

Responses to reviews for manuscript **Global Transition Rules for Translating Land-use Change (LUH2) To Land-cover Change for CMIP6 using GLM2**

To Reviewer #2 Eddy Robertson:

Reviewer 2: The paper provides a useful assessment of how the choice of implementation of landuse data can affect the simulation of tree cover and carbon emissions. A more detailed description of the model used is needed to allow better interpretation of the results. A clearer justification of the choice of optimal transition rule is needed. Key uncertainties in the model simulation need to be discussed, in order to assess whether the results show the optimal transition rule for all models or simply for GLM2. I have also suggested a few minor corrections.

Response: Thank very much for your time on reviewing our paper. Your comments are very helpful for us to improve the paper. We have carefully addressed your comments, please see the detailed responses below. Note that ‘transition rule’ has been renamed as ‘translation rule’ throughout the manuscript to avoid confusion with LUH2 land-use transitions.

Reviewer 2: P5, L21: Please provide more detail about the Miami model and the simulation of carbon stocks.

- What inputs does the Miami model use? Does it use climate data? What is the MSTMIP climatology?
- Is the Miami model a process-based model or a statistical model?
- What time period is being simulated? What period does the MSTMIP climatology cover? Does the model use CO₂ concentration from the year 850, or is CO₂ concentration simply not a factor the model can consider?

Response: The GLM2 estimate carbon stocks and fluxes using a statistical model which take temperature and precipitation into account. The input is from MSTMIP by averaging temperature and precipitation during 1901-2000. Since this model does not take CO₂ into consideration, CO₂ concentration is not used at all. We have reorganized these lines and clarified these questions at the first paragraph of section 2.3.

Reviewer 2: Discussion: The paper should comment on the significance of uncertainty in the map of potential carbon stocks, for example if the global total potential carbon stock were only 557 Pg C, do you think a different transition rule would be optimal?

- Related to the above point, is whether different rules are best for different ESM, because they will simulate different potential carbon stocks. Please comment.

Response: We added a discussion of this issue to the Discussion. Briefly, our goal was to provide a reference set of translation rules for this reference land-use dataset. However, we note that it is possible to obtain different results with different models using the same translation rules. The CMIP6 Land Use Model Inter-comparison Project (LUMIP) has organized an inter-comparison of model results using this forcing dataset (Lawrence et al 2016).

Reviewer 2: P5, L26 and discussion: Why was 2 kg C/m² chosen to define a forest? Is using 2.2 kg C/m² equally justifiable and if so, might this lead to a different transitional rule being optimal?

Response: The threshold value of 2 kg C/m² potential biomass was used for consistency with prior studies and GLM2/LUH2 (see references below).

Hurtt GC, Pacala SW, Moorcroft PR, Caspersen J, Shevliakova E, Houghton R, Moore B (2002) Projecting the Future of the US Carbon Sink. Proceedings of the National Academy of Sciences of the United States (PNAS)/ 99(3): 1389-1394.

Hurtt GC, Frohling S, Fearon MG, Moore B, Shevliakova E, Malyshev S, Pacala SW, Houghton RA (2006), The underpinnings of land-use history: three centuries of global gridded land-use transitions, wood harvest activity, and resulting secondary lands. Global Change Biol 12:1208–1229

G. C. Hurtt, L. P. Chini, S. Frohling, R. A. Betts, J. Feddema, G. Fischer, J. P. Fisk, K. Hibbard, R. A. Houghton, A. Janetos, C. D. Jones, G. Kindermann, T. Kinoshita, Kees Klein Goldewijk, K. Riahi, E. Shevliakova, S. Smith, E. Stehfest, A. Thomson, P. Thornton, D. P. van Vuuren, Y. P. Wang (2011) Harmonization of land-use scenarios for the period 1500–2100: 600 years of global gridded annual land-use transitions, wood harvest, and resulting secondary lands. Climatic Change 109:117–161

Reviewer 2: P10, L27 and figure 4: Disagreement with the average satellite-based forest cover does not mean that the model is not consistent with (i.e. within the range of) the ensemble of satellite-based forest cover. Please can you at least mention this possibility. You could account for this uncertainty, perhaps by adding an uncertainty bar to figure 4 showing the errors relative to the TCCF and GLC2000 datasets.

