

Interactive comment on “The Land Use Model Intercomparison Project (LUMIP): Rationale and experimental design” by David M. Lawrence et al.

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Review of gmd-2016-76: The Land Use Model Intercomparison Project (LUMIP): Rationale and experimental design

The authors present the rationale and experimental protocol for the upcoming LUMIP. It appears that they intend this to be the primary reference document for the modeling groups participating in LUMIP. They first provide a comprehensive background and context with respect to CMIP6, and then describe an idealized experiment, a set of historical land-only experiments, and a set of future experiments. They then introduce a plan to develop metric, discuss challenges to analyses, and describe linkages to other MIPs that will enable studies relating LULCC to land-coupling strength and extremes. The paper concludes with a description and examples of subgrid data reporting for

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LUMIP.

The introduction and context are thorough and compelling, and the set of experiments is quite comprehensive and ambitious. I am impressed by this expression of the tremendous effort put forth by the LUMIP team (and others who may have contributed).

I have reviewed this text as if I were a modeler expecting to participate in LUMIP. For the most part, the authors have done a good job explaining what is expected of the LUMIP participants. Apart from some clarification and additional detail, there is only one potentially major issue, and a few minor ones, that should be addressed prior to publication. I have summarized the main points here, with additional detail found in the specific suggestions and comments section below:

1) The experiments and the required simulations need to be presented in full, so that modeling teams can use this document for direct guidance. This means that the parent/control simulations shared with other MIPs need to be described with the relevant land configurations so that the experiments using LUMIP-specific simulations can be clearly presented or inferred. The tables 1-3 need to include all relevant sims, with the MIP-shared ones clearly marked, and the tier clearly marked. These tables will be an important reference. Please note that a simulation is not an experiment, and in most cases multiple simulations (at least on plus a control) are required to constitute an experiment. Of course, every little detail and contingency cannot be included here, and the authors do thankfully provide an online venue for further clarifications, updates, and details.

2) The potentially major issue involves the default land configuration for LUMIP and the rest of CMIP6. There are several aspects that should be addressed, but the one I am most concerned about is the use of gross (intra-annual) LULCC transitions as the default in models with this capacity. To make the most robust comparison across models, gross transitions should not be used, except as part of LUMIP to examine the consequences of including them. It is acknowledged that including gross transitions

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can have a large impact on the carbon cycle, CMIP5 has already shown how including gross transitions can create carbon cycle outliers, the biogeophysical impacts of including gross transitions in models are not well established, and the gross transitions are probably the most uncertain component of the land use/cover data. Furthermore, I expect that still only a minority of models will be able to use the gross transitions. These are related notes that I don't expect to be dealt with here or in CMIP6, but should be thought about for future model comparisons: Irrigation and fertilization and other land management activities also raise red flags in this regard, but these may have smaller and more local effects than gross transitions, and so may be of less concern when comparing against models that do not have crop or management components. But gridded nitrogen application data are also very uncertain, as are nitrogen model components in general. Prognostic biogeography is another capacity that should be turned off for general model comparison (until most models have it, anyway), and turned on (in something like LUMIP) for examining the differences it generates (I understand that this would pose challenges for teams to do additional, separate model spin-ups for the two configs, but one may ask what the utility is of additional model comparisons in which the models continue to diverge in basic capacity and initial state).

3) The experiment to explore the effects of fertilization is not complete. This might have been a practical consideration, but it does not independently address both primary fertilization causes of differences in crop growth: area and application rate. questions regarding nitrogen application rates loom just as large as questions regarding fertilized area, and it would be useful to include the other two complementary sims: constant area with changing rate, and constant rate with changing area. Irrigation could be subjected to a similar set of sims, but it is less clear what it would mean to impose a constant irrigation rate because it varies year to year, usually based on environmental conditions and need.

4) What is the recommended protocol for using the new forest/non-forest area data in the non-idealized sims and the rest of cmip6? You describe how different types of mod-

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els (i.e. different initial forest area, different definitions of forest area, (non-)prognostic biogeography) should deal with forest in the idealized sim, but give no guidance on how different types of models should deal with the new forest area input. Just having the forest area input without guidance could still cause considerable divergence in land cover across models. I suggest presenting a recommended protocol for using the forest area data so as to minimize such divergence.

