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Interactive comment on "Oil palm modelling in the global land-surface model ORCHIDEE-MICT" *by* Yidi Xu et al.

Anonymous Referee #1

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Land use changes driven by oil palm expansions have been major concerns for carbon emissions and biodiversity loss in the tropics and have drawn extensive studies in the recent decade. Yet, modeling oil palm in a land surface scheme of Earth system model only started recently. Representing oil palm as a plant functional type (PFT) in an LSM with oil palm specific morphological, phenological and physiological traits including a sub-PFT structure for oil palm's phytomers was first introduced in CLM (CLM-Palm, Fan et al. 2015). Here, this study adopts a similar sub-PFT structure and presents some advances, such as an age-specific parameterization scheme for photosynthesis and autotrophic respiration for the oil palm PFT, which is new. ORCHIDEE-MICT has an age-cohort vegetative structure that is different from the CLM (excluding FATES), and the oil palm integration in this study was based on existing leaf age cohorts-based

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phenology of tropical broadleaf trees and distinct age classes of the ORCHIDEE-MICT model. The developed model ORCHIDEE-MICT-OP shows reasonable agreement with observational data for simulating LAI, biomass pools, GPP and NPP. However, I recommend major revisions to address several main issues in the methodology as well as minor ones.

First, the methodology description of phenology and allocation needs to clarify how sub-PFT level processes are reconciled with the PFT-level processes in ORCHIDEE-MICT, particularly for leaf phenology. For example, it is unclear how the VPD-triggered leaf shedding for the whole palm works together with the phytomer-level leaf pruning. The allocation parameterization and results did not show sub-PFT/phytomer level leaf LAI or biomass dynamics. Without phytomer-specific leaf phenology, it is hard to call this a sub-PFT structure as individual leaf dynamics together with fruiting and harvest on each phytomer are the unique characteristic life cycle of oil palm (distinguishing it from natural trees). It is also difficult to understand the three-phase life cycle of the whole tree and the sub-PFT level phenology and allocation processes if without substantial clarification.

Second, the model calibration here involved published data from 14 individual sites for different variables of biomass, yield, LAI, GPP and NPP. However, there lacks an independent validation against separate sites or dataset. Calibration and validation should be conducted separately to ensure model generalizability and applicability. Moreover, several empirical parameters appear weakly constrained. Thus, a sensitivity analysis of newly introduced parameters is favourable but is currently missing. I also urge the authors to give more proper credit to the related work of CLM-Palm in several aspects and improve their model description and evaluation to highlight their own new/original contributions as mentioned above.

Below are specific comments:

L59: I suggest first referring to the CLM-Palm work here when talking about LSMs,

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either put in parentheses like '...without a specific representation in LSMs (except CLM-Palm)', or mentioning it at the end of this paragraph that at least one LSM CLM4.5 already introduced an oil palm specific PFT and related parameterizations (see below comment). L74: better cite an observational study here, rather than a modeling study.

L78: when first mentioning ORCHIDEE, there needs a couple of sentences introducing this LSM, such that incorporating an oil palm PFT into ORCHIDEE would contribute to modeling the carbon, water and energy cycle of this perennial crop in a variety of LSMs, in addition to CLM.

L88-90: "using a sub-canopy framework from CLM4.5" is not a proper description. As far as I know, the original CLM4.5 does not have a sub-canopy or sub-PFT structure. This was introduced in Fan et al. (2015) to CLM4.5 specifically for oil palm. A proper citing of CLM-Palm here could be: CLM-Palm was the first LSM that introduced an oil palm specific PFT and a sub-canopy/sub-PFT framework for modelling oil palm's phytomer-based structure and phenological and physiological traits in CLM4.5, or something similar. There are other locations that need similar care.

L95: does "tree cutting" refer to pruning of old phytomers or the clear-cut at final rotation?

L95-97: as mentioned above, the authors should cite the CLM-Palm work here, because the "sub-PFT structure" was clearly defined in Fan et al. (2015), including carbon allocation for leaf and fruit of each phytomer and management practice of pruning, fruit harvest and rotation (see their Fig. 1, Fig. 2 and sections 2.1, 2.2).

