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Interactive comment on "A sub-canopy structure for simulating oil palm in the Community Land Model: phenology, allocation and yield" *by* Y. Fan et al.

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Response to Referee #1 (add line numbers referring to the revised manuscript):

We acknowledge the referee's very helpful and detailed review and encouragement. We take the suggestions to reduce redundancy between model description and discussions. Now the discussions on the resource allocation mechanisms, i.e. sections 5.2 and 5.3, are removed and the subsections are condensed to one section. The model description is now focused only on oil palm and the detailed phenology description is moved to Supplementary materials. We revised the full manuscript and largely reduced its size (please see attached revised manuscript). This paper focuses on the

model development of oil palm phenology and allocation and its sub-canopy structure, which are the bases for simulating carbon, water and energy fluxes and for future application of the module to simulate forest to oil palm conversion and its impacts on carbon stocks and regional climate. The applications are being conducted in two following studies. Due to limited space, we only show validations of the module against LAI, yield and NPP here which are important for future large-scale simulations of energy and material cycling across Indonesia and even other regions.

Answers to specific comments:

Comment 1: P3 You should be more clear the concept of PFT and sub-canopy structure in the abstract for attracting many readers.

Answer 1: We revised the abstract in order to highlight the concept of PFT and sub-canopy structure and the new module: "…we introduce a new perennial crop phenology and allocation sub-model (CLM-Palm) for simulating a palm plant functional type (PFT) within the framework of the Community Land Model. The CLM-Palm is tested here on oil palm only but is meant of generic interest for other palm crops (e.g. coconut). The oil palm has monopodial morphology and sequential phenology of around 40 stacked phytomers, each carrying a large leaf and a fruit bunch, forming a natural multilayer canopy. A sub-canopy phenological and physiological parameterization is thus developed, so that each phytomer has its own prognostic leaf growth and fruit yield capacity but with shared stem and root components. …" (Lines 20-29; hereafter line numbers all refer to the attached revised manuscript)

Comment 2: P5 L1-2 Why the models are not meant for studying carbon, water, and energy exchanges? It is hard to understand difference between yours and previous studies, here.

Answer 2: The agricultural models such as OPSIM, ECOPALM, APSIM-Oil Palm and PALMSIM are specialized for simulating the growth and yield of oil palm but they do not represent the full biophysical and biogeochemical cycles as a land surface model does. Their time steps are usually coarse (daily or monthly) and growth may not be constrained by photosynthesis supply. Land surface models such as CLM simulate energy, water and material cycling in a prognostic manner and at finer time steps (e.g. half-hourly). They also have strict check for energy and material balances. A land surface model is also meant to be coupled to climate models by providing land-to-atmosphere energy, water and carbon fluxes so that the feedbacks of terrestrial biosphere to climate can be simulated in coupled earth system model. Our oil palm module is thus developed in the CLM framework, so that "it combines the abilities of an agricultural model and a land surface model", which allows us to simulate climatic effects of the oil palm system in the next steps. We stated this in the discussions. (see revised text in Lines 66-71 and Lines 545-548)

Comment 3: P6 L12 land-atmosphere fluxes of what?

Answer 3: land-to-atmosphere energy, water and carbon fluxes. We revised the sentence (Lines 99-100).

Comment 4: P6 L17 "Structure" means sub-model?

Answer 4: Yes, "structure" refers to the oil palm sub-model developed within CLM, including the new phenology and allocation subroutines. It also refers to the sub-canopy vegetation structure and the sub-canopy dimension that consider each phytomer as a simulation unit. "Structure" is modified to "new CLM-Palm sub-model" and we also give the "CLM-Palm" model name in the title. (Lines 105-106)

Comment 5: P6 L17 simulating "oil palm plantation" of what? Growth and yields and anything else?

Answer 5: As the answer to comment 2, we simulate the growth and yield as well as fluxes of energy, water and carbon between the oil palm land surface and atmosphere with 30-min time step. We revised this sentence to "In this context, we develop a new CLM-Palm sub-model for simulating the growth, yield, and energy and material cycling

of oil palm within the framework of CLM4.5." (Lines 105-106)

Comment 6: P10 L18 You showed "air temperature is the key variable or clock for the phenology". That sounds reasonable in temperate regions. Is it applicable in tropical regions? How about moisture (such as dry and wet seasons)?

Answer 6: We agree that soil moisture or drought stress will act as key variable for oil palm growth and yield. CLM includes soil moisture in the photosynthesis-stomatal conductance module (see Fig. 2 diagram) so that the effects of wet and dry season on assimilates supply are simulated. The effects pass to the carbon and nitrogen allocation module, which controls growth rate and yield. This process is operational for the oil palm PFT. On the other hand, the phenology module relies on GDD (growing-degree days; accumulated temperature) to measure the length of phenological phases as typical for many phenological models. The original CLM model indeed includes soil moisture as a clock for the phenology of stress-deciduous PFTs, but only to initiate leaf litter-fall during severe drought. Oil palm, however, does not shed leaves in dry seasons. Therefore, such a mechanism was not included. There might be effects of water stress on the timing of fruit initiation and maturity but the specific controls on this phenology step are not sufficiently known to allow developing an appropriate subroutine. That is why the CLM model only uses GDD as the clock for all the phenological phases of annual crop PFTs (e.g. wheat, corn). We thus simplify the sentence to "All phytomers are assumed to follow the same phenological steps, where the thermal length for each phase is measured by growing degree-days (GDD; White et al., 1997)". (Lines 161-162)

Comment 7: P10 L26 It is hard to understand concept of PFT level and sub-PFT level. Please define more clearly in section 2.2.1.

