Referee comments to *Fire Weather Compromises Forestation-reliant Climate Mitigation Pathways*

Referee #1:
https://egusphere.copernicus.org/preprints/egusphere-2024-15#RC1

1.0 Carbon sink is a crucial strategy for mitigating the effects of climate change, but wildfires have multiple perturbations to vegetation carbon storage. The authors simulated forestation-dependent climate mitigation scenarios using five integrated assessment models. The burned area caused by fire weather was projected over future forested regions. While the topic is very interesting and relevant to the scope of EGUsphere, the MS suffers from several major weaknesses that need to be addressed.

Thank you for this summary. As you mention later, you consider as a major weakness that such discrepancies hinder the credibility of these transformation pathways. However, we want to clarify that this is precisely our point: we use existing IAMs data and CMIP6 Earth System Model projections to confront them, and we exhibit lacks of consistency affecting the plausibility of the forestation scenarios. We thank you for acknowledging the relevance of our task.

Introduction:

1.1.1 The literature review section should not simply list what the other researchers have done. I suggest that the authors briefly discuss how the problems addressed by previous studies advance the research topic here.

Thank you for this observation. Upon your suggestion we will enhance the connection between the references to provide a comprehensive introduction to the debate on the feasibility of large-scale forestation under future climate conditions.

1.1.2 The authors thoroughly discussed the mechanisms of wildfires affecting carbon sinks. It would be useful to add more recent data on how much of the global carbon sink is affected by wildfires.

Thanks for this suggestion, this would be a good way to introduce the reader to a quantitative perspective on carbon dynamics under fire. As the Global Carbon Budget 2023 (Friedlingstein et al., 2023) details, a direct comparison of fire emissions with data on the land carbon sink at the global scale is not adequate as currently measured fluxes are a mixture of gross and net fluxes, hiding the role of natural disturbance-recovery cycles vs. net losses beyond such natural cycles (section 3.8.3). However, we will use recent ressources (e.g. Fan et al., 2023) to give this important perspective as far as possible with state-of-the-art data.

Friedlingstein, P., et al.: Global Carbon Budget 2023, Earth System Science Data, 15, 5301–5369, https://doi.org/10.5194/essd-15-5301-2023, 2023

Fan, L., Wigneron, J.-P., Ciais, P., Chave, J., Brandt, M., Sitch, S., Yue, C., Bastos, A., Li, X., Qin, Y., Yuan, W., Schepaschenko, D., Mukhortova, L., Li, X., Liu, X., Wang, M., Frappart, F., Xiao, X., Chen, J., Ma, M., Wen, J., Chen, X., Yang, H., van Wees, D., and Fensholt, R.: Siberian carbon sink reduced by forest disturbances, Nature Geoscience, 16, 56–62, https://doi.org/10.1038/s41561-022-01087-x, 2023.

1.1.3 The last paragraph: ‘How to set up and how to improve the experiment’ is not an appropriate scientific question. I suggest reorganizing this paragraph.

Thank you for this comment. We would like to reemphasize that with this perspective we try to shed light on how modeling procedures are currently set up. We think that discussing process representation and how it is currently limiting reliability, interpretability and scientific progress is

scientifically essential questioning. To clarify our ambitions and questions, we will reformulate the paragraph.

Results:

1.2.1 The 2090 fire risk for MESSAGE-GLOBIOM and REMIND-MAgPIE is lower than that during 2050 in Figure 4a, but in Figure 4b the results are reversed. It is confusing.

Thank you for pointing this out. Displaying relative changes of all forests in panel b vs. absolute values in panel a for A/R regions only (upper boxes) can lead to confusing perception. These upper boxes indicate the mean FWI in forestation regions.

As an example we here point out the case of MESSAGE-GLOBIOM. In this IAM, all forests show a mean danger of approx. 16 index points in 2020 (broad lower box in a).

Once forestation in very highly hazardous regions until 2050 (regional mean danger 22 index points, left upper box in panel a) is in place, the global mean forest danger increases by 5% (panel b).

As the forestation area until 2090 is added in highly hazardous (regional mean danger 20 index points, right upper box in panel a), the global mean forest danger increases further but only by another 1% (right half of panel b).

