

Dear Editor

Thank you for the opportunity to revise our manuscript title “Savanna ecosystem structure and productivity along a rainfall gradient: the role of competition and stress tolerance mediated by plant functional traits”. We appreciate the valuable feedback provided by you and the reviewers. We have carefully considered all comments and feedback and revised the manuscript accordingly. In the attached response document, we provide point-by-point responses to each reviewer's comment, including references to revised line numbers in the manuscript. We have thoroughly reviewed the manuscript for typographical errors and updated relevant sections, including figures, references, and the supplementary document.

First, we would like to thank both reviewers for their thoughtful and constructive review of our manuscript. We greatly appreciate your careful reading and insightful comments, which have helped us improve the manuscript.

Reviewer #1 comments responses sheet

Reviewer comments are in **blue colour**, and our responses are in normal type, and referring sections with line numbers are in **red colour**.

Major comments

Reviewer comment: First, the authors validate their model by comparing simulations done using their newly parameterised version of LPJ-GUESS to flux tower-derived GPP and evapotranspiration measurements. The ET comparisons (Fig. 2) look good. The GPP comparisons, with the exception of Stuart Plain, look okay. However, there is no control to compare the results of this new model parameterisation with. How should a reader assess whether the presented new version is an improvement compared to the standard version of LPJ-GUESS?

Response: We would like to clarify that our study does not involve developing a new version of the LPJ-GUESS model or introducing fundamentally new model components. Instead, we utilize the existing LPJ-GUESS framework and modify specific parameters, particularly by integrating regionally relevant PFT trait data. Whether this improves the performance relative to the standard global model or not, we argue that the incorporation of empirical data on the local savanna ecosystems that we are simulating is necessary and relevant to represent that system in the most realistic way. Following validation, this allows us to apply the model with confidence to investigate ecological processes related to competition, productivity, and community composition along the NATT rainfall gradient.

We have revised the Introduction and Methods sections of the manuscript to clarify this logic.

- **Introduction (lines 109-110 and lines 121-125) – updated and modified to explain the scope and intention of the model parametrisation.**
- **Methods (lines 161-162)- clarified that the model (standard) version of the model was adopted with updated PFTs, not structural changes in the model.**

Reviewer comment: Second, the authors acknowledge that “Good model performance in terms of replicating compositional patterns along environmental gradients may then provide confirmation of assumptions as to the eco-evolutionary basis of plant traits as encoded in the model.” (line 61). Yet, the authors have not dedicated any formal analysis to assess whether their model does indeed perform well in terms of replicating the compositional patterns along the environmental gradient. I also find very little text which discusses matches or mismatches. It should be possible to add observed PFT lines to Figs. 4, 5, and 6 and provide a map of simulated vs observed PFTs.

Response: *Field observations of tree species composition are available from the flux tower sites along the transect, reflecting compositional and abundance patterns along the rainfall gradient. However, the model is designed to simulate landscape average vegetation whereas local ecosystems are affected by local microenvironments, disturbance history and stochasticity which is not feasible for a model to replicate based on first principles. We have added observed plot-based point intercept coverage data from ausplot (Munroe et al., 2021) and simulated PFT distributions (Figure 6) along the gradient in Section 3.2 (PFT composition shift with rainfall) and further expanded the discussion section to elaborate on how the simulated vegetation composition aligns with the observed patterns at flux tower sites, providing a more nuanced interpretation of matches and mismatches.*

- In the result section- Lines 362-384 and Figure 5, observed projective foliar cover for each PFT using data from ausplot (Munroe et al., 2021), which were estimated using plot-based point intercept data. Similarly, PFT-wise simulated FPC and observed PFC along the gradient are kept in Supplementary Figure 5. Both data show similar patterns with tall eucalypts being dominant tree PFTs in the wet end of the gradient.
- We have added a result (Figure 7) that compares the Simulated LAI with MODIS LAI for the dry and wet seasons. In both season, monthly simulated LAI was within the range of monthly MODIS LAI (compiled across the longitude of the simulated grid) (Line 413-428).
- In the discussion section (Line 540-566), we improve the text that discusses the match and mismatch in PFTs composition along the rainfall gradient.