5) Please discuss the role of uncertainty in the LULCC data. There is a short section on uncertainty in atmospheric forcing data, and uncertainty in LULCC data is just as relevant, yet less understood. Addressing such uncertainty is beyond the scope of LUMIP, but the topic needs attention called to it because it will have to be addressed in the future.

specific suggestions and comments:

abstract

line 1: "...large [?changes?] to the..."

lines 12-13: not sure what you mean by "relative to fossil fuel emissions." see comment for line 677 below.

line 19: unfinished sentence "...with respect to ???"

line 20: How does this relate to the previous sentence? Are you only presenting activity (2)?

lines 18-21: I suggest expanding/explaining the acronyms here.

line 27: what is "a new subgrid land-use tile data request?" Does this mean you are also presenting activity (1)?

introduction

line 38: "...climate are relatively..."

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line 68: "...expansion have likely..."

line 71: NEE is also a surface flux, albeit a net one - maybe use "seasonality of mass and energy surface fluxes" or something similar

line 80: "...climate has led to open..."

line 93-102: expand these acronyms on first time use

lumip activities

line 111: I suggest you separate out this third question, which takes additional work beyond what is required for question 2.

line 115: not sure what you mean by "relative to fossil fuel emissions." see comment for line 677 below.

line 124: It would be useful to define a protocol for using the forest/non-forest data in the non-idealized experiments. The protocol could be similar to that outlined for the idealized deforestation experiments, which acknowledges differences between prognostic and non-prognostic biogeography models and differences in initial forest cover among models. For example, the protocol could focus on matching annual changes in forest cover, with all the prognostic biogeography models including biogeographical changes for matching in the historical period, but not including them for matching in the future period (because the IAMs do not incorporate biogeographical effects on land cover in their scenarios). It would make sense for all the models to do the lumip sims without the prognostic biogeography (and then add sims to explore the effects of biogeography), but this would require additional sims to replicate those shared by other mips. this is something to think about for future mips.

lines 138-142: are the luh2 wood harvest data by volume/mass, or by area? or are both provided? can all the LUMIP participants deal with wood harvest mass? if both are provided, you may want to recommend (or request) that groups use the volume/mass data.

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line 166: suggestion: "...variables on [individual] land-use tiles [within grid cells]..." or maybe 'distinct' or 'separate,' "multiple" is unclear

line 176: you may want to include a citation here as well, as evidence for this may not be widely acknowledged.

line 186: this example sounds more like land management (mowing vs not). maybe a better example of land use is whether forest is harvested or not (and rather than wood harvest be a management type, forest management options would include plantation vs tree selection vs clear cut). another land use example is whether grassland or shrubland is used for grazing/pasture or not, or whether cropland is annuals, perennials, orchard, or fallow (or whether there is cropland at all).

line 188: wood harvest is more like a land use, in that it describes the purpose (wood) for which humans exploit forest (or other land cover types). as mentioned above, there are several land management strategies that can be employed to achieve the land use of harvesting wood.

line 193: You may want to be clear that in this manuscript LULCC refers to ALCC only. I am not sure that this is generally the case, nor that it should generally be the case.

experimental design and description

lines 196-198: please revise and/or split this sentence to clarify it. also, expand DECK, as i think it is a first time use of the acronym

lines 198-199: awkward: "...coupled model idealized deforestation experiments..."

lines 201-202: "...the forced response of land-atmosphere fluxes to land cover change..."

lines 207-209: This information is incongruous and unclear. What does "request" mean? What do "tier 1" and "tier 2" mean? You also refer to tier 3 in table 3. What is tier 3?

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line 210: what about section 2.1? lines 119-215 focus on the lumip experiments, and then you jump immediately, and unexpectedly, to a non-lumip discussion

lines 225-249: suggestion: separate paragraphs for general guidelines, 1850-specific guidelines, and >2100-specific guidelines also, rather than use “relevant year” and “constant land use year,” pick a single, descriptive term to refer to the year that defines the “constant land use,” such as “constant land use reference year,” or something better

line 251: “. . .differences among CMIP6. . .”

line 255: need definition of “PI-control” - this can be done at first use, which may be line 221-220

phase 1 experiments

lines 268-270: it sounds like there is only one experiment also, table 1 includes only one simulation. it should also include the comparison/control simulation for the experiment, which appears to be the DECK picontrol.

line 276: is Fig X a supplemental figure? or should it be figure 2?

