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Interactive comment on "Comparing the influence of net and gross anthropogenic land use and land cover changes on the carbon cycle in the MPI-ESM" *by* S. Wilkenskjeld et al.

S. Wilkenskjeld et al.

stiig.wilkenskjeld@mpimet.mpg.de

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article

Answer to anonymous review #3

We thank the referee for his or her constructive review. We are happy that the reviewer found our paper helpful to the community in understanding the existing inter-model differences with respect to LULCC.

Specific comments

1. Section 5, first paragraph: ***The significance of the differences in LCE could be made clearer by comparing them to the spread of CMIP5 estimates of NBP or to anthropogenic CO^2 emissions rates.***

   We have added a comparison to the anthropogenic carbon emissions from fossil sources to our revisited manuscript.

2. Section 5, first paragraph: ***"The differences between the LULCC methods are getting smaller towards year 2100, probably due to establishment of equilibria between local carbon reservoirs and essentially constant LULCC-rates." Do the LCE differences between the LULCC methods get smaller because the differences between the areas of LULCC get smaller? A plot of the timeseries of area converted would be interesting.***

   Motivated by this question (and a similar question from reviewer #1 to whom this answer is co-listed) we investigated in more detail the reason for the convergence towards 2100 in RCP 4.5 and RCP 8.5 – a feature not found in a study by Stocker et al. (2014) also dealing with net vs. gross transitions (and which was published June 2014 in Tellus B). Towards the end of the 21st century some regions have – as expected – higher LCE for gross than for net LULCC, whereas others (mainly in the regions at the edges of the African and South American rain forests) have higher net than gross LCE. The convergence is thus in reality due to different regional phenomena which are canceling each other when integrated over the globe. The phenomenon arises as a complicated interplay between the forcing climate, the pasture rule, the dynamic vegetation, wildfire activity and the way JS-BACH/CBALANCE prevents its living carbon pools from becoming unrealistically high. There are several part-explanations of which two examples are:

   (a) JSBACH/CBALANCE has a structural (PFT-dependent) limit for the size of

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its living carbon pools and NPP which would lead to exceeding this limit is ignored. This is more often the case when using net than gross transitions since less carbon is removed by LULCC. Gross transitions rather use the NPP that net ignores to produce additional litter.

(b) As described in the paper, fire is (due to different litter availability) differently affected by net and gross transitions. Specially in the Sahel region, this leads to runs with gross transitions having more desert than those with net. With net transitions we thus have a larger vegetated area which can produce LCE.

We have adapted the relevant paragraphs (mainly the last in section 4.1.2 and the first in section 5) in the revised manuscript according to this new knowledge.

3. Page 12, Line 3: ***I would argue that gross transitions don't add extra uncertainty, but that they allow the uncertainty to be estimated/quantified. You could suggest that future work could quantify this uncertainty; with your model you could test the sensitivity to the forcing data, i.e. to Hurtt et al.'s assumptions (I'm not suggesting that this test is done here!).***

   Thanks for the good suggestion. We have changed paragraph 2 of section 5 along this line:

   "Hurtt et al. (2011) assesses the uncertainty of the LULCC data by testing a large ensemble of different assumptions, resulting in a large range of converted areas (both net and gross). Of this ensemble, the "Land-Use Harmonization Dataset" is just one member. Ideally the uncertainty in LCE for both gross and net transitions as well as the difference between them would be assessed by feeding the ESMs with more of the ensemble members."

4. Page 12, Line 20: ***Can you show LCE estimates from a net transitions sub-ensemble and a gross transitions ensemble? Or is it not clear which es-***

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timates should be in each sub-ensemble? If it's not clear, perhaps you should suggest that this should be made clear in future.

The CMIP5 protocol did not explicitly address the LCE question and thus no reference runs without LULCC were made in CMIP5. To our knowledge, the most thorough work done on inter-CMIP5-model-comparisons of LCE was the LUCID-CMIP5 study by Brovkin et al. (2013). We have added a reference to this study to the fourth paragraph (cited below) of section 5 parting the participating models according to there LULCC type.

