Answer to Reviewer #2 of manuscript for GMD:

"CLM-FruitTree: A new sub-model for deciduous fruit trees in the Community Land Model (CLM5)" (Dombrowski et al.)

- We thank the reviewer for taking the time to review our manuscript and for providing valuable feedback on our work. Below we provide the preliminary responses to the comments. The detailed revision and resubmission of the paper will follow in a timely manner. In the meantime, we hope the reviewer will find the comments addressed appropriately.

General comments

In this manuscript, Dombrowski et al. introduce a new kind of crop to the Community Land Model (CLM): fruit trees. They present a parameterization for apple trees but note that the code they've written could be applied to other fruit-bearing trees. This represents an important step forward for CLM, which, like many global gridded crop models, has heretofore mostly excluded anything woody or perennial. Incorporating this development into CLM, especially with additional types of fruit trees, would enable the simulation of crops important not just for food security in terms of calories, but also in terms of nutrition and economic productivity.

- We appreciate that the reviewer acknowledges the value of expanding the capabilities of crop modelling in land surface models such as CLM5 to study different aspects of food security and productivity of perennial crops.

The model performs well compared to observations in terms of most evaluated metrics, especially yield. The authors do a good job in most cases of identifying discrepancies and suggesting hypotheses for their causes, which are often structural issues with CLM which it would be outside the scope of this work to resolve. The manuscript does unfortunately use just one real-life orchard for parameterization and evaluation of the model; fully incorporating apples as a scientifically-supported crop within CLM will likely take more effort to generalize the parameterization. But the work presented here represents a significant enough advance that it does merit publication in *GMD*. Importantly, the authors performed and presented the results of a basic sensitivity analysis, which will aid in future parameterization work.

- We are pleased that the reviewer confirms the good model performance we achieved with the CLM-FruitTree development. While this work focuses on the sub-model description, the reviewer is right in pointing out that the validity of CLM-FruitTree should be further tested in future studies by using similar datasets from other geographic regions, and possibly with longer time series and different orchard types. As pointed out by the reviewer, another challenge is represented by certain general structural issues of CLM5 that need improvement but are beyond the scope of this manuscript and should be accomplished by future studies. We will have a further look into our text to see if such challenges could be better outlined.

The manuscript is laid out logically, well-written, and well-supported by the provided figures. Most of my suggestions are relatively minor, and thus I recommend this manuscript be ***published pending minor revisions***.

- In the following we present our responses to the reviewer's specific comments and technical corrections.

Specific comments

My only really substantive comments have to do with the exploration of discrepancies between the simulation and observations:

• L390-395: The simulated LAI in 2011 is too low, which the authors suggest could be due to pruning having been performed in the real world. But is the "alternate bearing behavior" something the authors actually expected the model to represent? If so, how? It seems like something that would need to be explicitly coded in.

- In the manuscript, we argue that the underestimation of LAI in 2011 is mainly due to a smaller C transfer from storage and lower solar radiation early in the growing season which led to lower simulated LAI. The discrepancy between observed and simulated LAI in this year may be exacerbated by a light pruning of the trees in the previous winter (compared to the normal amount of pruning) leading to a higher leaf biomass and higher observed LAI. This practice can sometimes be adopted by the farmer in an effort to manage the alternate bearing of the Fuji variety. However, such practice is not always successful, nor does it follow a regular frequency and the pruning is based on a somewhat subjective assessment of the farmer. Since information on the amount of pruning is usually not available and since other apple varieties and types of deciduous fruit trees do not exhibit such behaviour, we chose to represent the pruning as a fixed proportion of the seasonal stem growth. However, further developments may be considered in the future as the model is tested and applied more extensively. We will improve the paragraph by better explaining the effect of pruning and alternate bearing as well as their respective representation in the development in the revised version of the manuscript.

• L405-425: I would think that real-world management practices such as fruit thinning have the aim of *reducing* interannual variability (IAV), but it sounds like the authors are suggesting that CLM's IAV is too low because they're *not* represented. In general, it seems like missing physiological processes and/or extreme event representation would be more to blame for too-low IAV.

