Referee #2

[General comment] *This paper presents an improved, oil palm specific plant functional type (PFT) to be incorporated into the ORCHIDEE-MICT global land surface model. The authors offer this as an improvement on the existing typical practice of approximation using the PFT of tropical broadleaved evergreen trees. Given the intensively managed, and specific, nature of palm cultivation and harvesting there is little doubt as to how unsatisfactory the utilisation of a generic plant functional type is in modelling physiological and environmental dynamics in these systems. The paper is generally very well written and presented (with some caveats, see details below) and the results suggest a significant improvement over previous model practice. Reviewer #1 has provided some excellent and comprehensive technical comments and suggestions and I have little to add to those. I would comment though, that peat and mineral soil based plantations are likely to be very different, yields will be lower and palm mortality higher on tropical peat soils and crop rotations significantly shorter (18 to 20 rather than 25 to 30 years). With around 25% of the South East Asian oil palm plantations being on converted peatlands, a discussion around the significant differences likely to be found in yield and palm mortality (disease incidence, palm root anchorage and failure) on the two soil types and whether they should be separately parameterised, and what work would be required to do so, in the PFT would be welcome.*

[Response] We thank the reviewer for the careful review and great suggestions on the discrimination of peat and mineral based oil palm plantations. Accordingly, we modified several inaccurate statements in the manuscript (please see the reply to #6, #12, #23). We also added discussion about oil palm on the peat soil and mineral soil and the potential improvement regarding the inclusion of these two soil types in our future work in Section 4.2, Lines 550-567, "Another important factor is the difference between oil palms grown on mineral and peat soils. Although our model was able to reproduce the yield, GPP and NPP at one peat-based oil palm site (Site 12), the biomass is overestimated throughout the life cycle, indicating further work is needed to implement the peat oil palm in the LSMs (and other data from peat soils for yields). Previous studies suggested that the frond biomass of oil palm grown on peat soils was lower than on mineral soils in all age classes (Henson 2005). On peat soil, oil palm allocates less biomass to root system (Corley, Gray and Kee 1971; Othman et al., 2010). Further decomposition of peat subsidence after peatland drainage combined with poor anchorage of oil palm may cause palm leaning and even palm falling and hence increase mortality (Henson et al., 2003; Othman et al., 2010). Based on the yield and tree mortality, the rotation cycle also varies in mineral- (25-30 years) and peat- (18-20 years) based oil palm. A better representation of peat oil palm could be reached by using a separate parameterization scheme for peat oil palm (e.g., adjusting the partition between AGB and BGB and decrease the carbon assimilation rate), adopting a lower biomass threshold for oil palm rotation (Figure 5), modifying the carbon emission rate at the beginning years of oil palm conversion and so on. However, it would be a great challenge to implement some factors such as disease in the current stage without enough knowledge on the processes and impacts of disease on oil palm growth. Also, we note the optimal planting density is different between the two soil types (110-148 palms ha^{-1} on mineral soil and 160-200 palms ha^{-1} on peat soil) (Henson et al., 2003; Othman et al., 2010; Lewis et al., 2020). The mineral-based oil palm suffers a decline in frond biomass and production while that of the peat oil palm is less influenced (Lewis et al., 2020). These would also cause biases in simulated biomass and yield due to no separation between mineral- and peat-based oil palm." One ORCHIDEE version—ORCHIDEE-PEAT —already implemented the peat process in high latitudes (Qiu et al., 2018). Merging the oil palm specific morphology, phenology and harvest process of oil palm and the peat related process between these two ORCHIDEE versions would be our next step to better simulate oil palm yields and carbon, water and energy fluxes on peat soils. We added this point in Section 4.3, Lines 580-584). For the details of the discussion, please see the reply to #12, #15, #22, #23. Besides, we also added some explanations in Figure 3 to make it clear.

All of the specific comments and suggestions have been addressed and implemented in this revised manuscript. Please find below the specific reviewer's comments, followed by our responses and relevant changes in the manuscript. We believe that the revised version addresses all the issues raised by the reviewer.

Specific comments:

[Comment 1] *ln.20: "cause" should be "causes" (plural)*

[Response to #1] Thanks for the suggestion. We changed "cause" to "causes".

[Comment 2] *ln.36: "crop" should be "crops" (plural)*

[Response to #2] We modified "crop" to "crops".

[Comment 3] *ln.48: citations in the brackets should be in chronological order*

[Response to #3] We modified the orders of the citations as suggested (please see Section 1, Lines 47-48, 67-68, 268-269, 317, 546-547, 587).

