Comment on esd-2021-72
Vivek Arora (Referee)

Referee comment on "Impact of bioenergy crop expansion on climate–carbon cycle feedbacks in overshoot scenarios" by Irina Melnikova et al., Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2021-72-RC1, 2021

Major comments

Authors analyze the effect of land use change (LUC) related to bioenergy crops in the SSP5-3.4-OS scenario on the beta and gamma carbon feedback parameters. The manuscript is reasonably well written, especially, as it starts out but then the discussion becomes a little hard to follow. There is good science in the manuscript that needs to be reported but right now it is spread between the main text and the supplementary information that makes it somewhat difficult to follow the story coherently.

Other than this, my second major concern is that beta and gamma are just distractions from what is a decent science story. In my opinion, beta and gamma were never designed for scenarios in which CO2 concentrations stabilize or decrease let alone for scenarios with LUC. Recall that beta is given by cumulative change in carbon over land/ocean divided by change in CO2 concentration. Now consider a scenario in which CO2 concentration first rises and then drops back to its pre-industrial value. In such a scenario, cumulative C uptake will be positive but the change in CO2 concentration at the end of the scenario will be zero, yielding a beta value of infinity. As atmospheric CO2 concentration decreases after the peak, beta will keep on increasing since its being divided by a decreasing value of change in CO2 concentration since the pre-industrial times. And, for the same reason gamma is also not meant to be calculated in a scenario with decreasing temperature (which, of course, follows atmos. CO2 concentration). beta and gamma were only meant to compare their magnitude across models and that's also the reason they shouldn't be compared across models if scenarios with LUC and non-CO2 GHGs because the effect of different treatment of LUC and non-CO2 GHGs in models will be lumped into beta and gamma feedback parameters. This is the reason beta and gamma are compared across models from the 1pctCO2 scenario since they are not tainted by other processes that affect atmos-land C exchange.
At the end of the day, the scenario reported in the manuscript is a specified concentration scenario so change in CO2 is same across all models. What’s more important is the change in land C (i.e. the numerator term of beta) and that’s what the manuscript should focus on? My suggestion is to drop the beta and gamma altogether and just focus on the effect of BECCS through LUC on land C balance.

If you agree with the above reasoning then please also consider not recommending that LUC must be somehow taken into account in the gamma and beta framework. I agree that beta and gamma are functions of land cover but time-invariant land cover. As soon as land cover changes and LUC emissions are generated then land C balance will change but this has nothing to do with the response of a given land model to CO2 forcing.

This manuscript has good science to convey the overall message that the BECCS scenarios come at a cost of increased crop area with the associated LUC emissions. In this context, it also becomes important to check that the LUC emissions in the original IAM are not too different from that in the ESMs. Of course, the caveat is that (as you already mention) land use change information gets somewhat distorted as it goes from IAM -> LUH -> ESMs.

The other subtle point, which I am not sure about, is that these enhanced LUC emissions to account for BECCS must be the part of total carbon budget calculations in the IAM scenario. Unless I missed this, I can’t recall seeing a comparison of LUC emissions from ESMs with those from the IAM. So the IAM group who designed the scenario must have taken into account that the benefit of BECCS more than compensates for increased LUC emissions. That’s why CO2 goes down after its peak in this scenario.

Minor comments

Abstract. The last sentence of the abstract is too long. Please consider rewording it into two smaller sentences. Also its unclear what “so as to limit the reductions of the CO2 fertilization effect” means in this sentence.

Line 40. “In BECCS, atmospheric CO2 is captured via photosynthesis and fixed into plant biomass”. BECCS or not, photosynthesis always captures C and fixes it into plant biomass. Please consider rewording.

Line 77. “so that the effects of LUC on these parameters are overlooked”. This is by design in my opinion.

Line 89. “include the expansion of second-generation bioenergy crops (for BECCS) at the cost mainly of pasture lands”. I have always struggled with pastures. Pasture is not a land cover but rather a land use. Assuming all pastures are grasslands is an incorrect assumption. Are you able to shed any light on how ESMs treat pastures? I know, CanESM5 doesn’t treat pastures at all due to this ambiguity in its definition.

Equation (5). Note that in this eqn. beta_LUC depends on f_LUC and change in CO2. Since
f_LUC has nothing to do with CO2 (it depends on externally prescribed change in land cover) in my mind bringing in LUC into the beta and gamma framework doesn’t make sense.

Line 156. "In the sensitivity analysis, we examine a range of post-2015 cropland fraction thresholds of the grid box area and select the thresholds that best approximate the total cropland area change in 2015–2100 diagnosed by each ESM". Were these threshold ESM specific?

Line 180. “... provide the quantifications, including changes in energy and land use, for the scenario by the IAM”. The phrase “for the scenario by the IAM” is unclear.

Section 3.1. I think Figure S2 belongs in the main text. Also, in this section lines 191-200 are confusing and it seems at some places change is reported as absolute value. For example, on line 191 it’s mentioned “the cropland area increases by 50% from the 2010 level in the 21st century, so that it reaches 8.1 × 10^6 km2 in 2100”. The present day cropland area in LUH is around 15 million km2. So how can it increase by 50% from 2010 and still be 8.1 million km2.

The issue around transferring land use change information along this chain IAM -> LUH -> ESMs has been raised in the manuscript but it appears to suggest ESMs do not do a proper job. In fact, the problem is that land cover representation in models is very subjective and different from what IAMs and LUH does. Inevitably some information is lost in translation. Perhaps this can be made more clear.

Line 215. “... the predicted distribution does not coincide with the real one”. What do you mean by "the real one".

Line 252. “... we suggest that model teams provide variables contained within “fLuc””. Consider replacing this by “... we suggest that model teams provide explicit detail of processes that contribute to “fLuc”.

Section 4. Lines 273 to 294 are very difficult to follow. The fact that there are 8 lines in each panel of Figure 2 doesn't help either. The figures need to be simplified in somewhat. Perhaps just show the range (as shaded region) and the mean.

Line 306. “On top of it, earlier findings show that the ESMs misrepresent the amplitude and rate of changes in soil and litter carbon after LUC”. Please consider replacing the word “misrepresent” with “do not realistically”. Also the phrase “the amplitude and rate of changes in soil and litter carbon” is unclear. Please consider rewording this.
Line 359. “The estimated global β and γ feedbacks compromise these land-cover-related uncertainties”. Please reword this sentence. I am not sure what “compromise” actually means in this sentence.

Figure 3 is also very hard to follow with 20 something lines in each panel. You have to find a way to simplify this information.