***Reviewer comment:** Lastly, and most crucially for the current conclusions presented in the manuscript, LPJ-GUESS includes fire and its impacts on vegetation structure. Based on the simulation protocol it appears the BLAZE fire module was used for this study and fire was turned on for these simulations. The vegetation of this region has evolved with fire. Fire is a regular event in the study area. There is an extensive literature documenting this. How can the authors claim to have identified the mechanisms underlying the distribution of vegetation when they do not consider fire? How well does simulated fire (burnt area, fire return interval) match observations? Does fire and fire frequency, in combination with precipitation reductions, perhaps influence the change in the dominance of PFTs from tall eucalypts to C4 grasses along the gradient?*

Response: We confirm that the role of fire was indeed included in the simulations using the BLAZE fire module (Rabin et al., 2017), which simulates fire occurrence, spread, and impacts on vegetation based on climate and fuel conditions. This is stated in the manuscript, but we will add further detail to the Methods and Discussion sections to clarify model assumptions regarding the role of fire disturbance in vegetation assembly. We have added (section 3.1) results illustrating the simulated fire dynamics along the gradient. However, we also note that fire in these systems is a complex phenomenon influenced by multiple interacting drivers, including natural ignitions, vegetation structure, climate variability, and cultural practices such as Indigenous burning. Accurately analyzing and attributing fire impacts, including disentangling them from climate-vegetation interactions, would require a dedicated analysis with further fire-specific simulations and data inputs, which is beyond the scope of the current study.

- We added the description of fire model in method section (Line 174-181), which explains BLAZE model in detail.
- We have added a result illustrating flux from the BLAZE model and compared it with the Global Fire Emission Data (Vernooij et al., 2023) in the result section. Both data show similar patterns and confirm fluxes decrease with a decrease in water availability (Line 345-359, including Figure 4).
- In the discussion section, we added text (Line 519-525) that discusses potential reasons behind the underestimation of emissions in the wet end of the gradient. In the limitation section (Line 627-641), we have explained the complex phenomenon of fire in the savanna ecosystem and factors driving it, including natural ignitions, vegetation structure, climate variability, and cultural practices such as Indigenous burning in this system, and the need for separate study.

Specific comments

Line57: remove double full stop.

- Corrected.

Line 286: Where do SSR and SST come from? I don't see them in the preceding text. What were they used for? Perhaps link these to the calc for R^2 or leave them out.

- Corrected

- Tables 1 and S1 are the same? Why duplicate them?

Reviewer comment: Tables 1 and S1 are the same? Why duplicate them?

Response: Table 1 in the main text presents a summarized version of the PFT parameter values used in the model simulations, focusing on the final parameter values applied during the model simulation process. In contrast, Supplementary Table S1 provides a more detailed breakdown, including the original empirical trait data compiled from literature and databases, as well as the adjusted values used for model input. While there is some overlap, we believe that keeping both tables serves complementary purposes: Table 1 offers a concise overview for general readers, while Supplementary Table S1 provides transparency for those interested in the derivation and variation of trait values among species. We will clarify this distinction in the table captions and main text.

