Interactive comment on "Representing anthropogenic gross land use change, wood harvest and forest age dynamics in a global vegetation model ORCHIDEE-MICT (r4259)" *by* Chao Yue et al.

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The manuscript by Yue and colleagues presents model development in ORCHIDEE-MICT, incorporating a forest age structure and gross land use transitions, including shifting cultivation. Both aspects were subject to several papers in the recent years and it would be helpful if the authors set their implementation and their findings more (and more accurately) in context of the already published literature.

We thank the reviewer for the efforts to review our paper. As suggested, we included an overview table of the gross land use change implementations in current DGVMs. The introduction, model description and discussion sections are revised to take into account the existing work, and to make our implementation more relevant with other DGVMs. In addition, the whole manuscript has been carefully checked to avoid minor editing errors such as those raised by the reviewer in the technical comments.

In particular:

1. Regarding the effects of net vs. gross transitions, there has been a recent multimodel study by Arneth et al. (2017) that showed the importance of tree harvesting and land clearing from shifting cultivation. In this paper seven models were used to determine the influence of wood harvest and shifting cultivation. It might be helpful to relate to the findings of Arneth et al. (2017).

The work or Arneth et al. (2017) has been included in the discussion in our paper. Their work is now cited in the introduction as well in the revised manuscript. In both sections of introduction and discussion, references to this work are expanded.

2. The described approach to model gross transitions as matrices looks very similar to the implementation of gross transitions in the DGVM JSBACH, as described by Reick et al. (2013), which has not been mentioned at all in the manuscript so far (please also see the comment on the lines 87-93 below). It would be helpful to include some comparisons of the way Yue et al. represent gross transitions and the way it is presented in Reick et al. (2013). The same might hold for the mentioned paper describing LPX-Bern (Stocker et al., 2014). There are two further models listed in the 2015 update on the global carbon budget that include gross transitions (Table 5; Le Quere et al., 2015): CLM4.5 (Oleson et al., 2013) and Visit (Kato et al., 2013), which might also be worth looking at.

The similarity between Reick et al. (2013) and our work is that both are based on LUHv1 data and include gross transitions. There are two major differences: (1) Reich et al. (2013) focused on

reconciling dynamic vegetation process and external forcing data, while in our paper the dynamic vegetation is turned off and we relied on reconstructed historical land cover time series that are made consistent with the model. (2) Reick et al. (2013) made it an internal JSBACH model decision process on how to convert LUHv1 land cover types (i.e., primary and secondary natural lands) into model plant functional types (i.e., forest versus grassland, the pasture rule etc.). Whereas we focus on including different aged land cohorts in the ORCHIDEE model and implementing a set of hierarchical rules regarding the land cohorts subjected to different land use change processes. The allocation of natural lands into forest versus grasslands, and the reconciliation of LUHv1 land cover distributions and the current-day satellite-based PFT map, instead, are handled independently by external preparations of reconstructed historical PFT map time series. These differences are now discussed in the revised text where they're relevant. We also included references to other models as mentioned by the reviewer. In response to Beni Stocker's comments on a companion paper of the current study (bg-2017-39, Biogeosciences Discussions), we added an overview table of current DGVMs with implementations of gross land use change. For CLM4.5, we contacted Peter Lawrence and Danica Lombardozzi (personal communications) and they confirm that gross land use change has not yet been included in CLM4.5 but will be included in CLM5.

3. There are several DGVMs that have some kind of age structure, e.g. LPJ-Guess with its gap dynamics (Smith et al., 2014) and LM3V (Shevliakova et al., 2009). The latter is particularly interesting for the manuscript of Yue et al. because of the combination of simulated secondary regrowth and land use and land management, including shifting cultivation.

We thank the reviewer for referring to these highly relevant works. They're now cited and discussed in the revised paper in the introduction and discussion sections.

