

## ***Interactive comment on “From land use to land cover: restoring the afforestation signal in a coupled integrated assessment – earth system model and the implications for CMIP5 RCP simulations” by A. V. Di Vittorio et al.***

**Anonymous Referee #1**

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Authors tackle the issue of land use change in CMIP5 simulations. The CMIP5 future climate change simulations are based on RCP scenarios put together by integrated assessment models (IAMs). Other than emissions and concentration of various GHGs and aerosols, IAMs also provide land use change information. This land use change information is pre-processed and harmonized by the Global Land use Model (GLM) of Hurtt et al. (2011). The various climate and earth system modelling groups then use the harmonized land use change product from the GLM and generate land cover which is consistent with the land surface components of their climate or earth system models

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(ESM). These two additional steps (the use of GLM and the generation of land cover by individual climate and ESM groups) add inconsistencies and the land cover that is eventually used by climate or ESMs in their RCP simulations may not reflect what the IAM scenario had originally intended/simulated for a given RCP scenario.

Major comments

The above is the message of the manuscript. But, I am afraid this simple message doesn't come across properly. The manuscript needs to simplify the message in a major way and remove the unnecessary confusion. I explain the basis of these comments below.

The manuscript relies quite a bit on the submitted Bond-Lamberty et al. 2014 (Geoscientific Model Development Discussion) paper which got pretty harsh reviews and I do not know the status of that manuscript. This manuscript also relies on Collins et al. (2014) which hasn't been published. Please take away both these references and see if your manuscript stands on its own. I suppose it can if this manuscript is written clearly and concisely.

My next major comment is that after reading the manuscript, I am unclear if the simulations performed for the RCP 4.5 scenario were specified concentration or specified emissions simulations. Although, I realize that you mention at the beginning of Section 2.2 that the simulations uses RCP 4.5 emissions. In addition, the abstract mentions that the net effect of the inconsistencies added by the two steps (GLM and the generation of land cover by the NEWLUT module used by the CESM) lead to land taking up 19 Pg C of additional carbon and decreases atmospheric CO<sub>2</sub> by 8 ppm. The 8 ppm number seems like the back of the envelope calculation and not a model result. This becomes obvious only by reading page 7168 in the discussion section, where other back of the envelope calculations are also present (60 Pg C to 25 ppm, and 100 Pg C to 40 ppm). Authors appear to have missed an important subtlety here. Just like only about 50% of the emissions stay in the atmosphere, similarly a simulated 19 Pg C

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increased uptake by land (or ocean or both for that matter) in a specified concentration simulation will not translate to a  $19/2.12 = 8.96$  ppm reduced atmospheric CO<sub>2</sub> in a specified emissions simulation. It will translate to almost half that amount i.e. around 4.5 ppm. This makes me think that authors' conversion from Pg C to ppm is a back of the envelope calculation. And if this is the case, this number is not worthy to be mentioned in the abstract.

In the bigger scheme of things 4-5 ppm is not a big deal so please consider not making it a big deal. What's probably more important is the regional climate impacts of land use change where the increase in forest area in the original IAM's RCP 4.5 scenario was not transferred to the CESM. But that's an entirely different biophysical issue and I am not suggesting that authors consider that, although a mention would seem necessary. The fact the simulations are run with and without the "lost afforestation signal" up to only 2040 also makes things confusing. It's pretty standard in the community to run simulations until 2100 for the RCP scenarios.

Finally, the manuscript fails to completely mention that the CLM model has a dynamic vegetation component which is able to prognostically determine the fractional coverage of different plant functional types. How does prescription of land use/cover interacts with the dynamic vegetation component of CLM? Changes in crop area are easier to understand. When crop area increases then the model is not allowed to "grow" vegetation there. When the crop area decreases, natural vegetation can expand into that area. Although none of this is mentioned in the manuscript. But what about forests? They would have to be treated in a special way. How does the model treats the forests that need to be grown to take into account the increase the forest area according to a RCP scenario separately from that it would grow or not grow based on its dynamic vegetation module? What if the RCP scenario says – forest area needs to be increased in a region – but the simulated model climate is not suitable? I realized this aspect is touched on in the abstract but I didn't find any more discussion in the manuscript.

Minor comments

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Abstract – In its current form the abstract is too confusing, too long and needs to be simplified.

Page 7155. Lines 5-9. The mention to C4MIP here is totally irrelevant.

