Earth Syst. Dynam. Discuss., 5, C800–C810, 2015
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Interactive Comment

Interactive comment on "Local sources of global climate forcing from different categories of land use activities" *by* D. S. Ward and N. M. Mahowald

D. S. Ward and N. M. Mahowald

dsward@princeton.edu

Received and published: 5 March 2015

Responses to the review of ANONYMOUS REVIEWER #2

Overview The paper evaluates a wide range of mechanisms by which landuse change can affect climate. The data used is appropriate to the problem and it is well analysised. The results are important.

The two main revisions are to clarify what climate forcing data is used in the future simulations and to better explain the affect of LULCC in wildfire CO2 emissions.

RESPONSE: Thank you for your comments and suggested edits. We have addressed all comments in our responses below and with revisions to the text. Our responses are preceded by "RESPONSE". A copy of the revised manuscript with revisions highlighted is given as a supplement.

REVIEWER: *Minor Revisions* p1758 L25 – State how RF calculated from change in surface albedo. Is a radiative transfer model used? Is the surface downward shortwave flux somehow scaled?

RESPONSE: The following text was added to clarify the calculation of the albedo RF. This text was added at the line noted by the reviewer but note that this has been moved to Appendix A.

"The simulated changes in albedo alter the fraction of incident solar radiation that is reflected back into the atmosphere. The reflected solar radiation is multiplied by the fraction of outgoing radiation that reaches the top of the atmosphere at each grid point of a model climatology characteristic of the year 2000 in which clouds and aerosol scattering are implicit. The radiative forcing is then simply the difference in top-of-atmosphere net solar radiative flux caused by the changes in albedo."

REVIEWER: P1762 L14 – This assumption means that changes in soil carbon which could occur for a long time after a change in land cover are attributed to the direct category. It would be good to point out that these carbon fluxes due to "direct modifications," can occur for decades after the land cover change is imposed. Also, should harvest be included as a loss term along with burning and tillage.

RESPONSE: This is a good point and we had neglected to mention C emissions from disturbed and managed soils. These emissions are not captured in the Ward et al. (2014) simulations and therefore not included in this study. While changes in soil emissions due to land management are uncertain, there is evidence that they may be large (Lal, 2004). We note that we do not include anthropogenic changes to soil emissions in the text now:

Pg 1756, Line 2: "Carbon emissions from soils that are managed or disturbed by anthropogenic activities (Lal, 2004) were not included in this analysis."

We have included “harvesting” as a loss term in the referenced sentence.

REVIEWER: P1762 L21 – What errors do you expect from using 1948-1972 climate for the pre- industrial spin-up?

RESPONSE: We expect that terrestrial C storage is more sensitive to other factors, such as atmospheric CO2 and prescribed land cover, than it is to the period of reanalysis used to spinup the preindustrial land model. We add several supporting references to justify our use of this reanalysis:

Pg 1762, Line 18: “For these simulations we follow the same protocol as in Ward et al. (2014) and several previous studies (e.g. Kloster et al., 2010; 2012; Ward et al., 2012).”

REVIEWER: P1763 L16 – What climate forcing is used for the future? Do all simulations use RCP4.5 climate? Or does is each RCP landuse scenario used with the respective RCP climate?

RESPONSE: This is an excellent question and alerted us to the fact that we had not included this information. The following text was modified at the pg and line referenced by the reviewer:

“The future atmospheric forcing datasets„produced by Kloster et al. (2012), are derived from the output of two coupled climate models each following the SRES A1B1 future scenario. The same atmospheric forcing is used for all future simulations regardless of the LULCC scenario and in this way the impacts of the LULCC can be isolated (Ward et al., 2014).”

REVIEWER: P1766 Section 3.2 - Does the vegetation distribution respond to wildfire activity?

RESPONSE: The vegetation is not dynamic in this model so fires do not change the existing plant functional types (PFTs). Although, PFT changes due to anthropogenic land cover change are prescribed. We added:

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Pg 1763, Line 2: “Existing PFTs do not change type due to fires or climate in this version of CLM.”

REVIEWER: P1767 L5-7 – I don’t follow this argument, it needs more explanation. I think you need to state that fire activity is increasing during the historic and future simulations, and therefore reducing the burned area reduces the net loss of carbon from the land. It would also be good to add the reason why fire activity is increasing and whether this is a robust result. If I understand correctly the argument is as follows: If it is assumed that wildfires are carbon-neutral then changing the burnt area by increasing crop area will have no affect on the net carbon flux caused by wildfires. For there to be a net effect on the terrestrial carbon sink wildfires can not be carbon neutral and therefore the model must be simulating a period of trending global fire activity. In this case the trending fire activity must be an increase in fire CO2 emissions. In Figure 3 when there is no LULCC fires cause a small reduction in terrestrial car- bon (blue lines), supporting the idea that it is a period of increasing fire activity. Yet including LULCC greatly increases the affect of fires on terrestrial carbon (difference in green lines compared to difference in blue lines), by much more than neglecting fires altogether in the no-LULCC case (blue lines). Does this mean that fire activity must be increasing a lot in some locations and decreasing a lot in other locations and that LULCC mostly occurs in locations of increasing fire activity?

