

## Reviewer #2:

The manuscript '*TREED (v1.0): a trait- and optimality-based eco-evolutionary vegetation model for the deep past and the present*' by Rogger et al. presents a description of a numerical, grid-based model to simulate trait-based vegetation dynamics and associated carbon-water fluxes, either in steady-state or transiently in response to environmental perturbation. The majority of the manuscript outlines the model development hence is suitable for publication in GMD. The model performance is evaluated by comparing the modelled carbon fluxes and vegetation traits in a modern climate to observations. Finally, the authors provide examples to demonstrate how the model can be used for paleo applications.

A major advantage of this trait-based model compared to models that simulate many different plant functional types is that it is computationally cheap and circumvents the need to make assumptions about vegetation types in paleo-settings that are a large source of uncertainty. This makes the TREED model very suitable for paleoclimate studies. The new implementation of adaptation timescales and rate of evolution makes it especially interesting to study transient global-scale climate events of the past, both in terms of carbon cycle disruption and feedbacks at the onset of an event and also the expected timescales of recovery. Overall, the manuscript is well structured and describes all stages of the model clearly. Readers can easily identify the applied relationships in a transparent way and implemented equations are backed up with sufficient references for traceability. The model output compares well to present-day observations, demonstrating accurate simulation of carbon and water fluxes as well as key traits. Based on the above and added paleoclimate application, I strongly recommend publication in GMD. I only have a few comments or suggestions that could improve clarity in some areas.

We thank the reviewer for the positive evaluation and the constructive comments. We have implemented all of the reviewer's suggestions as detailed below.

### General comments/suggestions

Caption Figure 1. A model schematic in my eyes is very important to show model mechanics. Please expand description, e.g. describe difference between square boxes and circles, and which components are model inputs versus outputs. Perhaps in the figure or caption also note time stepping of each component, e.g. is a calculation or action done once, or iteratively as the model runs through time/months and how does this differ between steady state and transient simulations? Also, the 'adaptation' step is optional if I'm correct and is only needed in transient runs. You could clarify the alternative pathway for steady-state simulations by connecting the 'optimisation' and 'key traits' boxes. (I only noticed Figure 3 further down the text. Might be worth combining Figure 1 and 3 into one that describes the whole model structure, inputs versus output, order of actions, and time stepping. Also clarify that - presumably- the '1 year of monthly climate inputs' is updated to new fields in step 2).

As suggested by the reviewer, we have combined the schematic figures on the model structure and time stepping into one (now Figure 1a and b; L139). In the figure and caption we have clarified what are model processes, inputs, and what variables are being tracked in the model. Additionally, we also clarify the two pathways of using the model in steady state mode (continuous arrows) or considering eco-evolutionary adaptation dynamics (dashed arrows).

The evaluation against present-day observations in Section 5 demonstrates the model performance. However, from sections above it is not entirely clear if or how model tuning has been performed beyond “*All allometric constants were calibrated using present-day canopy height and above ground biomass data*”. I’d like to know e.g. which parameter values are inherited from previous studies, and which parameters have been tested to find the best match to present-day fields. If tuning was performed, please indicate what evaluation metric(s) have been used to find the best fit and what model vs data fields are compared. Might be resolved by adding an extra column to Table 1 that shows ‘source’ or parameter value and/or whether it’s tuned in this model development and how.

We have extended Table 1, now including a reference to all parameters indicating from where they were adopted and which were defined in this study, including references giving a plausible range for these values. Most of the parameters were adopted from other vegetation models, particularly the LPJ vegetation model family. Regarding the allometric constants that were calibrated in this study, we now clarify on L222-226 that they were calibrated by using observed vegetation height data and allometric equations 5, 6, and 12 and by minimizing the RMSE to observed above-ground biomass density data. The resulting height to above-ground biomass density relationship is illustrated in Figure 6b.

The PETM application is a nice demonstration of how the model can be used for paleo simulations. Considering this is a model development paper, I’d be very interested to see a more extended evaluation of model mechanics that drive the patterns in Figs 10 and 11. It would be a good opportunity to show the effects of e.g. the biotic stress components in the context of climatic niches (Eq.52-55). Any geographical regions that are particularly water- or heat-stressed given certain evolutionary adaptation potentials and rates of dispersal?

We thank the reviewer for this suggestion, which will help to clarify the underlying dynamics to the general reader. We have included an additional figure 11 and section L781-796 describing the spatial dynamics of what limits vegetation productivity following the perturbation. We outline the effects of spatially varying temperature and precipitation changes and how they affect the photosynthetic efficiency by surpassing critical thermal limits and resulting in geographic regions where the vegetation recovery is expected to occur particularly slowly.

For review, I also attempted to run the TREED model but climate input fields are currently not uploaded so I could not verify if the model runs okay or whether results as reported in the manuscript are reproduced. I can, however, confirm that the uploaded code is accessible and includes a readme with sufficient information to run the model.

We thank the reviewer for going through the repository. The climate inputs fields are available on the Zenodo repository under: <https://doi.org/10.5281/zenodo.17777279>.

#### **Line-by-line comments:**

- Line 69-70. “...are fundamentally different from the present, as is the case for most of Earth’s past (Judd et al., 2024), or as we expect ...”

Implemented.

- Figure 2. Instead of ‘Model’ in black, use TREED for clarity.

Implemented.

- Line 231-232. Needs reference to support 50% of downward SW radiation is photosynthetically active radiation.

We now include the following citations for this assumption on L245:

Schaphoff et al., LPJmL4 – a dynamic global vegetation model with managed land – Part 1: Model description, *Geosci. Model Dev.*, 11, 1343–1375, <https://doi.org/10.5194/gmd-11-1343-2018>, 2018

Haxeltine, A. and Prentice, I. C.: A General Model for the Light-Use Efficiency of Primary Production, *Functional Ecology*, 10, 551, <https://doi.org/10.2307/2390165>, 1996a.

- Line 286-288. Add reference for equation 30.

We now cite the following citations for equation 30:

Schaphoff et al., LPJmL4 – a dynamic global vegetation model with managed land – Part 1: Model description, *Geosci. Model Dev.*, 11, 1343–1375, <https://doi.org/10.5194/gmd-11-1343-2018>, 2018

Sitch et al., Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model, *Global Change Biology*, 9, 161–185, <https://doi.org/10.1046/j.1365-2486.2003.00569.x>, 2003.

- Line 329 “...using a modified Arrhenius equation that accounts for *declining* respiration rates with temperatures”. Should it be ‘*increasing* respiration rates with temperature’? Equation 39 shows a positive relation between temperature and g.

Thank you – we corrected the description on L342.

- Figure 4 and 6. Can you add column titles saying ‘TREED’ and ‘Observation’ for clarity?

We added the titles accordingly (now figures 3 and 5).

- Figure 8 caption. (c) Modelled latitudinal distribution...

Added accordingly (now figure 7).

- Figure 11 caption. Define the ‘alpha’ again as you did for ‘k’

Added accordingly (now figure 10).

- Line 746. Add a few sentences to clarify how the different scenarios are simulated? Have you used new climate field inputs that correspond to 2, 4, 6, 8°C?

We have clarified on L766-768 that the climate inputs for modelling the different warming scenarios were derived by simple linear interpolation using the available climate fields at 680 and 1590 ppm CO<sub>2</sub> to an atmospheric CO<sub>2</sub> that approximately correspond to 2, 4, 6, and 8 degrees of land surface warming.