Answer 7: We revised this sentence in section 2.1 to "Other processes in the model such as carbon and nitrogen allocation for growth of new tissues respond to this phenology scheme at both PFT level and phytomer level." (Lines 167-169). Another sentence in the preceding paragraph “The modified phenology module controls the life cycle of each phytomer as well as the planting, stem and root turnover, vegetative maturity (start of fruiting) and final rotation (replanting) of the whole PFT” illustrates the phytomer-level and PFT-level phenology (Lines 155-157). Details are in the Supplementary materials. We also clarified the concept of sub-PFT in section 2 so that it refers to phytomer: “Each phytomer can be considered a sub-PFT component that has its own prognostic leaf growth and fruit yield capacity. . .” (Lines 130-131)

Comment 8: P26 L4-5 It is very hard to see “LAI development also matches well with field measurements” in the Figure 4. Please more explanation for the Figure 4, that is more reader friendly.

Answer 8: We revised the caption of Figure 4 (now Fig. 5) and explained in the Results section 4.1 on the comparison of phytomer LAI with 3 leaf samples from the field (Lines 395-399). The LAI of an individual phytomer does not match perfectly with each leaf sample but they are comparable. It needs to be noted that a phytomer in the model is only meant to represent the average condition of an age-cohort of actual oil palm phytomers across the whole plantation landscape. We added this statement in the Introduction (Lines 108-110).

Comment 9: P27 L1 How did you determine “60-day” for the cumulative periods. 30-day is not enough?

Answer 9: 60-day corresponds to the main period of fruit-filling and oil synthesis for a fruit bunch on a phytomer (add in Line 423). Therefore, we assume the precipitation of a 60-day period before each fruit harvest has most direct influence on yield.

Comment 10: P28 L15 Average LAI of what?

Answer 10: The average LAI of 8 oil palm sites (4 H plots and 4 B plots). We revised this sentence to “The average LAI of the eight sites from the model is comparable with field measurement in 2014 (MPE = 10%) (Fig. 9b).” (Lines 456-457)

Comment 11: Some discussions are included in the results section (ex P29 L1-3). You should remove them carefully.

Answer 11: We removed this and other discussions from the results section. Redundancy is largely reduced throughout the text.

Comment 12: P29 L8 What is the meaning of the functionality here? Also, again, discussion concerning with processes in oil palm plantation should be removed from the MS, they must be done in intensive field measurement based studies, not modeling study. I rather want to see application of the model developed in this study, how the model contributes to understand impacts of oil palm expansions.

Answer 12: “functionality” refers to the capability or utility of the new CLM-Palm module for simulating oil palm’s phenology, allocation and yield. We changed this word to “utility”. The discussion section is largely revised following the suggestion by referee #1. This paper focuses on the model development of the phenology and allocation subroutines for oil palm as well as technical implementation within the CLM model. The sub-canopy structure requires adding a new dimension under PFT and structural adaptations of other CLM processes such as radiative transfer, photosynthesis and nitrogen cycling. But phenology and allocation are the base functions for oil palm physiology (growth and yield). Therefore, we only validated with LAI and yield data here. Now we also add a validation with field measured monthly NPP (see new Fig. 3). In a following study, a fuller picture of the carbon, water and energy fluxes over the oil palm landscape are being evaluated with Eddy Covariance flux observation data in Sumatra. The CLM-palm model in the CESM/CLM framework also allows coupling with climatic models so that the feedbacks of oil palm expansion to climate can be simulated. The impacts of land cover change driven by oil palm expansion are being examined for Sumatra and Kalimantan over the past two decades in another following study.

Comment 13: P34 Please include limitation of the model in the summary.

Answer 13: The limitation of the model is added in Conclusions: “Average LAI, yield and NPP were satisfactorily simulated for multiple sites, which fulfills the main mission of a land surface modeling approach, that is, to represent the average conditions and dynamics of large-scale processes. On the other hand, simulating small-scale site-to-site variation (50m $\times$ 50m sites) requires detailed input data on site conditions (e.g. microclimate, soil, and micro-topography) and plantation managements that are often not available thus limiting the applicability of the model at small scale. The point simulations here provide a starting point for calibration and validation at large scales.” (Lines 562-569)

Please also note the supplement to this comment:
http://www.geosci-model-dev-discuss.net/8/C1795/2015/gmdd-8-C1795-2015-supplement.pdf

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