4. I do not understand which of the implementations regarding age structure stem from ORCHIDEE-CAN and which are newly developed in this study (l. 190-221), and I think it would be helpful if the authors could revisit this paragraph for clarity. Particularly, I do not understand how cohorts are ageing in ORCHIDEE-MICT. Since this might be a critical aspect for the described carbon dynamics it would be helpful if the authors could put some more emphasis in describing the ageing of the forest, maybe an additional Figure could help.

The basic approach and code base to introducing sub-grid cohorts are brought from previous developments in ORCHIDEE-CAN, which was made with the purpose to represent sub-grid forests of different age classes. This is stated in the original manuscript (line 205–206). To make this clearer, we inserted the following sentence after the original line 206: "*The code base to include sub-grid forest cohorts are migrated from ORCHIDEE-CAN, with substantial adaptions being made in ORCHIDEE-MICT. Except for this, all other LUC developments have been achieved within the current study*." As ORCHIDEE-MICT is based on a single-leaf model, the aging of cohorts is simply represented by moving the concerned cohort to the next (older) one when its wood mass exceeds the cohort upper boundary. Except for cohort boundary, no further cohort-specific parameterization is done, so essentially all cohorts are governed by the same set of biophysical and ecological parameter values. However, in ORCHIDEE-MICT there do exist some "aging" processes to approximate some key changes when a forest ages, notably, the NPP allocation to belowground sapwood decreases with the time since establishment, that is, more biomass is allocated belowground to develop roots for young trees. We inserted the following

sentences at the end of the 3rd paragraph in Sect. 2.1.3 to clarify this: "*Forest ages by moving from the current cohort to the next one when the woody biomass exceeds the cohort upper boundary. Except for the cohort boundaries, no further cohort-specific parameterizations are done, so essentially all cohorts are governed by the same set of biophysical and ecological parameter values. However, in ORCHIDEE-MICT there are indeed some simple "aging" processes to proximate the key changes when a forest ages, notably, the NPP allocation to belowground sapwood decreases with the time since establishment*." We don't think an additional figure is needed so it is not provided.

lines 87-93: This paragraph is unfortunately not correct. Gross transitions are implemented in the DGVM JSBACH (see Reick et al., 2013), not in an emulator. Also, Wilkenskjeld et al. (2014) did not use an emulator but the carbon cycle sub-module of JSBACH, for efficient comparisons of net and gross transitions. Furthermore, JSBACH with gross transitions has already been used in the MPIESM simulations for CMIP5 and in TRENDYv4 simulations used in the global carbon budget in 2015 (Le Quere et al., 2015). In this budget, two further models beside JSBACH did include gross transitions (see "shifting cultivation", Table 5, Le Quere et al., 2015). The reason why no model included gross transitions in the 2016 update of the global carbon budget was because the LUH2v2h data set was not ready: "The more comprehensive harmonised land-use data set (Hurtt et al., 2011), which also includes fractional data on primary vegetation and secondary vegetation, as well as all underlying transitions between land-use states, has not been made available yet for this year. Hence, the reduced ensemble of DGVMs that can simulate the LUC flux from the HYDE data set only." (Le Quere et al., 2016).

Thanks for the reviewer for pointing out this mistake. It is now corrected. We added an overview table for DGVMs that have implemented gross land use changes (Table 1 in the revised manuscript).

line 115: "sub-grid sub-grid"

done.

line 113: "plant function types" -> plant functional types

done.

line 137: "forgings" -> forcings

done.

lines 215-217: this assumption might not be correct for natural grasslands and pastures (see e.g. Nyawira et al. 2016 and references therein).