L101: delete extra words. There are other typos in the text.

L115-120, Section 2.1: Although the number of sites used in this study seems abundant, the actual data availability for different variables is sparse at individual sites, e.g., only one Site-12 provided annual yield data and one Site-3 provided annual biomass data. This limits the model validation. It seems the author did not conduct independent model validation using new sites other than those already used for parameter calibration. Model calibration and model validation are different procedures to ensure applicability of a model to new locations. This section should at minimum describe what variables from which sites are used for calibration, and what variables from which other sites are used for independent validation.

L150-160, and Figure 3: It is hard to understand the phenology scheme from descriptions in section 2.3.2 and Figure 3. Please clarify if the oil palm will produce yield at CFT stages 1-4 (0-10 years), or only at CFT5 (10-25 years old)? From Figure 3c, it seems that fruit yield and harvest pertain only to CFT5 (productive stage), but from the phenology and allocation descriptions, it seems a phytomer will produce fruit as soon as its initiation and will be harvested before pruning when its age reach the longevity. The phytomer longevity is 640 days, which is smaller than 3 years of CFT1 – leaf initiation stage. Thus, the phytomer phenology implies fruiting and harvest starts around 2 years old (which is true according to field observations), but Figure 3c suggests otherwise (the CFT1 is only at leaf initiation stage with ÆŠfr=0 when palm age < 3 years). Great efforts are needed to clarify the logic link between PFT-level phenology and sub-PFT level phenology, especially how they are synchronized in the model?

L168: should be section 2.4?

L176-178: the described logic of phytomer initiation (controlled by management) and pruning (controlled by phytomer age) is counterintuitive. Here, phytomer initiation follows each pruning to maintain the total number of 40, but initiation should be controlled by physiological process rather than management. According to oil palm phenology and field management, phytomer initiation is regulated by the phyllochron (the thermal period between initiations of two successive phytomers) which increases with oil palm age, while pruning usually is done on the bottom phytomers (old but not necessarily dead ones) when managers observe the total number of phytomers exceeding $\sim$40. The described scheme of phytomer phenology is apparently weak, given the improper logic of initiation and pruning and use of fixed days for phytomer longevity.

L183-185: define SWdown; “weekly VPD is used to trigger the shedding of old leaves” – how the shedding of old leaves at the PFT level is merged with the above phytomer phenology? Each phytomer carries a large leaf, and it is initiated and pruned according to phytomer phenology. But the authors did not describe in detail how the phytomer-level leaf phenology is reconciled with the age-cohort based leaf phenology from Chen et al. (2020). Presumably they are synchronized, such that the sum of phytomer-level LAI and leaf biomass should always equal the PFT-level LAI and leaf biomass to maintain carbon balance. The authors mention earlier “the leaf, branch and fruit bunch belonging to each phytomer were linked with the original leaf, sapwood biomass pools,” but from the schematic Figure 2, it is unclear how each leaf enters the litter pool. Does the leaf carbon enter the successive cohort cycle even after pruning of the supporting phytomer? At minimum, the authors should describe how the VPD-triggered leaf shedding works together with the phytomer-level leaf initiation and pruning in this section.

L188: “a fixed allocation of 10% to reproductive plant tissues” – how this fraction of reproductive allocation is related to the phytomer specific fruit allocation? Fruit is usually considered part of the reproductive organ.

L198: according to the calibrated values of coefficients ðİŚČ1, ðİŚČ2 and ðİŚČ3 , the maximum value of Eq. (1) is ÆŠbr+fr,min + (ÆŠbr+fr,max - ÆŠbr+fr,min) x 0.07 when a phytomer reaches max age; the range of the modifier 0 to 0.07 (instead of 0 to 1 normally) seems to be too small, which would exert very weak phenological effect on this allocation parameter.

