We thank the reviewer for their insightful and helpful feedback. We have addressed the comments and incorporated the suggestions into our manuscript. In the text below, answers to the reviewer´s comments are written in italics, and changes made to the manuscript text are underlined.

Reviewer 1 comments (29 Sep 2023):

The manuscript is very well written, clearly structured, generally very well illustrated, and covers an highly interesting topic. The presented results are original, novel, and based on an innovative approach. However, before publication can be recommended, the following should be addressed:

Title, abstract, and elsewhere:
The terminology is somewhat unclear. The term 'microclimate' usually refers to the conditions (T, RH, prec) in the direct and closest environment of a wooden item. MC and T over time are usually named 'material climate', i.e. the conditions inside the material. The hierarchy is global climate – macro climate – meso climate – local climate – micro climate – materials climate. Suggest to adapt the terminology (see also numerous publications on 'decay modelling of timber structures using this terminology in accordance with ISO standards, e.g. ISO 15686 series).

We understand the reviewer's concern about the term microclimate, but in ecology and biogeosciences, the term materials climate is unfamiliar. We proposed instead to change the title to "<u>Climate-based prediction of carbon fluxes from deadwood in Australia</u>." Additionally, we have replaced microclimate with "<u>wood moisture and temperature</u>" throughout the manuscript to clarify that we are only referring to these two variables.

General comment / Introduction:
During the last approx. 20 years. Research developed parallels in wood material science and forest ecology. Decay models were developed for timber structures in use (above ground and in soil contact) as well as for deadwood and debris. The intro would significantly improve if similarities and differences between the two approaches would be highlighted. E.g. the hypothesis formulated in L 72-74 has been shown to be correct by different studies in the field of wood material science (e.g. lab tests with pine blocks performed at VTT, Finland, and calorimetry measurements at Lund University, Sweden).

We agree with the reviewer that our manuscript benefits from including some of the literature in wood material sciences. We have added the following sentences relative to decay models to the introduction and reformulated our hypothesis:

Line 54: Few studies <u>in ecology</u> have measured wood moisture content and temperature directly, and those that have are limited to a low temporal resolution or impacted by wood degradation processes ...

Lines 72-74: Similar climate-based moisture content models have also been developed for timber structure risk assessment and successfully capture daily and seasonal moisture content trends (Hansson et al. 2012). Our approach has the potential to provide wood moisture and temperature at an hourly time resolution.

Line 77-85: From the perspective of wood integrity and durability, extensive literature in wood material sciences suggests a positive correlation between wood decay and wood materials climate (Viitan 1997, Brische and Rapp 2008a). Additionally, wood moisture and/or temperature are better predictors of wood decay than macroclimate (Brischke et al. 2006, Brischke and Rapp 2008a & 2008b, Niekerk et al. 2021). We extended this idea and further hypothesized that cumulative mass loss of pine blocks corresponds to CO_2 flux predicted from wood moisture and temperature. If other pathways of mass loss are active, such as termite-mediated decay, then cumulative mass loss should exceed predictions of cumulative CO_2 flux from deadwood. Likewise, we hypothesized that the strength of the relationship between wood moisture and temperature and CO2 fluxes should differ across our precipitation gradient.

L9 and 89: Has it been Radiata pine sapwood? Please clarify.