RESPONSE: These ideas are complex and our original explanation was probably not sufficient to communicate them. We made major revisions to this section of the text, detailed below. We are considering only changes in terrestrial carbon emissions due to LULCC and the wildfire response to LULCC. These changes are isolated from trends in global fire activity due to climate changes and transient CO2 since we are looking at the differences between simulations with and without fire, and simulations with and without LULCC. For this reason we do not mention or discuss historical or future trends in global fire activity, although we cite several papers that do (e.g. Kloster et al., 2010; 2012; Ward et al., 2012).

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We believe that the confusion here comes at least partly from our too-brief explanation of an artifact of this methodology that we exclude from our calculations of atmospheric CO2 concentration changes from these sources. This was compounded by our reference to a shaded region of Figure 3, which we mistakenly did not include in the actual figure. This has been corrected, and the paragraph containing the lines referenced by the reviewer has been expanded and largely rewritten to clarify these points, with more references to specific aspects of Figure 3. Please refer to the revised manuscript to view the changes.

REVIEWER: P1767 L9 - "About half of this..." I found this sentence confusing at first. Can you explicitly say that this component is included in the direct modifications sector, and can you remove the reference to figure 3.

RESPONSE: We have clarified this with the expanded and revised paragraph mentioned above.

REVIEWER: P1768 L4 – Why is RCP4.5 non-LULCC antropogenic forcing used for all future scenarios? It would be more informative and clearer to use the non-LULCC forcings from the rescpective futrue scenarios. I accept the point that the LULCC scenarios are not tightly linked to the CO2 concentration scenarios, but it would still be useful to see the range of each.

RESPONSE: We did not compute non-LULCC anthropogenic RFs for the other RCP scenarios. This would require an additional set of Community Atmosphere Model (CAM) simulations and offline analyses (from Ward et al., 2014) for each scenario. We can show RCP4.5 because Ward et al. (2014) used non-LULCC emissions from this scenario for background atmospheric composition to compute the LULCC forcings. We agree that ideally the LULCC RFs could be compared to non-LULCC RFs from the same scenario (although as the reviewer notes they are not always tightly linked) but this is not necessary to be able compare the magnitudes of the LULCC forcings alone which are the focus of this study. We added the following text to the manuscript to address this point:

Pg 1756, Line 10: “Future RFs were computed against a background of non-LULCC anthropogenic emissions following RCP4.5 (Wise et al., 2009).”

Pg 1768, Line 4: “We are only able to compare the LULCC RFs against non-LULCC RFs from RCP4.5 for which fossil fuel burning emissions were used to compute background constituent concentrations in Ward et al. (2014). Note that the contribution of non-LULCC activities to global RF would be larger if RCP6.0 or RCP8.5 was shown.”

REVIEWER: P1768 L5 – this is only true of the TEC scenario and not of the Trop-BAU scenario.

RESPONSE: We agree and have removed the reference to Trop-BAU in this sentence.

REVIEWER: P1770 – It would be good to add something on the uncertainty in these results. If this study were repeated using different models would the aerosol indirect effect/fire/NPP responses be expected to be the same? Or is there evidence that this model represents these processes robustly?

RESPONSE: This is a good point. There is substantial discussion of the uncertainties in the global LULCC RFs for each forcing agent (which we use in the current study) and how they are calculated in Ward et al. (2014). Since the focus of this study was more on the proportions of the total LULCC RF contributed by different sectors/locations we had not thought to summarize this discussion in our manuscript here. However we agree that it is important for the reader to understand the level of uncertainty in the global RFs which are the starting point for all the work shown in this study. We add the following text to make sure this is put across:

“They compute uncertainties for the RF from each forcing agent and find that LULCC account for 40% +/- 16% of year 2010 anthropogenic RF by a combination of substantial positive forcing from non-CO2 greenhouse gases and the absence of major negative forcing from aerosols. The forcings calculated by Ward et al. (2014) are

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within the uncertainty ranges in estimates of the total anthropogenic RF published in major assessments (e.g. Myhre et al., 2013; van Vuuren et al., 2011), suggesting that different approaches would likely achieve similar results."