[Comment 4] *ln.54-55: "do not allow to represent the land use change", poor English, perhaps: "do not allow representation of land-use change..."*

[Response to #4] We modified this sentence as suggested.

[Comment 5] *ln.60-61: change "according to the genotypes and locations" to "dependent on genotype and locations..."*

[Response to #5] We changed this sentence as suggested.

[Comment 6] *ln.84: rotations of 25-30 years would be specific to mineral soil-based plantations, peat-based plantations are likely to be significantly shorter*

[Response to #6] Thanks for your suggestions. We changed this sentence to "Also, oil palm planted in mineral soil is managed in a rotation cycle of 25-30 years (manually cut) due to the difficulties in harvesting and the potential decline of fruit production (Hoffmann et al., 2014; Röll et al., 2015)" (Please see Section 1, Lines 84-86) and discussed the rotation cycle of peat land oil palm in the discussion part (Section 4.2, Lines 557-558).

[Comment 7] *ln.148: change "corresponded" to "corresponding"*

[Response to #7] Revised accordingly.

[Comment 8] *ln. 158: "begin to flourish"*

[Response to #8] We modified this sentence as suggested.

[Comment 9] *ln.201: a space needed "accelerated (Corley and Tinker, 2015)*

[Response to #9] Thanks for the reminding. We added a space between accelerated and (Corley and Tinker, 2015).

[Comment 10] *ln. 222: delete "types", already included in the PFT acronym*

[Response to #10] We deleted "types".

[Comment 11] *ln.241: change "correspondingly" to "corresponding"*

[Response to #11] We modified "correspondingly" to "corresponding".

[Comment 12] *ln.305: "we assumed that there is no natural mortality for the oil palm,", this is un- realistic as there will be disease losses from the original planting density (with some replacement) and specifically in peatlands, losses and yield reduction due to leaning palms. These need discussing.*

[Response to #12] We changed this sentence to "In ORCHIDEE-MICT-OP, we assumed that oil palm is manually cut down for rotation before the natural mortality without considering the disease and other causes of tree loss as well" (Please see Section 2.4.4, Lines 330-332). Disease was not considered in our model since it is difficult to quantify the impacts of diseases on oil palm in a grid-based land surface model. Implementing the individual tree disturbance for PFT-level oil palm simulation would be a great challenge and we also admit the limitation in the Discussion (Please see Section 2.4.4, Lines 558-563) "A better representation of peat oil palm could be reached by using a separate parameterization scheme for peat oil palm (e.g., adjusting the partition between AGB and BGB and decrease the carbon assimilation rate), adopting a lower biomass threshold for oil palm rotation (Figure 5), modifying the carbon emission rate at the beginning years of oil palm conversion and so on. However, it would be a great challenge to implement some factors such as disease in the current stage without enough knowledge on the processes and impacts of disease on oil palm growth.".

[Comment 13] *ln.313: "Figure S3" should be "Figure 3"*

[Response to #13] Sorry for the mistake. It was corrected in the revised version.

[Comment 14] *ln.369: "is reproduced of 1.7" Perhaps this should be "is calculated at..."?*

[Response to #14] Yes, we modified this sentence as suggested.

[Comment 15] *ln.376: this distinction between peat and mineral-based plantations, and its implication for scaling model output needs to be discussed further*

[Response to #15] As suggested, we further discussed the distinction between peat and mineral-based plantations and implications for model parameterization in Section 4.2. Lines 550-563 "Another important factor is the difference between oil palms grown on mineral and peat soils. Although our model generally was able to reproduce the yield, GPP and NPP at one peat-based oil palm site (Site 12), the biomass is overestimated throughout the life cycle, indicating further work is needed to implement the peat oil palm in the LSMs (and other data from peat soils for yields). Previous studies suggested that the frond biomass of oil palm grown on peat soils was lower than on mineral soils in all age classes (Henson 2005). On peat soil, oil palm allocates less biomass to root system (Corley, Gray and Kee 1971; Othman et al., 2010). Further decomposition of peat subsidence after peatland drainage combined with poor anchorage of oil palm may cause palm leaning and even palm falling and hence increase mortality (Henson et al., 2003; Othman et al., 2010). Based on the yield and tree mortality, the rotation cycle also varies in mineral- (25-30 years) and peat- (18-20 years) based oil palm. A better representation of peat oil palm could be reached by using a separate parameterization scheme for peat oil palm (e.g., adjusting partition between AGB and BGB and decrease the carbon assimilation rate), adopting a lower biomass threshold for oil palm rotation (Figure 5), modifying the carbon emission rate at the beginning years of oil palm conversion and so on. However, it would be a great challenge to implement some factors such as disease in the current stage without enough knowledge on the processes and impacts of disease on oil palm growth.