line 276: this should be included in table 1 also, it should be made clear that picontrol needs to be in equilibrium for several years prior to the branch, and how you intend to use picontrol as the control sim for the experiment. I am guessing that you intend to use an average of pre-branch picontrol years as the control for comparing the deforestation and post-deforestation years of the lumip sim (assuming that the picontrol isn't continuing in parallel, which would also work). however, 30 years of constant forest may not be enough time for the land carbon cycle to equilibrate, so comparison with pre-deforestation may not be robust. I suggest adding another 30 years to the post-deforestation part of the sim to ensure some stability for comparison with picontrol.

line 285: you may want to state “by the end of year t,” which clearly includes models that change forest area throughout the year and models that make a single area change

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during the year.

lines 288-296: It should be made clear that $t=1850$ is the initial state (i.e. $t=0$). especially in equation 2, where the t limits are not shown (maybe they should be).

lines 291 and 296: do you mean F_{tot} ? and in line 296, this should be less than or equal to 20 M km^2 .

lines 292-293: shouldn't this be equation (2)? and it is currently duplicate.

lines 303-306: It should be requested that modeling teams report the annual spatial land type data (for diagnostics such as figure 2), and the global area of forest removed, so as to know which models were able to remove 20 M km^2 of forest, and which ones were not able to do so.

line 305: “the examples shown in figure 2” should probably be in parentheses, as this phrase muddles the sentence a bit

line 332-335: land-hist is missing from the tier 1 list. it is still tier 1 even though this sim is also required for another cmip6 mip, which should be made more clear here and in table 2.

line 333: what is “X?” 13? and it looks like the period can be either 165 or 315

lines 334-335: the land-hist sims need to be described in detail, as it is the basis for all the other sims. for example, is the prognostic crop model part of this sim? are gross (intra-annual) lulcc transitions standard here?

lines 342-346: This is redundant, and as such, confusing. It sounds like something additional, but it isn't. It can be removed.

line 349: what do you mean by the “TRENDY” simulations? there is only one climate-related sim listed, and it is not indicated as a TRENDY simulation. Besides, these are LUMIP simulations, and it seems unnecessary to complicate things by calling one simulation a TRENDY simulation.

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lines 350-351: not sure what “clean comparison” means. yes, the climate forcings will be the same, but there will still be land cover, land use, and land management differences among the models. And probably resolution differences as well. Different initial years and land states and how they came about will also introduce differences among the model outputs.

lines 372-377: this paragraph is evidence that the default for all cmip6 models should be either gross or net transitions. given that only some models can represent gross transitions, the high uncertainty of the gross transition data, and the accompanying uncertainty due to land cover translation (particularly non-forest), the default across all cmip6 should be net annual transitions. otherwise some models will have grossly different carbon estimates in all simulations and experiments. this means that the LUMIP simulation here should be land-grossTrans, where the gross transitions are enabled to explore their effects on surface mass and energy exchange.

lines 378-380: need to reference section 2.3.1 to tell reader that the appropriate GCM simulations will be available.

lines 381-389: Uncertainty in the driving land use/cover data poses the same challenge for comparison to observations. This needs to be acknowledged here as well, and I would expect it to be discussed more thoroughly in the LUH2 paper. Related to the uncertainty in the driving land use/cover data is the remaining uncertainty due to the translation of land use to land cover, which includes differences between land cover classes and plant functional types, the changes in non-forest land cover (which are not harmonized), and differences between the definition of forest in the LUH2 data and in the models, and how different models will implement the forest cover changes (e.g. prognostic vs. non-prognostic biogeography models). I don't think it is possible to explore the model sensitivity to land use/cover uncertainty in cmip6, but this exploration should be noted as a target for future cmips and land mips, with the potential for using additional land use/cover data sets to drive the models.