While we think that this way is well representing the data, we will make these details much clearer by adapting the caption text and the explanations in the main text.

1.2.2 The multi-model results reveal a less than 35% increase of FWI in 2090, but the increase in the burned area could be close to 80% (Figure 4a, b).

Your observation that the relative increase in burned areas (BA) is significantly higher and more uncertain than the relative increase in area-weighted FWI (danger) is an important detail. In our understanding it arises from two features: first, the BA in response to warming and drying trends naturally is more uncertain than the exposure. In our estimation procedure, this is due to spatially more heterogeneous coverage of the BA as ESM output than FWI. Naturally, this arises from heterogeneous vulnerability and ignition sources (see e.g. Jones et al., 2022). Second, fire response to drivers like dryness in some regions have been found to follow non-linear relationships (e.g. Zheng et al., 2023, Fig.4c on fire emission response).

1.2.3 If planted trees are greatly likely to be at risk of fire, are they still needed? If they are needed, how can they be protected from fire based on your results? I suggest the authors briefly discuss it.

Questioning the necessity of A/R under these circumstances might seem reasonable. However, a complete answer to this question cannot be given in this work, because it goes far beyond the limits of this manuscript. As a short answer, re/a-forestation may be necessary to mitigate climate change, but it has to be done carefully.

This means choosing the right locations, adequate species, ecologically adequate fire management, etc. The purpose of this manuscript is to show that this should not be ommited in IAMs in the pursuit of more robust transformation pathways. The decision on whether or not A/R still is useful under projected FWI and burned area increases depends on the comparative evaluation of other services, hazards and vulnerabilities of A/R. In the framework of IAMs, when carbon loss from disturbances like fire and costs of fire prevention is attempted to be internalized, realized A/R

allocation might decrease. In assessments including aspects beyond quantifiable measures however, the picture might look more severe. Not at every place where IAMs foresee forestation, forest establishment, and in particular senseful fire prevention is plausible. We would like to refer you to lines 116 - 118 (risk reduction by exclusion of highly exposed areas), 120 - 124 (fire prevention potential), 178 - 180 (internalization of services and fire prevention in IAMs), where we briefly discuss such aspects.

Jones, M. W., Abatzoglou, J. T., Veraverbeke, S., Andela, N., Lasslop, G., Forkel, M., Smith, A. J. P., Burton, C., Betts, R. A., van der Werf, G. R., Sitch, S., Canadell, J. G., Santín, C., Kolden, C., Doerr, S. H., and Le Quéré, C.: Global and Regional Trends and Drivers of Fire Under Climate Change, Reviews of Geophysics, 60, e2020RG000 726, https://doi.org/10.1029/2020RG000726, 2022.

Zheng, B., Ciais, P., Chevallier, F., Yang, H., Canadell, J. G., Chen, Y., van der Velde, I. R., Aben, I., Chuvieco, E., Davis, S. J., Deeter, M., Hong, C., Kong, Y., Li, H., Li, H., Lin, X., He, K., and Zhang, Q.: Record-high CO 2 emissions from boreal fires in 2021, Science, 379,912–917, https://doi.org/10.1126/science.ade0805, 2023.

1.2.4 There are large differences between the projected and observed forest areas in 2020 (Figure 1). There are also large differences in the magnitudes and patterns of projections from different models (Figure 5), although they all show an upward risk. How can these results be credible?

All these IAM simulations had been performed prior to and independent of this study. Assessing them, we find their A/R pathways showing substantial differences both in planted forest distribution and volume and resulting changes in average exposure and danger. This is precisely what we want to show, that the transformation pathways in the literature lack in credibility on this aspect: the plausibility of forestation according to IAMs' SSP1-2.6 is low. Yet it remains that this way of modeling land use is state of the art while in the process of being improved. To foster this improvement, we discuss the spread and diversity we found in these existing simulations. It is owed to diverse assumptions, initializations and modeling methodologies (see Appendix C for a detailed discussion).

1.2.5 Figure 5 sets values from -0.5 to 0.5 to the same color, which does not help distinguish the areas of decreasing FWI.

Thank you for this detailed observation. We will alter the color bar such that we keep transparency high close to zero change.