2) yields; 3) NEE; and 4) energy fluxes. Highlight differences among sites within each paragraph. You can also include an opening paragraph that mentions that CLM_WW improves trends for nearly all variables compared to CLM_D,

so the remainder of the discussion focuses on the evaluation of CLM_WW.

Figures 2-5: Is it possible to compile these into a single, multi-panel figure? Given that they all show the same variables for different sites, a single panel would allow the reader to compare across sites more easily. Another, possibly better, alternative is to combine all sites and separate the figures into LAI (Fig. 2) and energy fluxes (LH, SH in Fig. 3). It would also allow you to streamline the description of trends throughout Section 4.1. If I understand the legends correctly, simulations and observations in Figs. 2 and 5 are averaged over multiple years. Can you add uncertainty estimates to these plots? If you plot all individual years (it looks like you possibly do that for observations, but not model), it might be easier to plot averages across years and then plot the uncertainty range associated with interannual variability. Fig. 2 states that the observations are GLAI, whereas Figs. 3-5 state that the observations are LAI. Are the observations LAI, GLAI, or does this vary by location? If it is different by location and both LAI and GLAI are used, how might this change the ability to evaluate CLM? Fig. 5: There aren't any LAI observations plotted in panel a, yet the figure legend suggests that there should be site observation data for LAI.

Lines 394-5: As you state, it looks like the LAI peak is indeed too early. However, even more noticeable (and not mentioned) is the fact that the LAI peak looks to be dramatically underestimated.

Lines 413-4: Table 4 suggests that crops are only harvested ~ 1 month too early, but there are higher observed LH fluxes later in the season than just one month. Is this due to cover cropping, which is not included here?

Line 420: I think the phrasing "overestimated early growing season LAI" is potentially misleading. While it is technically correct, the simulated peak LAI values are actually similar to observed peak LAI values, but happen earlier in the year. I think it might be more informative to state that the peak magnitudes are similar, but that the peaks happen too early in the year.

Lines 422-3: What does “growing cycle” refer to here? As you mentioned earlier, LAI peaks too early and planting and harvest start early, suggesting that phenology is not accurate. Therefore, it is unclear what you mean by “generally good correspondence in growing cycle and LAI”.

Lines 437-8: How can you say that CLM_WW resulted in more realistic magnitudes when you stated in the previous sentence that observations aren’t available?

Lines 438-9: This is confusing. Does it refer to only the simulations, or also reference the observations? I get the sense that you are conflating simulated peak LAI with simulated and observed crop yields. It implies that lower LAI causes the lower crop yields, although I don’t think you can say that for sure.

Line 440: I think this may be backwards. Table 4 suggests that yields are overestimated in 2011 and match really well for 2016.

Lines 453-4: Are all the subsequent mentions (including the metrics in Table 5) calculated using the cumulative monthly sums?

Line 459: You just stated that the BE-Lon sites high some of the highest correlations in the previous sentence, and here single out this site as having high RMSE and biases with low correlations.

Lines 460-461: This sentence should be moved to above, where you briefly mention the mismatch in late-season LH. Also, how does this affect the metrics in Table 5 (see above comments as well).

Line 464: Are you referring to CLM_WW? I suggest clarifying here, as you do include simulations that represent cover crops.

Lines 471-2: It is not quite accurate to say that NEE observations match better due to improved LAI. Consider changing to: “in part due to the better representation of LAI”.

Line 473: Are you actually using cumulative monthly values? Fig. 6 show NEE in

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unites of $\mu\text{mol CO}_2/\text{m}^2/\text{s}^{-1}$.

Line 475: Both sites? You mentioned three in the previous sentence. If only referring to two sites, please specify which ones.

Section 4.2: Perhaps this should be titled “New Parameterizations” or “Sugar beet and Potato Parameterizations” to distinguish from the modified winter wheat parameterization in Section 4.1

The evaluation of corn here seems a bit out of place since this section focuses primarily on the new parameterizations. I’m not sure where it goes (perhaps in supplemental?), though. Perhaps this section could be refocused as “Evaluation of other crop types”, which includes corn and also the new crop types.

Lines 489-91: I suggest rephrasing to add some detail: “The modifications to winter wheat in CLM_WW do not affect other crop types. Therefore, we add new parameterizations for sugar beet and potatoes to this code.”