Section 2.3.3: Inconsistency between model schematic in Figure 2 and allocation descriptions. In Figure 2, fruit to fruit-bunch allocation is independent of sapwood to branch allocation, but the descriptions and equations here suggest fruit allocation is part of sapwood allocation. Figure 2 also shows leaf to phytomer-leaf allocation, but there is no indication of this sub-PFT leaf allocation process in the text. Only a PFT-level allocation parameter ÆŠleaf is described in Eq. (5). If phytomer specific leaf carbon pool is not modeled, some parts of Figure 2 should be modified. And the text description of sub-PFT phenology for branch, leaf and fruit for each phytomer is not accurate (e.g., L28 in abstract).

L219: “fruits will be harvested after the phytomer age in the oldest phytomer reaches ðİŘť geffbcrit” – does this imply that fruit initiation happens at the same time as phytomer initiation? It needs to note that phytomers develop their leaves first before initiation of fruit. But the equations (1) to (5) suggest that fruit allocation at each phytomer starts immediately after phytomer initiation.

Section 2.4: this section lacks a sensitivity analysis for newly introduced oil palm parameters. Although the results show general agreement with observational data by a one-time calibration with all sites, readers gain little insight on how sensitive are the oil palm LAI or biomass pools to different parameters and to climate and surface forcing without showing a sensitivity analysis or independent validation using different sites.

L227: missing Yin and Struik, 2009 in the reference list.

Section 2.4.3: I suggest merging this section to section 2.3.3 as they both describe allocation. Again, leaf allocation (ÆŠleaf) is only described for the whole palm, not for each phytomer. If only an PFT integrated leaf carbon pool is grown for the whole palm, Figure 2 and several places in the text about sub-PFT structure should be modified.

Section 2.4.4: Since Ageleafcrit equals Agephycrit, one of these parameters could be eliminated. But it needs to note that, in reality the leaf longevity is smaller than phytomer longevity as there is a lengthy “spear leaf” (a bud that grows to as long as $\sim$3 meters) stage before the it fully expands to be able to photosynthesize.

L300: if leaf carbon pool is not specifically simulated for each phytomer like branches and fruits, how pruning of each leaf is conducted, and how this is reconciled with the VPD-triggered leaf shedding? It needs to avoid double accounting of leaf litterfall flux from these two processes. In oil palm plantations, natural leaf loss/shedding is almost impossible without pruning due to very high lignin content. Thus, I suggest only one leaf litterfall mechanism is implemented for oil palm.

L350-355: it will be more convincing to compare the simulated annual yield with real observations rather than the fitted curve in Figure 7d. This can be achieved either from using continuous harvest data or using space-for-time substitution with multiple sites.

L376-377: calibration an LSM using all sites without reserving some sites for independent validation is not standard. Also, the reason of overestimation should not be attributed to "no calibration was applied for this site". LSM is aimed for regional or global applications. Thus, even a perfect calibration for an individual site does not mean good predictive power for other sites. That's why I urge the authors to do independent validation after model calibration using separate datasets.

Section 3.5: again, the fact that leaf LAI and biomass pool is not specifically simulated for each phytomer should be clarified much earlier when introducing the sub-PFT structure and in Figure 2.

L412: "The fruit production and harvest begin after entering the fruit development phase" can be described earlier when introducing Figure 3. The 3-phase description is confusing as it sounds like only the productive phase (CFT5) has yield and harvest.

L440-441: Fan et al. implemented age-dependent carbon allocation strategy (their section 2.2.1) and showed age-dependent trend in yields validated against different sites (their Figure 10).

L445: this is not true; Fan et al. used 2 sites for model calibration and an additional 8 sites for independent validation. The study here used all 14 sites for both calibration and validation, which violates the normal procedure of model validation using independent sites and undermines its generalizability to other locations.

L446: this is not necessarily the case; parameterizations from ORCHIDEE-MICT-AP can only be applicable to other LSMs if they share very similar model structures. Without a sensitivity analysis and independent validation, such claim is premature.

Section 4.3: when talking about application in LUC impact assessment, it is important to note the limitation that effects of different land cover types, soil carbon and nutrient content, and fertilization management on oil palm growth and yield can hardly be represented by the current model without a nitrogen cycle.

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