Henson, I. E., and Dolmat, M. T.: Physiological analysis of an oil palm density trial on a peat soil, Journal of Oil Palm Research, 15, 2003.

Henson, I. E.. Modelling vegetative dry matter production of oil palm. Oil Palm Bulletin, 52, 25, 2005

Corley, R. H. V., Gray, B. S., & Kee, N. S. (1971). Productivity of the oil palm (Elaeis guineensis Jacq.) in Malaysia. Experimental Agriculture, 7(2), 129-136.

Lewis, K., Rumpang, E., Kho, L. K., McCalmont, J., Teh, Y. A., Gallego-Sala, A., and Hill, T. C.: An assessment of oil palm plantation aboveground biomass stocks on tropical peat using destructive and non-destructive methods, Scientific Reports, 10, 2230, 10.1038/s41598-020-58982-9, 2020.

Othman, H. A. S. N. O. L., Mohammed, A. T., Harun, M. H., Darus, F. M., & Mos, H. A. S. I. M. A. H. , Best management practises for oil palm planting on peat: optimum groundwater table. MPOB Information Series, 528, 1-7, 2010.

[Comment 16] *ln.408: change "characteristics" to "characteristic" (singular)*

[Response to #16] We modified "characteristics" to "characteristic".

[Comment 17] *ln.436: change "special" to "specific"*

[Response to #17] We changed "special" to "specific".

[Comment 18] *ln.440: change "increasing" to "increase"*

[Response to #18] We changed "increasing" to "increase".

[Comment 19] *ln.440-441: "To our best knowledge, age-based allocation dynamics for oil palm have not yet been..."*

[Response to #19] We modified this sentence as suggested.

[Comment 20] *ln.441: change "simulating" to "simulate"*

[Response to #20] The word "simulating" was modified to "simulate".

[Comment 21] *ln.452: change "phytomer" to "phytomers" (plural)*

[Response to #21] We changed "phytomer" to "phytomers".

[Comment 22] *ln.487-488: the authors mention the impact that planting density will have when scaling from palm to area, again this will differ between peatland and mineral and needs more discussion.*

[Response to #22] We added the discussion of the influence of planting density on peatland and mineral soils in Section 4.2 Lines 563-567, "Also, we note the optimal planting density is different between the two soil types (110-148 palms ha^{-1} on mineral soil and 160-200 palms ha^{-1} on peat soil) (Henson et al., 2003; Othman et al., 2010; Lewis et al., 2020). The mineral-based oil palm suffers a decline in frond biomass and production while that of the peat oil palm is less influenced (Lewis et al., 2020). These would also cause biases in simulated biomass and yield due to no separation between mineral- and peat-based oil palm".

[Comment 23] *ln.496-497: The authors state that "soil carbon change may take a long time", they do not elaborate on what a "long time" is, but in peat systems there are huge carbon emissions observed in the first 5 years following conversion, likely a similar amount of time needed for forest residues to decompose which would disagree with the thrust of this sentence.*

[Response to #23] Thanks for the great point. We modified this sentence to "In reality, the biomass loss from deforestation is fast but soil carbon change may take a long time in mineral soil. A more complex condition would happen in the conversion to oil palm plantation on the peat soil, where huge carbon emission was observed in the first 5 years following conversion (Hooijer et al., 2012; Cooper et al., 2020)" Section 4.3, Lines 575-578.We also discussed the potential implementation of the conversion from peat soil to oil palm plantation based on ORCHIDEE-MICT-OP and another branch of ORCHIDEE for high-latitude peatlands (ORCHIDEE-PEAT) in Section 4.3, Lines 580-583. "One of the ORCHIDEE branches, ORCHIDEE-PEAT, has already implemented the peat processes for high latitudes (Qiu et al., 2018). Merging the oil palm specific morphology, phenology and harvest processes of oil palm and the peat related

processes in these two branches would help characterize the oil palm yields as well as carbon, water and energy fluxes on peat soil palms."

Cooper, H. V., Evers, S., Aplin, P., Crout, N., Dahalan, M. P. B., and Sjogersten, S.: Greenhouse gas emissions resulting from conversion of peat swamp forest to oil palm plantation, Nat. Commun., 11, 407, 10.1038/s41467-020-14298-w, 2020.