- Table 1 presents the three PFTs and their parameters used for simulation (line 255, Table 1). Supplementary Table 1 displays the tree PFTs and their parameter values, including field-observed values and adjusted values for simulation representing a savanna ecosystem.
- Table S1 and corresponding text. Please use consistent terminology. Aren't the parameters for your PFTs your traits? Isn't this what makes it a trait-based approach? Though all DGVMs always had trait values that defined the behaviour of PFTs. Traits, not parameters, mentioned in the title. For example, in your text you call all of the traits as parameters "The parameters included leaf phenology (evergreen or rain green), leaf longevity, wood density, specific leaf area, shade tolerance, leaf turnover rate (calculated as $1/\text{leaf longevity}$), and the ratio of leaf area to sapwood crosssection area (k_{latosa})."
- Used parameter as DVM used parameter (even though parameters are traits values).
- Supplement "Traits and parameter values". Please specify the "various sources" used to collect trait data and provide references.
 - Added including references list.
- The PFT cluster names (Fig. S.1), PFT names (Figs. 5, 6, Tab. 1, Tab. S.1) don't match the PFT names used in Figs. S2, S3, S4. I can only guess which pft matches which pft.
 - Changed and Updated.

Reviewer #2 Comment Response sheet

Reviewer comments are in **blue colour**, and our responses are in normal type and referring sections with line numbers are in **red colour**.

Major comments

Comment: The authors are trying to present this effort as directed towards answering a research question related to the driver of the transition of Australian vegetation from Eucalyptus to C4-grass dominated savannas in the South. In my opinion, they did not answer to any specific new research question, as it seems to me that most results are just reasonable model outcomes. Possible solutions to this issue that come to my mind are i) rephrasing the paper as a new-model description ii) performing model experiments to answer clearer research questions. If choosing i): the validation against flux tower data is very good; however, a validation of model outcomes in terms of functional type distribution, LAI etc is lacking and should be added if possible.

Response: We disagree that our study does not answer new research questions. The role of stress, competition and disturbance are a key theme in savanna research but the hypothesised underpinning mechanisms of how these factors control savanna structure and function have rarely been explored using process-based vegetation models that explicitly represent those mechanisms. We argue that our study is a new and unique contribution in demonstrating how these mechanisms play out for Australian savannas, thereby validating the assumptions as encoded in our model. Regarding the reviewer's suggestion to reframe the paper as a 'new-model description', we would like to clarify that our study does not involve developing a new version of the LPJ-GUESS model or introducing fundamentally new model components. Instead, we utilize the existing LPJ-GUESS framework and modify specific parameters, particularly by integrating regionally-relevant PFT trait data. We argue that the incorporation of empirical data on the local savanna ecosystems we are simulating is necessary and relevant to represent that system in the most realistic way. Following validation, this allows us to apply the model with confidence to investigate ecological processes related to competition, productivity, and community composition along the NATT rainfall gradient.

We have revised the Introduction and Methods sections of the manuscript to clarify this logic.

- Introduction (lines 105-125) – updated and modified to explain the aim and objective of the model parametrisation.
- Methods (lines 161-162)- clarified that the model (standard) version of the model was adopted with updated PFTs, not structural changes in the model.

Adding functional type distribution:

- In the result section- Lines 362-384 and Figure 5, observed projective foliar cover for each PFT using data from ausplot (Munroe et al., 2021), which were estimated using plot-based point intercept data. Similarly, PFT-wise simulated FPC and observed PFC along the gradient are kept in Supplementary Figure 5. Both data show similar patterns with tall eucalypts being dominant tree PFTs in the wet end of the gradient.
- In the result section 3.3 (Line 452-472), Tree and grass functional component composition along the rainfall gradient was compared with a study done by Haverd et al.,

2016. According to the results of Haverd et al. (2016), fPAR and GPP (gC/m²/day) remain relatively constant throughout the year for the tree component, in contrast to the fluctuating values in our simulated results. Fluctuations in tree productivity are attributed to the deciduous nature of our PFT composition. In both results, the grass component's contribution to overall ecosystem productivity increases with a decrease in rainfall.

Adding (observed) LAI:

- We have added a result (Figure 7) that compares the Simulated LAI with MODIS LAI for the dry and wet seasons. In both season, monthly simulated LAI was within the range of monthly MODIS LAI (compiled across the longitude of the simulated grid) (Line 413-428).