Throughout the manuscript phrases like "land type distributions" (e.g. page 7156), "land use distributions" (page 7157), "land implementations" (page 7157), "land dynamics" (page 7157), "land types" (page 7159), "land units" (page 7159), "land use harmonization" (page 7159), "land designations" (page 7161), "land coupling" (page 7169) etc. are used. Please use a consistent terminology and at the very least consider introducing your reader to all these terms. Even as a land surface modeler myself, I am not sure what do all these terms exactly mean.

Page 7157, lines 6-7. "Inter-model spreads for individual scenarios are greater than inter-scenario spreads for individual models". What quantity is being referred here (is it the land carbon uptake) and a reference is needed here.

Page 7157, lines 15-17. "These targets do not include radiative forcing from albedo change or other climate effects associated with land use change". Are you sure this is indeed the case? See page 50 of [http://www.pik-potsdam.de/~mmalte/rcps/data/RCPs\\_FINAL\\_RELEASE\\_31May2010\\_OVERVIEW.pdf](http://www.pik-potsdam.de/~mmalte/rcps/data/RCPs_FINAL_RELEASE_31May2010_OVERVIEW.pdf). It seems that the RCPs do consider land use change radiative forcing.

Page 7157, lines 21-26. "Furthermore, the shared socioeconomic pathways for mitigation, adaptation, and impact studies in the Intergovernmental Panel on Climate Change (IPCC) fifth Assessment Report (AR5) are likely to produce different land use distributions that meet the same RCP target. As a result of the wide range of land-related uncertainties in climate projections, an increased emphasis on land dynamics is a high priority for CMIP6 (Meehl et al., 2014)." Yes, this is true for all forcings including GHGs. We all know that a radiative forcing pathway can be achieved through numerous combinations of different emissions of GHGs, aerosols and land use change. So this sentence seemed a bit irrelevant.

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Page 7158, line 6. I am not exactly sure what does “evolving vegetation productivities” mean. Why can’t you simply say that time varying net and gross primary terrestrial productivities simulated by CESM are used by GCAM. This brings us back to the Bond-Lamberty et al. (2014) GMDD paper. The authors need to explain the methodology used without referencing this manuscript which is still in discussions stage.

Page 7158. Regarding the “lost afforestation signal”, as a reader I feel that some context is needed here. IAMs have their own vegetation modules. The increase in forest area in the RCP 4.5 scenario simulated by the GCAM IAM – is this the result of changing climate or is it indeed “afforestation” (meaning forests are grown at places where they were not present originally) to make RCP 4.5 a mitigation scenario.

Page 7158, lines 24-25. I find the mention of second stage irrelevant at this point. If you do need to mention this, this should be mentioned in the discussion or conclusions section.

Page 7159, line 17. “. . . for the final year of GCAM’s time step . . .”. I do not understand what does this sentence exactly means.

Page 7159 and at other places please consider using some other word than “ingesting”.

Page 7160. Replace “historical transient land use run from 1850 to 2005” to “1850-2005 transient historical run with land use change”. “Land use run” doesn’t mean anything.

Page 7160. What does “GCAM initial conditions are calibrated to 2005, energy, economics . . .” means. Recall that your audience is ESM community that is not familiar with IAM terminology and concepts.

Page 7161, lines 19-21. “The LUT does, however, use the primary and secondary land area to normalize the GLM total harvest area, which is applied only to forest area in CLM”. This sentence is unclear.

Page 7161 lines 22 to page 7162 line 5. Just like the Bond-Lamberty et al. (2014)  
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GMDD paper this paragraph is very difficult to understand. Please simplify.

Page 7162, line 8. “For the iESM, GLM was modified to better facilitate forest area change matching with GCAM in an effort to increase the afforestation simulated by CESM”. Okay, CESM doesn’t simulate afforestation as far as I understand. Afforestation is planting trees where they don’t grow originally. The purpose of afforestation in RCP 4.5, I think, is to be able to sequester more carbon because RCP 4.5 is a mitigation scenario (as opposed to RCP 8.5 which is more like a business-as-usual scenario). That’s why I mentioned context earlier. The manuscript does not say what is the context of this afforestation in the RCP 4.5 scenario. I am just using my common sense. CESM does not simulate afforestation, it simulates the changing distribution of natural vegetation based on what the climate does using LPJ’s dynamic vegetation module.

Page 7162. “Spatial allocation [of crop and pasture area, I presume] to the half-degree grids was done with a preference for expanding agricultural area onto non-forested land, and contracting agricultural area on potentially forested land . . .”. This sentence is confusing. I am not sure what “contracting agricultural area on potentially forested land” means.