Hooijer, A., Page, S., Jauhiainen, J., Lee, W. A., Lu, X. X., Idris, A., & Anshari, G. Subsidence and carbon loss in drained tropical peatlands. Biogeosciences, 2012,9(3), 1053-1071.

Qiu C, Zhu D, Ciais P, Guenet B, Krinner G, Peng S, et al. ORCHIDEE-PEAT (revision 4596), a model for northern peatland CO2, water, and energy fluxes on daily to annual scales. Geosci Model Dev.11(2):497-519, 2018.

[Comment 24] *ln. 499-500: change ",it is also in urgency to..." to ",there is an urgent need to..." ln.504: change "crops" to "crop" (singlular)*

[Response to #24] We modified these sentences as suggested.

[Comment 25] *Figure 3: change "prunning" to "pruning". Also, please include full versions of acronyms used in the figures in their associated legends (e.g. CFT in fig.3). The legend for fig. 3 is generally inadequate and needs more detail. It should stand alone and not require recourse back to the text.*

[Response to #25] The word "prunning" was changed to "pruning". We added the full versions of the acronyms in Figure 2 and Figure 3. We also added the details in Figure 3 and the captions. Please see the figure below.

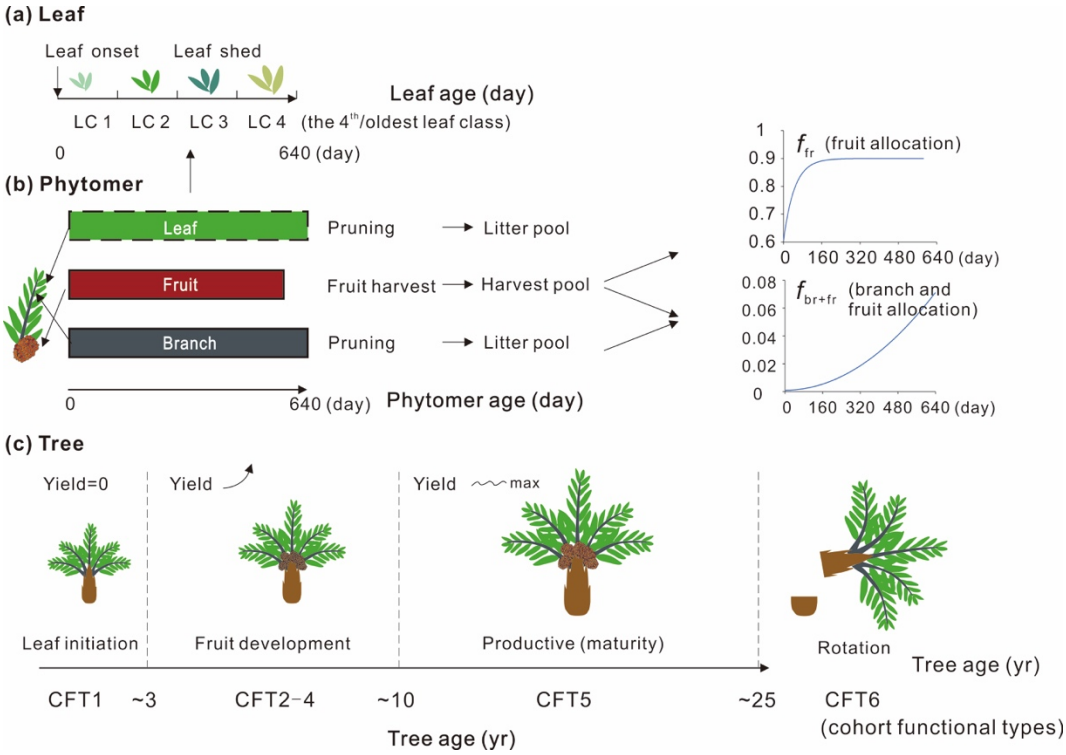

Figure 3 Schematic of (a) leaf, (b) phytomer and (c) plant dynamics with leaf, phytomer and tree ages. The branch and fruit allocation is a function of phytomer age. The oil palm PFT experiences an increase of fruit yield during CFT 2-4 and reaches the maximum and steady yield at the most productive period (CFT5). The leaf component is not specifically simulated for each phytomer (dashed rectangle) but implemented at the PFT level with four leaf age cohorts. The major phenological phases for phytomer during the oil palm life cycle are presented with tree ages. LC and CFT refer to leaf cohort and cohort functional type, respectively.