Lines 502-4: Is this parameter set modified, or new? What is it strongly improved compared to, if these didn’t exist in CLM? I assume it was compared to the default CLM crop model (where the crop might be represented by another type of crop), and it would help to know for sure.

Line 507: You reference spring wheat here. Is this the crop type that default CLM uses for these sites? If so, you might want to make this clearer (and mention it earlier). For example: “The default parameterization in CLM uses spring wheat for these crop types and effectively reproduced the growth cycle and seasonal LAI, simulations using the potato and sugar beet parameterizations better captured harvest date and growth cycle.”

Line 509: As in previous comments, I don’t think “modified” is the best way to describe this. I suggest using “crop-specific parameters” or “parameterizations for new crop types” or similar. As far as I understand, parameters for new crop types were added,

not modified.

Lines 510-2: It looks like the latent heat flux is very similar for the other site, which might be worth mentioning.

Lines 528-30: Performed better for NEE? Please clarify.

Figures 8 & 9: I suggest updating the use of “default” and “modified” here based on above comments. Please specify that the LAI results are daily (if they indeed are). In previous figures, NEE is described as “cumulative monthly”, but here is described as “monthly averaged”. Can these be calculated and referred to in the same way for consistency?

Section 4.3 It seems that this section focuses on crop rotation as much as cover cropping. I suggest updating the heading to “Cover cropping and crop rotation” or similar to reflect this.

Lines 553-4: Is the simulation of a second crop growth onset for the same crop or for the cover crop? The current wording suggests that a second onset is for the same crop within one year AND for the cover crop. If this isn’t intended, perhaps change to “simulation of a cover crop as a second crop growth onset within a single year”

Line 556: “Greening mix” is this the same as cover crop, catch crop? Please be consistent in your terminology throughout.

Lines 556-557: Perhaps it would be more accurate to say “the cash crop rotation of barley (simulated using the spring wheat CFT)”.

Line 557: Spring wheat in CLM is not considered a perennial. It can simulate multiple years of spring wheat in a row, but that doesn’t make it perennial.

Lines 559-561: Can the effects of planting cover crops and the crop rotation be isolated?

Line 563: Please change “plantation” to “planting”

Line 576: Similar to above, spring wheat is not a perennial crop in CLM, as it's planted every growing season.

Figures 10-11: It looks like these are for the same site and continuous. Why not plot the full time series on the same panel, adding lines or shading to show the transitions and associated crop type labels. Also, do you not have observational data for LH for 2017-2019 (Fig. 11)?

Section 5

In addition to the benefits and challenges of the new model developments that you include, I was hoping to see further big-picture discussion, for example about how these new developments might improve future large-scale simulations, possible interactions with climate, etc. Consider adding a paragraph to highlight how your improvements can improve our understanding of larger-scale processes. Also, NEE isn't mentioned at all. Why do you think that NEE didn't improve as much as energy fluxes?

Lines 597-8: As mentioned in a previous comment, higher LAI does not mean higher grain yield. There are many factors that affect yield, including photosynthetic rate, nutrient availability, etc. Also, the results presented in this sentence further support that LAI does not directly correspond to yield: grain yield was higher at BE-Lon (which had lower LAI) than DE-Rus.

Line 603: CLM may not represent different varieties, but the parameters could be changed (as you did here) to represent different varieties, especially when simulated at single points.

Line 607: It might be clearer to say "The early leaf onset and harvest for winter wheat simulated by CLM..."

Lines 619-22: Can this be more specific? How would discretizing plant hydraulic properties improve yield prediction? Also, why does the reference include "Daniel"? How could the properties (parameters?) be estimated by inverse modeling or data assimilation?

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lation?

Lines 629-31: Why isn't it applicable to regional simulations? If a simulation is set up to use land use change, the distributions of vegetation, including crop types, will change, even on a point scale, and can be customized by the user if desired.

Line 634: Do you mean before fall of 2018? Fall of 2017 would be the same year.

Line 635: I don't see Figure 12.

Section 6

Line 665: Is higher flexibility for crop rotations possible beyond your study and beyond single point simulations? Because it isn't clear how cover cropping was incorporated in the methods, the applicability of this beyond your study or single point sites isn't clear.

Lines 675-8: I appreciate that there are numerous improvements that will improve CLM. However, none of these seem strongly related to the work presented here. For example, there is no evidence that lack of management or incorrect plant hydraulic properties are contributing to model biases.

Interactive comment on Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2020-241>, 2020.

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