- We thank the reviewer for this comment and agree that the argumentation in the manuscript is not conclusive at this point. Indeed, the aim of field management is usually to reduce yield variability while poor management such as insufficient pruning or fruit thinning can result in undesired yield variability. More importantly however, yield variability is caused by the complex interaction of tree physiological processes and environmental conditions (e.g., frost, drought, hail, pests) some of which are

missing or no represented well in CLM5. We will improve our manuscript in this respect and provide a better description of physiological processes and/or extreme event representation affecting the interannual variability.

• L472–480: It's unclear from the data presented here that autotrophic respiration actually is too high in CLM5. Yes, it's too high a proportion of total ecosystem respiration, but the authors have established that soil respiration is too low. This paragraph should discuss absolute units in addition to relative ones.

- Thank you for this comment. We will add and discuss absolute units of Ra in the revised manuscript to make this point clearer.

In addition, some general comments:
• Please consider making your parameterization script(s) available as well.

- Thank you for your suggestion. The parameters were adjusted one-at-a-time through a mostly manual process. Therefore, the potential of the scripts for reuse or creation of a more automated parameterization script for CLM5 is limited and we thus do not consider them to bring much added value to the published code.

• According to *GMD* rules, the title needs a version number for CLM-FruitTree. Ideally this would correspond to a release tag in the GitHub repository.

- The GMD website states: "If the model development relates to a single model then the model name and the version number must be included in the title of the paper." which is the case for our title. However, for the sake of clarity, we could change the name of the new sub-model to "CLM5-FruitTree" which corresponds to the release tag of "CLM5_FruitTree" in Github.

Technical corrections and minor comments

- L17: EC is undefined
  - We will define EC in the revised manuscript.

- L33: Apostrophe should be a comma
  - We will make the suggested correction in the revised manuscript.

- L57: Adding abbreviation of "(LPJmL)" might be useful
  - The abbreviation will be included in the revised manuscript.

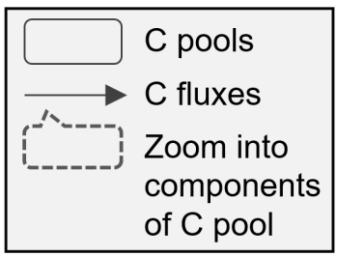
- L67: "buildup" would be clearer than "deposition"
  - We will replace "deposition" with "accumulation" in the revised manuscript.

- L92 and throughout: Should also cite Lombardozzi et al. (2020, *JGR: Biogeosci*: "Simulating Agriculture in the Community Land Model Version 5"), in addition to/instead of Lawrence et al. (2018)
  - ➢ We will add the suggested citation in L92 and L105 of the revised manuscript.

- L116-7: "active growth in the current season" is unclear
  - ➢ We will modify this part of the sentence as follows: "separating the growth from C reserves of the previous year, and photosynthetic growth of the current season".

- L144: "full bloom" is unclear
  - ➢ We will replace "after full bloom" with "at the end of flowering" to be clearer.

- L150 (Fig. 1):
  - "brown" would be more accessible than "ochre" for non-native English readers
    - ➢ We will make the suggested change in the revised manuscript.
  - "DISPLAY" is unclear. Is this a standard CLM term? If so, define it; if not, another word would be better.
    - ➢ The display carbon pool is a standard CLM term. Following a similar comment of referee #1, we will add a definition of the terms "display", "storage", and "transfer" pool in section 2.1 of the revised manuscript.
  - Unclear from this that each plant part has its own storage and transfer pool (except, presumably, fruits)
    - ➢ Thank you for the suggestion. We went through multiple iterations of this figure to represent all important processes while still keeping it readable and not too congested. Finally, we decided to sketch the individual pools only in the display pool as only here different fates (e.g. flux to litter or harvest pool) apply to them. For the other two pools, we therefore only made a remark in the figure caption stating that the same components can be found in transfer and storage pool. A possible improvement could be editing the legend of the figure as follows:



- L162-5: Is *all* the C in storage pools transferred over the 50 days? If not, what "portion" is?
  - ➢ A portion of 0.5 is transferred out of the storage pool over the 50 day period based on the assumption that resources are partially mobilized to support growth of the new season but lacking more specific knowledge on that fraction. This is the default fraction used by CLM5 in the seasonal deciduous trees algorithm. We will add this information to the revised manuscript.