"Brovkin et al. (2013) compares for a slightly different experimental setup than ours the (cumulated) LCE for a sub-set of five CMIP5 models. Indeed, the two models with highest LCE (MPI-ESM and MIROC) are using gross transitions, while the others used net transitions. MPI-ESM is the only of the five models implementing wood harvest."

5. Page 13, Lines 15–27: ***I think the line 25 to 27 requires elaboration. Why have you chosen these numbers and what is the implication of this estimate? What is the significance of 0.1 Pg/yr? Why not assume a delay of 50 years? Can you constrain either the delay or the harvest emission? Alternatively, the paragraph could be removed, the paper is about LULCC emissions and not about wood harvest.***

   We wanted to support the hypothesis that wood harvest is only a minor contributor (compared to that of land use changes) to the LCE and thus also to the differences between the different models. This analysis was made offline, directly from Hurtt's data on wood harvest, just to get an idea of the order of magnitude of the effect. There is no special significance about 0.1 PgC/yr, except from that it is a number which hopefully everyone can agree on to be small compared to the LCE from the land use changes.

   To answer a question from reviewer #1 (pt. 1 in that review) we performed ad-

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ditional experiments without land-use-changes but with transient wood harvest. Comparing these experiments to our original “without LULCC” experiments gives us quantitative numbers for the contribution of wood harvest to the LCE. These are (annual means): 0.09, 0.22, 0.26 and 0.32 PgC/yr for the historical, RCP2.6, RCP4.5 and RCP8.5 scenarios respectively (figure 3-1, added as S7 in the supplemental material of the revised manuscript).

The new study by Stocker et al. (2014) also presents a quantitative number for the LCE from wood harvest: 23PgC (or 0.15 PgC/yr on average) for the historical period. In our revisited manuscript, we have removed the crude “0.1 PgC/yr estimate” and replaced this part of the discussion based on the findings from these two new analyses.

6. Page 15, Lines 9–10: ***Please clarify the last sentence of the appendix, as I read it it says that: Using net instead of gross transitions underestimates the area of land converted by*** ≈ 66***% during the historical period, and underestimates the area converted by*** ≈ 90***% during the RCP period. Is this what you mean? From the values in section 4.1.2 I calculate that using net instead of gross transitions underestimates the area by 57% during the historical period (at MPI-ESM-LR resolution). I can't find the equivalent values for the future period, please could you add these in. Again, a plot of the timeseries of area converted would be interesting.***

   Actually you have understood the sentence right. Since not much land is net changed in the future scenarios, shifting cultivation and other sub-grid-scale LULCC becomes an even larger part of the total LULCC in the future scenarios than in the historical period. Thanks for pointing out the discrepancy between the numbers in the “main” paper and the appendix. Unfortunately a wrong number for our net transitions slipped through into the submitted manuscript. It should be 40×10^6 km^2 instead of 58×10^6 km^2. The remaining minor discrepancy between the numbers is due to the appendix analysis being performed directly on the original 0.5° grid, while the numbers in the main paper are from our model grid and land-sea mask. We have added the corresponding numbers for the RCPs:

"During the RCP period a total of 127 (13) $\times 10^6$, 91 (10) $\times 10^6$ and 112 (9) $\times 10^6$ km^2 are gross (net) converted in RCP2.6, RCP4.5 and RCP8.5 respectively (Figures S4 and S5)."

A timeseries (figure 3-2, added to the supplementary material as Figure S4) shows that the land use changes stabilizes towards 2100. In the case of net land use, the transitions are in all cases decreasing during the RCP-period, while in the gross case, RCP4.5 decreases, RCP8.5 stays on the level of the end at the historical period and RCP2.6 is slightly increasing wrt. this value before it stabilizes. Figure 3-3 (S5 in the supplementary material) shows (partly) the geographical distribution of the transitions.

Figure caption of figure 3-3: Yearly average land-use changes [10^3 km^2/latitude band/yr] (in the T63 Gaussian grid, the shown latitude bands are about 1.87 degrees) between pairs of vegetation classes for the scenarios. E.g. in the upper panels, the blue curve is the gross conversion from forest to crop, the black gross crop to forest, the red net forest to crop and the magenta net crop to forest. Note that the scale of conversions between pasture and crop (lower panels) is 1/30 of that of the others.

Technical Corrections.

The corrections have been included in the revised manuscript.