

Biogeosciences Discuss., referee comment RC2
<https://doi.org/10.5194/bg-2022-227-RC2>, 2023
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Comment on bg-2022-227

Anonymous Referee #2

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-RC2>, 2023

The manuscript entitled 'A comparison of the climate and carbon cycle effects of carbon removal by afforestation and an equivalent reduction in fossil fuel emissions' investigates the method of atmospheric carbon dioxide reduction in a climate change context. More specifically, the authors use a simple Earth system model to investigate the impact on the climate system of reducing atmospheric CO₂ by fossil fuel emission reduction or by afforestation (increase C uptake by vegetation). The authors pose an interesting and timely question as to whether the carbon dioxide reduction method matters, but the manuscript has in its current form several shortcomings, that need to be addressed before further publication.

Overall, the manuscript would benefit from thorough proofreading, as many paragraphs are not clear and concise. Below follows major and minor comments and suggestions to improve the manuscript.

Major comments:

Biophysical feedbacks: Throughout the manuscript, the authors state how afforestation affects biophysical feedbacks. Yet, they only consider one aspect of biophysics, namely albedo. The authors completely fail to mention the cooling effect of evapotranspiration. This is a major shortcoming of the current study and needs to be addressed. I am not familiar with the UVic ESM, but since it includes an energy-moisture model for the atmosphere, I assume that evapotranspiration can be inferred. This needs to be included in the analysis.

Discussion of results is lacking: The authors are completely uncritical towards their results and do not relate or put them in context to other similar studies. This is a major shortcoming of the manuscript and needs to be included.

The impact on the ocean: The authors have chosen to look at how carbon content in the ocean and pH are affected by afforestation and a reduction in fossil fuel emissions. This part is not well linked to the rest of the manuscript. The two variables they are focusing on are tightly linked to the atmospheric CO₂, and as this is essentially the same in both simulations (AFFOREST and REDUCED_FF) they arrive at the same results. It is by no means a surprise and it follows logically that when the atmospheric CO₂ is lower than in the reference simulation, the carbon content of the ocean is lower, and the pH is higher. Maybe some more interesting variables to investigate could be sea surface temperatures or variables related to heat transport in the ocean. The analysis of the impact on the ocean needs to be a better couple to the rest of the manuscript.

Introduction: The introduction is not well linked to the rest of the manuscript. Some suggestions as to how to improve the introduction follow below:

- L28-L42: the facts described here are all well-established. This could be shortened to free more space to describe how the different methods of reducing atmospheric CO₂ would affect the climate system.
- L66- L71 focus on deforestation, while the focus of the manuscript is on afforestation, why afforestation should also be the focus of the introduction. Thus, it would make more sense to rewrite this with a focus on afforestation, and likely also new references should be included.
- Several of the studies highlighted in the introduction are not well described. For example, in L48-L50 Jayakrishnan et al., 2022 find that fossil fuel emissions and deforestation affect the climate system fundamentally differently, but it is not stated wherein this difference lay. Please include such information. In L51—L53 Simmons and Matthews, 2016, find that it is important to include biophysics, but it is not stated why it is important. Please explain why.
- L71-L72 is a very bold statement. A vast number of studies are indeed looking at the biophysical effects of changes in vegetation cover (Zeng et al., 2017, Luyssaert et al., 2018, Alkama et al., 2022 and many more). Therefore, you cannot state that biophysical effects are often neglected.
- The link to the ocean (which is analysed in section 3.3) is not introduced in the introduction, thus this analysis seems very decoupled from the rest of the manuscript.

Method and evaluation of the modelling setup: The method could benefit from some more details in particular concerning the vegetation dynamic. I would go more into detail as to how the dynamic vegetation works in terms of competition between the PFTs (it seems

rather static for the non-afforestation cases). Also, the present-day fraction of forest is only 0.2 which is low. It would be good with a validation of the model against present-day forest extend or LAI. Moreover, I would move the description of VEGBURN from the result section to the methodology section, and I would even include some of the descriptions from the supplement as this is better described. In addition, you also need to describe how the ocean is spun-up.

Figures and tables: I would suggest moving fig. S6 to the methodology section in the manuscript. I would recommend moving table S2 to the results section in the manuscript, as it very nicely summarises the results. Moreover, I would combine figures 1, 2, 3 and 4 into one figure, and I would combine figures 6 and 7 into one figure. In addition, I find it confusing all the references to the figures in the supplement, thus you might want to consider combining or moving them to the main manuscript and whether all these figures are needed. In addition, the figure captions contain a lot of text describing the results which are also included in the main text. I suggest you delete this, as it is already contained in the main text.

Minor comments:

L13-L14 state that 'fossil fuel emissions directly alter the biogeochemical cycle of the climate system' but it also affects the physics of the troposphere via its impact on radiation and the energy budget. Thus, please rephrase this sentence.

L34 change 'fossil fuel use' to 'fossil fuel emissions'

L35-36 please delete 'in the recent decade' and rephrase to 'During the period 2010-19, CO₂ emissions from fossil fuel use and land use and land cover changes were 9.6 ± 0.5 PgC yr⁻¹ and 1.6 ± 0.7 PgC yr⁻¹, respectively'

L42 please rephrase to 'two major strategies considered for mitigating climate change are'

L130 move to L111. e.g. : i) prescribed fossil fuel emission simulation with fixed agricultural land (FIXED_AGR) corresponding to the year 2005, which corresponds to the reference simulation

L137 please change 'land carbon' to 'land carbon stock', also throughout the manuscript.

L139 please add globally to 'approximately 0.2 to 0.4 globally'

L160-L163 please rephrase these sentences as it is very hard to understand.

L172 please change 'over land' to 'in land'

L175-L176 additional already implies the amount is larger, rephrase the sentence.

L176-L179 Please rephrase for clarity

L184-L185 please add global 'the global land surface albedo'

L186-187 please explain why the global albedo decreases initially.

L188 please change 'less' to 'lower'

L189 is the 0.011 globally?

L194-196 this could be deleted, as this is more fit for the conclusion

L205-206 please rephrase to: Initially, atmospheric CO₂ increases until around the cessation of fossil fuel emissions in the year 2250 whereafter the cessation of emissions around 2250, atmospheric CO₂ decreases slightly until ...

L207-L208 I do not understand the last part of the sentence 'because of further carbon uptake by the ocean (Sect. 3.3) in all nine simulations'. Please elaborate.

L214 I think you need to add reduced_ff to the sentence thus 'relative to AFFOREST and REDUCED_FF simulations'

L222 Please explain why the cooling impact decreases with the warmer SSP scenarios.

L225 please rephrase 'this offsetting is almost full'

L229 please add 'the warming effect from decreases in surface albedo due to'

L236-L239 this could be deleted, as this is more fit for the conclusion

L262 There is no Figure 22. Is this figure S2?

L271-L273 this could be deleted, as this is more fit for the conclusion

L298 'grow trees artificially', what do you be by that? By using irrigation?