

Review of manuscript for GMD:

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

This manuscript describes the development of a fruit-tree sub-model as part of CLM5, a well-established land and vegetation model. As pointed out by the authors, the inclusion of new agricultural vegetation types in large scale simulation models is an important advancement for understanding and quantifying their role in many biophysical earth-system processes as well as improve the representation of the agricultural sector production. Overall, the manuscript is of good scientific quality.

One limitation of the study is that it is performed on a single point for only a few years, which limits the possibility to evaluate its validity under different conditions. On the other hand, an extremely rich dataset of measurements is used to calibrate and validate the new model. This gives confidence on the representation of processes, such as GPP, NPP, Carbon allocation and crop yields.

The results are well presented with a good structure and informative figures. Yet, some aspects have not been covered, hampering full understanding of the conceptual model and the reproducibility of results:

- 1) One of the greatest challenges in modelling orchards is the representation of the canopy structure, which is not closed and uniform in space, as usually assumed for arable crops and for natural forest. This is a crucial aspect that affects the way radiation is intercepted by the crop canopy. In the paper, it is not described what assumptions have been made regarding radiation interception and whether changes to the CLM5 model have been necessary.
- 2) It is not mentioned what are the structural characteristics accounted for to represent the orchard in the model. Particularly:
 - The planting density
 - The in-row and between-rows planting distances and the ground covered by the canopy
 - How large are seedlings transplanted from the nursery and what is their allometry at establishment (e.g. tree height, stem diameter, LAI, sapwood/heartwood partition, ...)?
- 3) An important process of fruit-tree species is flowering, which is not explicitly represented in the CLM-FruitTree model. Although, it is clearly an acceptable simplification in this kind of model, the assumptions behind this choice (e.g. optimal pollination, compensation effects between fruit numbers and size, ...) and its implication should be presented and discussed.

Below I provide further comments on specific sections, lines and figures that need improvement.

Methods

Structure

In general section 2.1 gives the motivation for developing the CLM-FruitTree, but I think it would be better structured in this form: “to simulate fruit trees we need a model that does XYZ; CLM5 with its improvement is a good base for this, indeed it includes ABC; yet, it still misses ZYX that we implement in this paper.” Otherwise it is not clear why you describe those aspects of CLM5.

Section 2.2 is not very informative in terms of model conceptualization. Please, use this section to (1) give an overall description of what system your model describes (e.g. what kind of apple orchard, extensive / intensive), (2) explain which components of the system should the model represent well (e.g. it should be at least good at simulating average yields and carbon stocks), (3) describe the model

concept, preferably referring to the diagram displayed in Fig. 1. Here it would be a good place also to define the three C pools that are mentioned also in 2.2.2 without a proper explanation.

Section 2.2.1: It is good to start off with phenology. Please, stick to that and do not mix phenology with growth processes. E.g. why is initial biomass mentioned in L157? Similar for L163. Maybe, put these into a paragraph at the end of 2.2.1, describing growth processes triggered by phenological events.

Section 2.2.3: Please, restructure the paragraph L219-232 to make clear what is common practice in the “real world” and what is implemented in the model. First explain the common practice and then what’s in the model.

Line-specific comments

L97-99: As the names of these pools appear here for the first time, the sentence is a bit confusing. I would suggest to clarify the sentence as follows, use italic for the pool names and refer to later sections for additional details: “Once a new onset growth period is initiated, C and the corresponding N fluxes occur out of a *storage* pool, which are temporarily stored into an intermediate pool (*transfer* pool) and then gradually transferred to the *display* growth pools (see section XYZ for details).”

L100: Are there other stoichiometric relationships other than C:N ratios? If yes, the sentence is fine, otherwise please, remove stoichiometric relationships.

L101-102: Sounds like a repetition of L93, please merge the two.

L122: Unclear whether the management options are related to phenology management (e.g. choice of cultivar?) or to other management practices somewhat connected to phenology (e.g. pruning?).