Also it is noted in the text that for most forcing agents the majority of relevant emissions/changes occurs in a single sector or are dominated by a single sector. This cuts down on uncertainty that is introduced by partitioning the total LULCC RF into smaller categories.

Technical corrections/suggestions P1753 L29 delete "seasonal"âĂÍ RESPONSE: Removed "seasonally"

p1755 L24 change "and" to "however" RESPONSE: Changed

p1757 L5 delete "at the year the RF" RESPONSE: Changed to "at some future time"

p1757 L15 change "Rfs" to Rfs" RESPONSE: Changed to "RFs"

p1758 L16 delete comma RESPONSE: Changed (note this text is now in the appendix)

p1765 L8 change "2100 present day" to "2100"âĂÍ RESPONSE: Changed

p1765 L25 add (1.65 W/m2) after "agricultural CH4"âĂÍ RESPONSE: Changed

p1770 L5 delete ", or, in the case of Ward et al. (2014), LULCC effects as a whole" RESPONSE: Changed

p1770 L10 change "Therefore," to something like "We find that these changes cancel out and that" RESPONSE: Changed

p1771 L27 add "(Fig. 2)" after "in this study"âĂÍ RESPONSE: This sentence had been removed already.

REFERENCES:

FAO: Global Forest Resources Assessment 2010, Rome, 2010.

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Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., Kommareddy, A., Egorov, A., Chini, L., Justice, C. O., and Townshend, J. R.: High-resolution global maps of 21st-century forest cover change, Science, 342, 850-853, 10.1126/science.1244693, 2013.

Hohne, N., Blum, H., Fuglestvedt, J., Skeie, R. B., Kurosawa, A., Hu, G., Lowe, J., Gohar, L., Matthews, B., de Salles, A. C. N., and Ellermann, C.: Contributions of individual countries' emissions to climate change and their uncertainty, Climatic Change, 106, 359-391, doi:10.1007/s10584-010-9930-6, 2011.

Kloster, S., Mahowald, N. M., Randerson, J. T., and Lawrence, P. J.: The impacts of climate, land use, and demography on fires during the 21st century simulated by CLM-CN, Biogeosciences, 9, 509-525, 10.5194/bg-9-509-2012, 2012.

Kloster, S., Mahowald, N. M., Randerson, J. T., Thornton, P. E., Hoffman, F. M., Levis, S., Lawrence, P. J., Feddema, J. J., Oleson, K. W., and Lawrence, D. M.: Fire dynamics during the 20th century simulated by the Community Land Model, Biogeosciences, 7, 1877-1902, 10.5194/bg-7-1877-2010, 2010.

Kim, D.-H., Sexton, J. O., and Townshend, J. R.: Accelerated deforestation in the humid tropics from the 1990s to the 2000s, Geophys. Res. Lett., doi:10.1002/2014GL062777, 2015.

Lal, R.: Soil carbon sequestration impacts on global climate change and food security, Science, 304, 1623-1627, 10.1126/science.1097396, 2004.

Lawrence, P. J., Feddema, J. J., Bonan, G. B., Meehl, G. A., O'Neill, B. C., Oleson, K. W., Levis, S., Lawrence, D. M., Kluzek, E., Lindsay, K., and Thornton, P. E.: Simulating the Biogeochemical and Biogeophysical Impacts of Transient Land Cover Change and Wood Harvest in the Community Climate System Model (CCSM4) from 1850 to 2100, Journal of Climate, 25, 3071-3095, 10.1175/jcli-d-11-00256.1, 2012.

Margono, B. A., Potapov, P. V., Turubanova, S., Stolle, F., and Hansen, M. C.: Primary forest cover loss in Indonesia over 2000-2012, Nature Climate Change, 4, 730-735, 10.1038/nclimate2277, 2014.

Matthews, H. D., Graham, T. L., Keverian, S., Lamontagne, C., Seto, D., and Smith, T. J.: National contributions to observed global warming, Environmental Research Letters, 9, 014010, 10.1088/1748-9326/9/1/014010, 2014.

Meyfroidt, P., and Lambin, E. F.: Global Forest Transition: Prospects for an End to Deforestation, Annual Review of Environment and Resources, 36, 343-371, 10.1146/annurev-environ-090710-143732, 2011.

Myhre, G., Shindell, D., Breon, F.-M., Collins, W., Fuglestvedt, J., Huang, J., Koch, D., Lamarque, J. F., Lee, D., Mendoza, B., Nakajima, T., Robock, A., Stephens, G., Takemura, T., and Zhang, H.: Anthropogenic and Natural Radiative Forcing, in: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by: Stocker, T. F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley, Cambridge University Press, New York, NY, USA, 659-740, 2013.