We agree with the reviewer that our parameterization of herbaceous MTCs in terms of soil carbon changes cannot accommodate changes of SOC in all different LUC types. The effectiveness of this feature of differentiating herbaceous MTCs is limited by the model's simulation of soil temperature and moisture and the computation efficiency (as is explained in the original text, line 481–486). Therefore, this feature is more for informative purpose and serves as

a “place holder” for the future improvement in this scheme, rather than having solid scientific significance. We added in the revised two blocks of texts to clarify these points. We inserted the following texts in the 4th paragraph of Sect. 2.1.2: “*Because the directional change of soil carbon largely depends on the vegetation types before and after LUC and climate conditions (Don et al., 2011; Poeplau et al., 2011), ideally agricultural cohorts from different origins should be differentiated. However, to avoid exploding the total number of cohorts and the associated computation demand, as a first attempt, we simply divide each herbaceous MTC into two broad sub-grid cohorts according to their soil carbon stocks and without considering their origins. We expect that such a parameterization can accommodate some typical LUC processes, such as the conversion of forest to cropland where soil carbon usually decreases with time, but not all LUC types (for instance, soil carbon stock increases when a forest is converted to a pasture).*”. We inserted in the last paragraph of Sect. 2.2.3 the following texts: “*Overall, this feature of separating herbaceous MTCs into multiple cohorts is coded more as a “place holder” for the current stage of model development rather than having solid scientific significance. To fully track soil carbon stocks of different vegetation types and their transient changes following land use change, a much larger number of cohorts are needed. But for a global application, this is limited by the computation efficiency.*”

line 285: "The cohort age subject to LUC of is one..." -> remove the of

done.

line 328: According to their webpage (http://gsweb1vh2.umd.edu/luh_data/LUHa.v1/readme.txt) LUH1 also makes a distinction of harvest from mature and young forest. Do youuse this information in your model, too? Furthermore, LUH contains "harvest from non-forested land", is this information used?

We treat harvest from mature forest in LUH1 as primary forest harvest, and this has already been explained in section 2.1.4 in the original manuscript (line 336). Harvest from young forest in LUH1 is implemented as secondary forest harvest (also see details in the same paragraph. “Harvest from non-forest land” is not included in our analysis. We inserted the following sentence in the 2nd paragraph of Sect. 2.2.3 to clarify this: “*Wood harvest from primary and secondary forests in LUH1 is used, while wood harvest from non-forest is not.*”

line 341: "first go first for" -> first go for

done.

line 347: should this maybe be secondary?

We indeed mean “primary harvest” here.

line 359: "to ensure the their" -> to ensure that their?

We changed “the” to “their”.

line 386: but it respires in the grid cell where it is harvested?

Yes. Spatial relocation of harvested crops is not considered in the model. This point is now explained in the revised manuscript.

line 403: I do not understand this sentence

We apologize for this confusion. This sentence is changed to "$F_{Pasture}$ *for carbon sources from pastures other than harvest*".

line 427: remove the "and"?

done.

line 430: replace "on" with "by"?

done.

line 445: held constant or held as constants

It should be "held constant", now changed.

line 447: a hypothetical scenario

done.

line 448: I do not understand the sentence "Forest harvest of the same intensity..."

We mean "forest harvest of the same annual areal fraction". This is revised.

lines 556-561: But why is the NPP in simulations with age dynamics smaller? Is the forest in these simulations not yet as productive than intermediate-age forest?

For this particular case NPP is smaller with age dynamics, but the global run shows NPP with age dynamics is higher, in principle due to lower autotrophic respiration (because of slightly lower biomass) in the simulation with age dynamics. In general, as ORCHIDEE-MICT uses a big-leaf approximation that allows LAI to quickly level out and NPP reaching its maximum, and because cohort woody mass boundaries are the only parameter that differ among forest cohorts, we expect such differences in NPP between S_{age} and $S_{ageless}$ to be subtle and do not have significant scientific implications in the ecological process. The difference in simulated E_{LUC} is dominated by the difference in the forest biomass density being cleared. Therefore, the small differences in NPP between S_{age} and $S_{ageless}$ have not been explored in depth.

line 702: Do you mean Hurtt et al. 2006? Else the reference is missing.

We mean Hurtt et al., 2006 and we apologize for this typo.

lines 710-715: It might be helpful to mention here again that LUH does include biomass harvest but that this is not used in your model.

This has been added.

line 748 this is section 6

This has been corrected.

line 753 and this section 7

This has been corrected.

line 1015: Fig. 9 does not include a "panel b"

This has been corrected.