Comment: *If choosing ii): I completely agree with the other reviewer that the effect of fire should be taken into account explicitly, given these are well-known to be fire ecosystems. In this respect, I would add the remark that post-fire response traits, such as resprouting (not currently mentioned in the section describing traits) should be included in the definition of plant functional types in Australia (see e.g. Harrison et al 2021, Kelley et al. 2014, Venesky et al 2019). Furthermore, given the focus the authors put on disentangling the importance of rainfall gradients in these Australian woodlands and savannas, I would highly Recommend reading Holdo and Nippert 2023 excellent New Phytologist review on the subject.*

- We added the description of fire model in method section (Line 174-181) which explains BLAZE model in detail.
- We have added a result illustrating flux from the BLAZE model and compared it with the Global Fire Emission Data (Vernooij et al., 2023) in the result section. Both data show the similar patterns and confirm fluxes decrease with a decrease in water availability (Line 345-359, including figure 4).
- In the discussion section, we added text (Line 519-525) that compares fire response and flux results. In the limitation section (Line 627-637), we have explained the complex phenomenon of fire in the savanna ecosystem and factors driving it, including natural ignitions, vegetation structure, climate variability, and cultural practices such as Indigenous burning in this system, and the need for a separate study.

Response on adding resprouting:

We agreed that post-fire recovery traits, particularly resprouting capacity, are ecologically important in the Australian savanna system. However, implementing resprouting as a dynamic process would be a significant model development quest and is also limited by observational and knowledge gaps regarding details such as the phenology of carbohydrate storage under different conditions and remobilisation in response to different disturbances. While relevant to the overall topic, this would be well beyond the scope of this study.

- Added (Line 101) post-fire resprouting dynamics as important traits / plant strategies of Australian savanna.

- We have added this in the limitation section (Line 637-641), we have explicitly stated which data are missing and what information we need to integrate resprouting into the model.

Adding suggested references:

We will add suggested references (Harrison et al., 2021; Kelley et al., 2014; Venesky et al., 2019 Hodo and Nippert (2022)) in the discussion of limitations in the treatment of fire in the Introduction and Discussion section.

- Added in relevant Section.

Specific comment

Comment: The abstract lines ‘We hypothesise that biotic competition and abiotic stress exhibit opposing patterns along the NATT rainfall gradient and aim to disentangle these effects on vegetation structure and productivity. Using a trait-based dynamic vegetation model, we simulated vegetation responses to varying competition and stress along the NATT.’ I did not see how and where this hypothesis was tested given the model-centered approach.

Response: This hypothesis was formulated as a conceptual framework to interpret signals emerging from model simulations and capture the existing knowledge about the system. The LPJ-GUESS model integrates both competition and abiotic stress mechanisms by simulating resource acquisition, growth, and mortality at the cohort level, based on functional trait differences. The emergent vegetation dynamics in the model simulations are influenced by these representations and their underpinning assumptions. In this way, they express the interaction of biotic (e.g., light competition, asymmetric growth) and abiotic (e.g., water limitation) constraints along the NATT rainfall gradient. Our approach uses the model as a ‘digital twin’ to explore how simulated structural, compositional, and functional patterns vary along the rainfall gradient and evaluate whether these patterns align with ecological expectations derived from the model.

- We have revised the Introduction (Line 104-124) to bring out such reasoning and explain our study’s inferential approach more clearly.

Fig. 1. Caption is not complete, what is the map of Australia showing? If it’s vegetation types, as the middle panel: why the state borders change the types of biomes so dramatically? I would also indicate more clearly which part of Australia you are studying, which seems the only relevant info one wants to have from the map. Some fonts are too small, e.g. the names of the flux towers.

- Vegetation in the studied state (Northern Territory) was highlighted to show the study location. Now, the brighter vegetation section inside the Australia map is removed and kept in the middle panel, and the map is updated.

- l. 234 variables

- Corrected

- l. 264 ciclying? (without re-)

- Corrected

- l. 285 is

- Corrected

- l. 413 trees

- Corrected