Pongratz, J., Reick, C., Raddatz, T., and Claussen, M.: A reconstruction of global agricultural areas and land cover for the last millennium, Global Biogeochemical Cycles, 22, GB3018, 10.1029/2007gb003153, 2008.

Vuuren, D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G. C., Kram, T., Krey, V., Lamarque, J.-F., Masui, T., Meinshausen, M., Nakicenovic, N., Smith, S. J., and Rose, S. K.: The representative concentration pathways: an overview, Climatic Change, 109, 5-31, 10.1007/s10584-011-0148-z, 2011.

Ward, D. S., and Mahowald, N. M.: Contributions of developed and developing countries to global climate forcing and surface temperature change, Environmental Research Letters, 9, 074008, 10.1088/1748-9326/9/7/074008, 2014.

Ward, D. S., Kloster, S., Mahowald, N. M., Rogers, B. M., Randerson, J. T., and Hess, P. G.: The changing radiative forcing of fires: global model estimates for past, present and future, Atmos. Chem. Phys., 12, 10857-10886, 10.5194/acp-12-10857-2012, 2012.

Ward, D. S., Mahowald, N. M., and Kloster, S.: Potential climate forcing of land use and land cover change, Atmos. Chem. Phys., 14, 12701-12724, doi:10.5194/acpd-14-12701-2014, 2014.

Wise, M., Calvin, K., Thomson, A., Clarke, L., Bond-Lamberty, B., Sands, R., Smith, S. J., Janetos, A., and Edmonds, J.: Implications of limiting CO2 concentrations for land use and energy, Science, 324, 1183-1186, 10.1126/science.1168475, 2009.

Figure R1: Comparison of projected annual rates of forest area change. Colored lines and shading represent the change in global forest area between 2010 and 2100 for the Representative Concentration Pathways (red) and the theoretical extreme case (light blue). The grey shaded region is bounded by the annual rate of forest area change required to completely reforest to the estimated prehistoric forest area (Pongratz et al., 2008), or remove all forests by year 2100. Reported and projected forest area change from Meyfroidt and Lambin (2011) (purple) and FAO (2010) and Hansen et al. (2013) (green) are depicted as constant rates through year 2100 to show the result if these rates were sustained.

Please also note the supplement to this comment:
http://www.earth-syst-dynam-discuss.net/5/C800/2015/esdd-5-C800-2015-supplement.pdf

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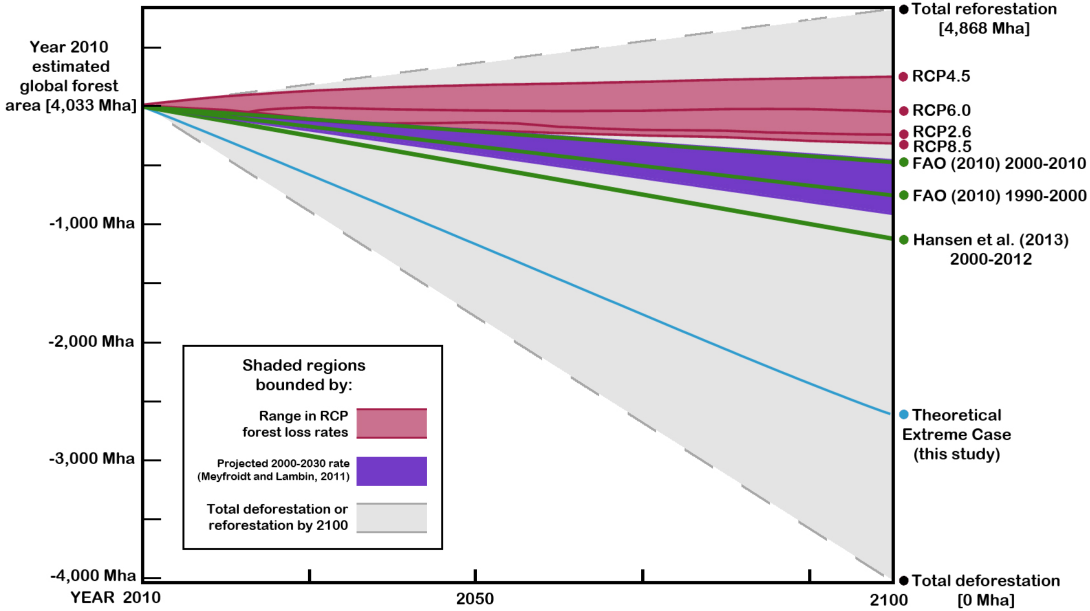

Fig. 1.

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