Page 7162. “In the new algorithm, GLM matches GCAM forest area changes by moving cropland and pasture around within each land unit to “expose” enough potential forestland for regrowth to meet the GCAM forest area changes.” Can you be please more explicit than “by moving cropland and pasture around”.

Page 7164. “2.3.4 Pre- and post-harmonization CMIP5 RCP4.5 land use distributions for CESM”. At this point the reader doesn’t really know what does harmonization means.

Page 7164. “3.1 CMIP5 RCP4.5 land area inconsistencies”. The land area, i.e. the global land area is a constant. So how can there be inconsistencies in that. What is probably meant here is something else?

Page 7164, lines 17-18. "RCP4.5 and GLM pasture decreased by 4.69 million km<sup>2</sup> from 2005 to 2100 while CLM herbaceous PFTs increased by 1.11 million km<sup>2</sup> over the same period." Here and elsewhere "RCP 4.5" refers to the results from the simulation for the RCP 4.5 scenario done by GCAM. This is an awkward and confusing way of referring to GCAM results. RCP 4.5 is not a model but rather a scenario.

Page 7165. The term "total herbaceous area" is unclear. Please be explicit and say "area covered by herbaceous PFTs".

It appears Figure 6 and 7 show the same results but Figure 6 shows the changes and Figure 7 shows the absolute numbers. If yes, please say this somewhere.

Page 7165, lines 22-24. "NEWLUT also improves CLM's simulation of absolute cropland area (Fig. 7) through normalization of GLM and CLM area." CLM doesn't simulate cropland area. It uses crop area that is outputted by NEWLUT. Or am I missing something. My understanding of how land use/cover change information is processed is GCAM -> GLM -> LUT. Is this correct? I also do not understand what does normalization means in this context? What is the difference between normalization and harmonization?

Page 7166, line 1. "The iESM and RCP4.5CESM land area discrepancies ...". You mean the discrepancies in the simulated area of different plant functional types. Land area is a constant.

Page 7166, line 9. "... for ESMs to adequately simulate climate and energy policies generated by IAMs." ESMs do not simulate energy policies.

Page 7166, lines 13-15. "A primary challenge for improving the CMIP5 land coupling is to increase the amount of specific land cover information being shared between the historical period, IAMs, and ESMs". I don't understand this. "historical period" is of course a period and IAMs and ESMs are models.

Page 7166-7167. "The LUT algorithm uses only the GLM crop and pasture area in-

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formation to adjust PFTs because CLM does not keep track of primary vs. secondary land". Thank you for providing this info and the other details in this paragraph. This is important piece of information that I was struggling with as a reader. All this should be mentioned upfront so that the reader is aware of the GCAM -> GLM -> LUT process.

Page 7167, line 27. "Even partial restoration of the lost afforestation signal in iESM has a significant impact on global carbon balance". How do I know this is significant? You haven't show the atmosphere-land CO<sub>2</sub> flux from the two simulations, with and without the "lost afforestation signal". The manuscript only shows the difference.

Page 7168. Lines 6-7. "As a result, the NEWLUT simulation increases vegetation carbon gain by 19 PgC and decreases atmospheric CO<sub>2</sub> gain by 8 ppmv from 2005 to 2040 in comparison to OLDLUT (data not shown)." You decided not to show the 8 ppm effect but yet mention it in the abstract. As a reader, I want to see the simulated atmospheric CO<sub>2</sub> from two RCP 4.5 simulations (with and without your "lost afforestation signal").

Page 7168, line 9. "... total afforestation could potentially increase these changes to 100 Pg C". How can you speculate this when in Figure 5 the majority of increase in forest area has already occurred by 2050?

Page 7169, lines 13-14. "... and, as we have shown, a mismatch in this boundary condition can determine whether or not an ESM is simulating a particular scenario". Not sure what this means.

Page 7169, line 25-26. "... CESM simulating very little afforestation ...". CESM doesn't simulate afforestation, it uses information about land cover as an input.

Page 7170 lines 9-10. "... afforestation has a significant impact on iESM's global carbon cycle through increased vegetation carbon and decreased atmospheric CO<sub>2</sub> concentration". The manuscript doesn't show the split between vegetation and soil carbon, so in a strict sense you can't say all additional carbon went into vegetation.

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Page 7170, line 23. “In the RCP 4.5 scenario, . . .”. You mean the one simulated by the GCAM IAM?

Page 7172. Line 9. “A standard present-day land area data set . . .” The global land area is a constant. What you mean is area covered by different plant functional types.

Page 7172. Point 4 in conclusions. As a reader, I haven’t been told what are “net transitions” and “gross transitions”.

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