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Comment on bg-2022-227

Anonymous Referee #4

Referee comment on "A comparison of the climate and carbon cycle effects of carbon removal by Afforestation and an equivalent reduction in Fossil fuel emissions" by Koramanghat Unnikrishnan Jayakrishnan and Govindasamy Bala, Biogeosciences Discuss., https://doi.org/10.5194/bg-2022-227-RC4, 2023

"A comparison of the climate and carbon cycle effects of carbon removal by Afforestation and an equivalent reduction in Fossil fuel emissions"

Jayakrishnan & Bala in Biogeosciences

This study addresses the question of the climate impact of different carbon mitigation strategies. The authors raise the question of whether a similar decrease in atmospheric carbon resulting either from afforestation or from a cut in anthropogenic emissions have the same effect on land surface temperature and ocean carbon content.

To tackle this question, they set up two extreme modeling experiments under 3 future climate scenarios (SSP2, SSP3, SSP5): 1/ all agricultural land is abandoned and left for forest to grow (AFFOREST) or 2/ the same amount of carbon that would be captured by such a large-scale afforestation is cut from the anthropogenic emissions (REDUCED_FF). Both extremes are compared to a baseline simulation where there is no land use change (FIXED_AGR).

The authors conclude that the reduction of atmospheric carbon from a net reduction in anthropogenic emissions has a larger impact on atmospheric cooling compared to the afforestation strategy. This results is explained by the biophysical feedbacks of albedo. The study concludes that reducing fossil fuel emissions is more effective than afforestation in mitigating climate change.

Despite a timely topic, some aspects of the paper leave me doubtful about the relevance of the experimental setup and the conclusions.

Experimental setup

The scenarios are presented as ” idealized” (L75). Indeed abandoning all agricultural land has no other reality than the brutal mass extinction of humanity, which then would be followed by the total cut of FF emissions. The unrealism of the scenarios is a strong limit to the study’s conclusions that should therefore be toned down as they should not be translated into policy recommendations (L23, L306).

No order or magnitude is given for the carbon emissions that are cut (L284). Making it difficult to get an idea of the strength of the scenario. Give some reference values, for example global carbon stored on land.

It is not clear to me what level of feedbacks is included in the model between emissions and climate? Are SSP climate trajectories and AFFOREST and REDUCED_FF mitigation scenarios consistent, and if not, does it matter? In the scenario REDUCED_FF, fossil emissions are cut significantly with respect to FIXED_AGR and AFFOREST scenarios. Then climate in which the trees grow, say for the SSP8.5 climate trajectory should not be the same. Is this accounted for?

Model description

The description of an Earth System Model cannot be done in 10 lines. The readers need to know which processes are included and how they are modeled to be able to understand critically the simulation outputs. Some of the questions that need to be addressed are:

What types of vegetation types are included? How is the model parameterized? In the afforestation scenario, what vegetation type takes over the abandoned agricultural land? How do simulated biomass, carbon fluxes and stocks, water fluxes compare to observations (for example the value given on L145 needs to be compared to literature)?

Another information needed in the model description is the sensitivity of the model to drought-induced mortality or other disturbances? Climate change scenarios as applied here for 500 years come with intense and frequent droughts, fires or storms that might impede the growth, and hence the sink simulated from fertilization effect, especially in the afforestation scenario. Are these processes included? If not, the time horizon could be reduced and the effect of these assumptions should be discussed.

Results

About the explanation of the different global climate effect between AFFOREST and REDUCED_FF, the authors argue that it is the result of albedo changes only. This is overly simplistic. As an example, many studies (for example Li et al., 2015 Nature comm. or Bonan 2008) show that growth of tropical forests have a cooling effect due to water fluxes as opposed to boreal forests that would have a warming effect due to the albedo decrease. The current study's results in the tropics are the opposite of these (L235 afforestation in the tropics leads to warming) and no explanation is given to this apparent contradiction. More generally, the water-based energy exchanges are not discussed at all even though they are a key part of the climate system. This is a key lack of the study.

Also in Figure 5 the difference in AFFOREST result between the 3 climate trajectories are not explained when it is an important and surprising result (L235 and L293).

Format

The choice of figures needs to be rethought.

- Too many figures from SM are cited showing their relevance to the authors' demonstration, then they should be included. Also it is hard to follow because there are so many figures. Some should be merged.
- The only displayed figures in the article show differences to the reference scenario and hide the inherent dynamics of the scenarios. These dynamics are however essential to understand the processes so the figures currently shown in SM showing the 3 scenarios are the ones that should be in the paper.