Response: Good suggestion. We have recreated the Figure 4 by comparing rule estimates to each of the six datasets as well as to the average satellite-based forest cover. The new Figure 4 still suggests Rules 1, 2, 3 outperform Rule 4 in terms of gridded forest cover as long as the same satellite-based dataset is used as the reference.

Reviewer 2: Figures 5, 6 and 9: Please add results from rule 4 to figures 5, 6 and 9. I don't know why you have stopped considering rule 4.

Response: We stopped considering Rule 4 because it has relatively large bias than Rules 1-3 in forest cover and vegetation carbon estimates. However, we have included Rule 4 again in our recreated Figure 5 and 6.

Reviewer 2: Discussion: More justification is needed for your choice of optimal rule. I agree that, all else being equal, using rule 1 is best because it is consistent with HYDE 3.2. It's fair to exclude rule 4 because it produces too much tree cover (table 4) and compared to the other rules it has twice the carbon stock error in the tropics (Figure 8). However, in the discussion you need to more clearly state why rule 4 is excluded. I don't know why rule 3 has been excluded, please can you justify this choice?

Response: We have added detailed justification at the results section.

Reviewer 2: Discussion: Will the choice of rule matter less in future simulations? Is there less range-land expansion in future?

Response: We believe discussion of impacts of rule choices is very helpful, however our experiments and diagnostics really limit this kind of analysis, therefore we only state that this study only aim to propose a recommended rule for translation of historical land-use change to land-cover change in the introduction.

Reviewer 2: P2, L18-22: This sentence needs to be made clearer. I also think that you are underselling the importance of LUH2, it is not only used in land-use specific model simulations, it is a key input to the DECK and historical simulations as well as for future projections (scenarioMIP). Additionally, you could mention that it is used to simulate the biophysical effects of land-use change as well as the biogeochemical effects.

Response: We have rephased these lines to appropriately credit the significance and importance of the LUH2 for the reasons you mention. The revised sentence is “*Quantification of historical Land-Use and Land-Cover Change (LULCC) is important because it serves as the basis for examining the role of human activities in the global carbon budget and the resulting impacts to Earth’s climate system. For this purpose, LULCC reconstructions enter Earth System Models (ESMs) (Lawrence et al., 2016), Dynamic Global Vegetation Models (DGVMs) (Le Quéré et al., 2018) and bookkeeping models (Hansis et al., 2015) to quantify biogeochemical and biophysical impacts of historical land-use change as part of historical simulates (DECK and CMIP6 historical simulations), future projections (scenarioMIP), impacts studies (ISIMIP), paleoclimate studies (PMIP), land-use specific simulations (LUMIP), and biodiversity studies (IPBES)*”

Reviewer 2: P3, L11-15: This sentence needs to be made clearer.

Response: We have reorganized this part by removing some irrelevant description. The revised sentence is “However, explicit suggestions for land-cover and carbon stock modifications resulting from these new defined land-use types are not yet provided, but are crucial for the translation of land-use change to land-cover change within ESMs or DGVMs”.

Reviewer 2: P8, L1: What is the “wood fraction?”

Response: The fraction of NPP is allocated to cumulate stem and branch biomass annually. We have added explanation for it.

Reviewer 2: P13, L4: Please remove reference to the “Miami-LU model” and replace with “Miami model” or “GLM2,” as appropriate.

Response: We have replaced ‘Miami-LU’ by ‘GLM2’.

Reviewer 2: Caption of Table 5: Should refer to table 3 not table 4?

Response: Yes, it should be ‘Table 3’. Change made.