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Biogeosciences Discussions

Interactive comment on "Sensitivity of Holocene atmospheric CO_2 and the modern carbon budget to early human land use: analyses with a process-based model" *by* B. Stocker et al.

Anonymous Referee #3

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The study described in this manuscript attempts to quantify the role of anthropogenic land cover change (ALCC) in the global carbon cycle over the Holocene, particularly during the preindustrial period. The authors use the Bern Carbon Cycle model, a well known model that has been employed many times before for similar analyses of long-term trends in the global carbon cycle, to a variety of scenarios of Holocene ALCC, ranging from those that place most ALCC during the latest preindustrial and industrial period, to a sensitivity test using an "extreme" scenario where most of the land under human land use at the present-day is placed in that state by AD 1400. Based on their modeling results, the authors conclude that there is no discernible effect of ALCC on atmospheric CO2 concentrations before industrial times. The manuscript is well written;

the English is clear, if sometimes a little long-winded. The figures and tables are appropriate and easy to comprehend. Unfortunately however, this study suffers from major flaws regarding its design, which strongly affect the conclusions drawn by the authors. The unrealistic assumptions behind all of the their ALCC scenarios make the final results questionable, and it seems that the authors might have designed these scenarios specifically to support a pre-formed conclusion that preindustrial human impact had no effect on the carbon cycle. Before recommending publication of this manuscript, I would require that authors strongly moderate the text of their conclusions, and ideally, improve this study by using more realistic ALCC scenarios and considering peat accumulation and revise their analysis and discussion in light of the new results before submitting a revised manuscript.

General comments

My largest concern with the study is the very low values of cumulative CO2 emissions from ALCC predicted by the model. As shown in Figure 1, and commented in the text, cumulative emissions approach only 150 GtC towards the end of the simulation in all except the X2 scenario. These values seem very low to me. I will make a very simple "back of the envelope" calculation to illustrate what I mean. Most preindustrial people converted forestland to farmland, as opposed to grasslands or other marginal habitats, importantly because heavy steel plows and widespread irrigation needed to cultivate natural grasslands and other semi arid regions were not available before the late 19th-century. This fact alone – grasslands were not widely cultivated before industrial times because of technological limitaions – is a major limitation of the X1 and X2 scenarios, because they relate to present-day agricultural land use patterns which were likely very different in preindustrial time. Typical forest ecosystems have an aboveground biomass of 10E4 to 10E5 kg dry matter per 0.1ha (Niklas & Enquist, Nature 410, 2001). Global human population at 1000 BC was between 50 and 300 million, and by 1 AD probably at least 300m (Dearing, Clim. Past, 2006). According to the current manuscript and several others, preindustrial per-capita land use of 3 ha per person is not unreasonable.

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Calculating out these numbers and assuming dry biomass is 50% C, we would expect cumulative ALCC emissions at 1000 BC to be 7.5-500 GtC depending strongly on both the estimate of human population and forest biomass; at AD 1, given a more definite estimate of 300 m for global population, the range for cumulative emissions is 45-500 GtC. While the highest-end estimates of cumulative emissions are might be unrealistic, given these lower limits it seems that the values presented in this paper are very much on the low end. Furthermore, this study does not appear to take into account the role that long-term agricultural land use has in reducing soil carbon stocks through erosion and reduced slow-turnover litter input. Finally the authors' estimates of cumulative 'primary' carbon emissions through the present day (153-183 Gt) are below most previous estimates. They are well below Olofsson & Hickler (275), Straussman's earlier estimate (284), and that of Olson (240-360). Given that the authors use a revised, untested version of LPJ, it is possible that the total biomass simulated by the model is unrealistically low. The authors do not provide values for simulated total terrestrial carbon storage for the present day (or any other time period for that matter). It would be helpful to show at least some evaluation of the model in light of observations of, e.g., aboveground biomass.

With regards to the land use scenarios used in the current study, the authors explain in the introduction that constant land-use is not a valid assumption, but later on they repeatedly refer to their HYDE (HY) and H2 scenarios as "plausible". Both statements cannot be true. It can be easily seen in the HYDE dataset that there is almost no ALCC in the Western Hemisphere before AD 1500; this result is simply not supported by archaeological and paleoecological records (e.g., well known evidence of deforestation from Inca and Maya civilizations). The sensitivity test scenarios X1 and X2 are so unrealistic so as to not be useful; the X2 scenario simulates no land clearance after AD 1000, while the X1 simulates only a very small amount, despite the increasingly better documented record of ALCC that occurred during this time. While no study has claimed that preindustrial per-capita agricultural land use was as high as 8-30 ha/person, the authors neglect land use requirements for fuel and construction ma-

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terials, and that even non-agricultural societies can effect significant deforestation (cf. Australian aborigines). When the authors use these implausible scenarios and end up with implausible model results, they conclude that those scenarios were invalid. This obvious conclusion is the result of a badly designed study, not a thoughtful sensitivity test.

Finally, but very importantly, the authors note that early on that the possibility of large-scale burial of terrestrial carbon in peat would complicate their use of 13CO2 trends to constrain terrestrial carbon emissions. But then they use a deconvolution analysis based on the 13CO2 trend that completely ignores peat burial of carbon. Had the authors considered a reasonable amount of peat burial, they would have been forced to conclude that larger net anthropogenic emissions are needed to balance the global carbon budget. A recent study by Frolking and Roulet (Global Change Biol, 2007) estimated Holocene carbon accumulation in peat to be 250-450 GtC; another study by Z. Yu calculated $\sim$270 Gt C. Any value in this range would be far larger than the cumulative ALCC emissions of 153-183 Gt estimated in the current study and require a large modification of the ALCC or other sources of C to rectify. Any revision of the current manuscript must acknowledge Holocene peat accumulation as a major C sink and explain more clearly how their results would be affected by taking peat accumulation into account. Even better would be to show a scenario that included peat accumulation. Without considering peat, I do not see how any of the authors' (strong) conclusions can be justified or even taken seriously.

Interactive comment on Biogeosciences Discuss., 7, 921, 2010.