L123-124: “were modified” is too vague. As you don’t have space here to go into details, I’d suggest to be brief but explanatory, e.g. “CN fluxes and allocation were modified to fit”.

L124-128: These are very technical details and not so much part of the model conceptualization. I wonder whether it would be possible to make a separate section on “technical implementation” to describe these.

L135-136: This seems quite long for modern orchards. What kind of orchards are you simulating? Intensive / extensive, low / high density, what are the assumptions on the rootstock?

L158: Apple growth or apple-tree growth?

L163: how large is the portion of C transferred?

L164: Please, provide a reference or justification for the 50 days assumption.

L165-167: From this description (“fruit starts 4-5 w after bud break”, “leaf senescence occurs after harvest”) it does not seem that leaves and fruits development are independent from each other.

L186: Shouldn’t “except for fruits where all allocated C is assigned to the displayed pool” be part of the previous sentence?

L199-200: Allocation to fine roots and stem decline, not the root and stem pool themselves, right?

L210: Please, expand a bit on the N retranslocation strategy, not just by referring to Lawrence et al., 2018. Doesn’t this belong to 2.2.2 as it refers to N allocation. Then you could call section 2.2.3 simply “Representation of management practices” and include here details of all managements, including the assumed orchard design (planting densities, row arrangement, training system).

L220: What do you mean by “dead stem”? Usually pruning is meant to remove living branches. Might be that CLM does not explicitly distinguish stem and later branches. Yet, more explanations are needed here to justify the implemented pruning routine.

L313: for clarity, X and deltaX also need to be defined.

Results and Discussion

Figures

Fig. 3: To improve readability, I suggest to name the parameters with their extended names and the short name in parenthesis, e.g. gross primary production (GPP), directly in the plot and not in the caption.

Fig. 5: It is not clear whether the x-axis ticks refer to the beginning/midday/end of the months. Moreover, more ticks would help reading the timing of events, e.g. when is full canopy development reached.

Fig. 6: According to Zanotelli et al., 2019 (section 2.1), yields in 2015 has been 63 t ha⁻¹. Please, double check.

Line-specific comments

L368-370: why “primarily”. Isn’t it all allocated to those organs? In the methods it is stated that storage Carbon is used for growth of all organs except fruits in the first 50 days after bud breaks. Moreover, from Fig.4 it looks like growth is supported by storages way beyond early May, rather until early June. When the fruit curve is already taking off.

L372: In Fig. 4, leaf biomass seems to reach the plateau earlier, in June. The peak in July better refers to observations, correct?

L390: for clarity, replace “light pruning” with “a lighter pruning compared to the previous year” or similar. Moreover, if such lighter pruning happens on-field every second year, it should not sound like it was an extraordinary event in 2011 that cannot be captured by the model, but rather a flexibility in management that is not well represented in the model. If the model with fixed management “sees” an alternation of “good” and “bad” years, it could mean that it represents processes well, and it has a too simplified management that leaves room for improvement.

L407-409: Not clear. Usually management should aim at reducing yield variability for both arable and perennial crops, e.g. irrigation to reduce precipitation variability, pruning to reduce alternate bearing of fruit trees, etc.

L438: what is indicated in parenthesis? Standard deviation, range, ...

L457-463: This paragraph is unclear and hard to follow. Please, report measured values along with observed values and vice versa. E.g. in L457, how much is Rs and its share in Reco for the simulations? Please, move “In contrast, simulated Reco for the same year [...]” of L459 right after “[...] measurements within the orchard (total soil respiration).” in L458.

L472: The representation of the different components of respiration in CLM should be explained in the methods, as this is one of the metrics to evaluate the new model implementation.

L462 & L478: It is not clear why citrus orchards should be a valid reference also for apple orchards. The discussion needs to be improved, bringing more references (e.g. on more tree species) if existing or justifying why citrus trees can be a good reference.

L536: In the figure soil moisture (SM) is called soil water content (SWC). Please, be consistent.