- L169-70: Are these GDD parameters something that can be set for each fruit tree PFT, or are hard-coded?
  - Yes, the GDD parameters as well as all other parameters listed in the table of Appendix C are part of the crop/PFT parameter file and thus can be adjusted by the user. We will clarify this in the revised manuscript.

- L173: "offset"? Is this the same as senescence?
  - Yes, offset is synonymous with senescence, we will consistently use senescence throughout the revised manuscript.

- L180 (Fig. 2)
  - What are the bars, exactly? Period of growth?
    - The bars correspond to the time any plant organ is present on the field, i.e. coarse roots and stem are the woody perennial parts of the plant that remain on the field throughout the orchard lifetime while leaves and fine roots are shed and newly grown each season, and fruits are removed by harvest. As the tree is dormant there is no growth of any of the plant organs outside the growing period. We will provide additional explanation of the coloured bars in the figure caption in the revised manuscript.
  - Would be clearer and more consistent for "canopy development" to just be "leaves"
    - We will edit the figure as suggested in the revised manuscript.

- L211-2: "CLM-FruitTree adopts the same N retranslocation strategy as used in the BDT phenology," but above (L149) it says "minor adaptations" were made.
  - The minor adaptations in the script include only the addition of the flag for perennial crops so that the N retranslocation strategy is used, but no changes to the strategy itself were made. We will make this clearer in the revised manuscript.

- L228: "effects" should be "affects"
  - Will be corrected.

- L270: Was the forcing de-trended during spinup?
  - The dataset was not de-trended during spinup. The CRUNCEP atmospheric forcing dataset used for spin-up is specifically designed to drive the community land model over a long period. It is the combination of two existing datasets and has been used for multiple studies including vegetation growth and gross primary production with CLM.

- L393-5: "In consequence to" should be "Due to" or "As a consequence of".
  - We will replace with "As a consequence of".

- L399-400: This sentence is unclear.
  - The sentence will be changed as follows: “Another reason could be some premature leaf fall in the summer as observed during field sampling.”

- L405: Delete “at”.
  - Will be corrected.

- L437: “Returns **to** positive”
  - Will be corrected.

- L520: “phenomena” should be “phenomenon”.
  - Will be corrected.

- L531-2: This sentence is unclear. “Patchy” what?
  - We will replace “patchy” with “heterogenous (grass-covered alleys between tree rows)“.

- L579-580: But also overestimation of soil respiration!
  - Soil respiration was in fact underestimated by the model as discussed in L457-471. Simulated autotrophic respiration mainly of leaf maintenance was higher than the observed values as discussed in L471-480. Both aspects are again taken up on in the conclusion L579-584. For more clarity the sentence in L 579 can be extended to: “The model exhibited small biases in NEE and R_{eco} that were most likely caused by the overestimation of R_a, especially leaf maintenance respiration, and an underestimation of R_s.”

- L588-9: What about pruning and fruit thinning?
  - As addressed in the “Specific comments” section, the particularities of the Fuji variety regarding alternate bearing behaviour pose a challenge to the implemented pruning, while the implementation may be sufficient for most other apple cultivars and fruit tree species. However, future developments could be envisioned once the model is further tested and used. Fruit thinning implementation would be a greater challenge to the current model structure as apples are not represented as individual fruits but rather one fruit pool. Therefore, it may be more feasible to account for this effect through parameterization of the carbon allocation to fruits instead of explicitly implementing this process. We will amend this section of the conclusion with some remarks to these two processes.

- L630 (Fig. B1): Please use a thicker font for this (or maybe a higher-res image); it disappears at medium zoom levels.
  - We will improve the readability of Fig. B1 in the revised manuscript.

- L635 (Fig. B2): Same issue as Fig. B1.

- We will improve the readability of Fig. B2 in the revised manuscript.