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phase 2 experiments

line 395: “Historical” seems like an extra word here

line 399: describe all the relevant aspects of the cmip6 historical concentration-driven simulation. for example, what land use/management processes are included?

line 416: you may want to move your parenthetical note about ssp scenarios from line 420 to here. You should also include the relevant details of the parent sims here. e.g., what land use and land management activities are active.

line 422: land management isn't isolated in these experiments. the changes will be a combination of differences in land use, cover, and management (same issue in figure 3 caption). there may be individual pixels that can be extracted that have only land management/use/cover differences, but there will also be dependencies on the surrounding land what the total effects are for a given pixel. At the subgrid level this may work out for the crop data, but only if there are comparable crop areas between sims within the given pixels and only the management options are different (e.g. irrigation and fertilizer).

line 434: again, land management isn't isolated in these sims. and there will effects of surrounding land on a given pixel.

land use metrics and analysis plans

line 491: paired simulation analyses means that you need to ensure that your main control sims (which are shared with other mips) are well described in this paper as well the lumip specific ones, so that your lumip experiments are clear.

lines 527-531: redundant sentences

line 533: rf mip - another acronym needing expanding

lines 535-540: i suggest briefly describing the rf mip land experiment and how it complements lumip to make this paragraph more relevant.

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lines 543-558: this is a good idea, and differences in land coupling strength among models may (or may not) also help identify where land use/cover/management may be different among models.

lines 592-594: This is a good idea, but I think that the forest and non-forest areas need to be separated out to replace the primary/secondary land category, to the extent possible (i expect that not all requested variables are kept track of at the forest/non-forest level, but some of them, such as carbon, are kept track of at the pft level in some models). for variables and models that do not distinguish between forest and non-forest, the primary/secondary value can be placed in one category with a flag in the other signifying that land cover is not segregated. This may not be practically feasible due to how the models store and write outputs, however, so it is something to consider for future comparisons, and maybe with more land cover types distinguished from each other.

lines 601-604: figures 6 and 7 don't seem to help much here, as they are not complete and clear about the variables (e.g., only biogeochemistry is shown, and fig 7 shows processes rather than variables). A table of all the requested variables, with the subgrid ones noted, would be more useful. please provide a link or a supplemental table of the full list of variables requested.

lines 651-654: please reference figure 9 if you want to include it.

line 674: for the future runs, land management isn't isolated (or will be extremely difficult to isolate, even at the subgrid level). you can get information about this from the historical land-only experiments, however.

line 677: not sure what you mean by "relative to fossil fuel emissions." It seems that the experiments are designed to quantify the effects of lulcc, in a more absolute sense, which can then be compared to the total emissions effects. I don't see quantification of fossil fuel effects only, nor outputs that would be lulcc effects relative to fossil fuel effects.

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Tables and Figures

Table 1 please include other simulation required for the experiment it should be more clear that this is a tier 1 experiment

Table 2 it should be more clear which tier the experiments are in, and this should be noted in the same column for all. I suggest stating the tier at the beginning of each description or notes column, for each experiment. Or adding a narrow "tier" column on the right, with the appropriate number indicated. land-hist needs to be clearly marked as a sim that is shared by another mip. land-crop-nomanage: is all crop area constrained to 1850? so this is like a constant crop sim, and the pasture area and harvest can change over time? can irrigation amounts change? what about fertilization area? what is a "prognostic crop model" and how does it differ from what is used in the control sim? The description needs to be more complete as to what is different from the land-hist sim land-crop-nofert: i suggest two more sims to ask questions about the effects of changing area vs changing amounts: one with constant area and changing rate, and one with constant rate and changing area. land-netTrans: unclear what it means to maintain gross transitions in excess of net transitions also, the degree to which spatially gross transitions are included at coarser resolution depends on the up-scaling process; the finer grid cells can be summed to get a net change for a coarser grid cell.

Table 3 the tier of each simulation needs to be clearly marked. i suggest adding rows for the control cmip6 sim, and the tier 2 and 3 ensemble members. tier 3 needs to be explained in the text. see comments above.

Table 4 This does not seem necessary, as this information, plus more, is directly available in the text.

Figure 3 Why note only 1 of the 3 additional lumip sims in the caption? note all or none. maybe state that the brown text are the additional sims.

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Figure 4 I would classify wood harvest as land use, with various types of silviculture/harvest (e.g. tree selection, clear cut, plantation, coppice) as land management. see the definitions you invoke in section 1.3.

Figure 5 This figure and its caption is not consistent with the section on net lulcc emissions. LULCC emissions are also “seen” by vegetation in prescribed transient CO2 sims also because the historical atmosphere data include all emissions (LULCC occurred historically) and the IAM projected CO2 emissions include their respective estimates of LULCC emissions. Furthermore, figure 5c also has LASC, even with constant CO2, because different land covers have different potential rates of carbon uptake.

Figure 9 not referenced by text

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