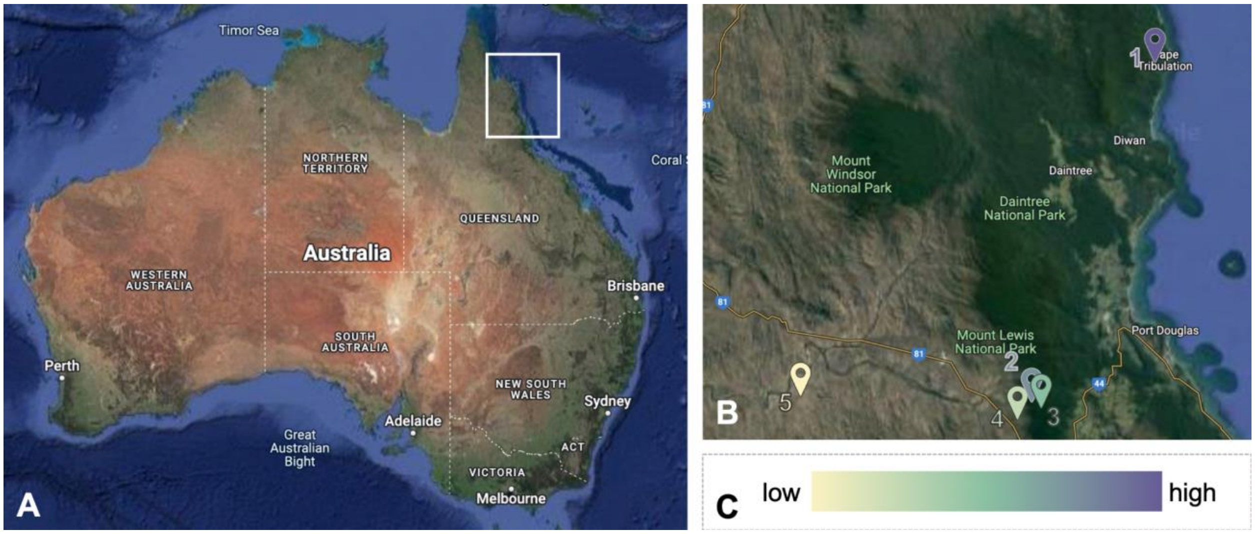
We have added the following sentences to clarify this point:

Lines 99-101: Pine blocks were cut from pine planks obtained from a saw mill. They were harvested from trees grown for timber, so the blocks were likely heartwood. We used this method as we followed a standard protocol for assessing termite activity developed by Cheesman et al. (2018).

Line 109-110: Native stems were harvested directly from our field sites and include heartwood and sapwood (additional details in Law et al. 2023).

Figure 2: The colour scale is hard to interpret. Differences in colour between the test sites are hard to distinguish (even for me, and I am not colour blind).

We agree the figure was difficult to read. We have raised the saturation of the site colors and added outlines to the markers on panel B.



L 94: Unclear what is meant with ‘treatments’. Is it the application of the mesh? Treatment of wood usually refers to a coating or impregnation with repellents and biocides.

Yes, we use the term “treatment” to refer to the difference in mesh bags to allow or exclude insect activity. We have reworded the description to clarify this:

Lines 103-106: For each timepoint, two blocks enclosed in 280 μm lumite® mesh (BioQuip) were deployed in each plot <u>to represent two insect access treatments</u>: one <u>completely closed</u> to exclude insect activity and another with 10 holes, 5 mm in diameter, in mesh to allow insect access. Blocks were deployed and harvested at 6, 12, 18, 24, 30, 36, 42, and 48 months to capture seasonal variation in CO2 fluxes (2 <u>insect access</u> treatments * 8 harvests * 5 plots * 5 sites = 400 blocks deployed).

L 128: What is meant with ‘intact wood’? Is it non-decayed wood? The wood MC will drastically differ between decayed and non-decayed wood – how has this been considered?

We use the term “intact wood” to refer to wood blocks that still had structural integrity at the time of harvest, as opposed to wood chips or shavings from blocks shredded by decomposer activity. Wood classified as intact showed signs of decomposition (i.e., changes in porosity, fungal growth), but held their shape and were thus able to be measured for volume and gas flux. We added the following descriptions to clarify:

Lines 122-123: Each wood sample was separated into intact wood <u>(wood pieces with structural integrity)</u>, carton (created from termite activity), soil (any soil that entered the bag), and excess (wood shavings and chips) with each component weighed individually.

Section 2.2.2:
It stays unclear how the dimension of deadwood components can be considered.
L 183 / 192: Unclear what fuel moisture sensor is referred to. What kind of sensor? Where installed?

As mentioned in L 174, we used a Campbell CS506 and 10 h Fuel Moisture Stick to measure fuel moisture content over time. To clarify this, we added the full name of the sensor and change some instances of “stick” to “sensor” or “wood dowel” throughout the manuscript. We also elaborate on our model calibration approach.

Line 190: Fuel moisture sensors (Campbell CS506 Fuel Moisture Sensor, 10 h Fuel Moisture Stick) were placed at each site to measure fuel moisture content.

Lines 197-199: We followed a two-step calibration approach, in which we first fitted moisture content measured from standard fuel moisture sensors and then derived wood moisture and temperature of cylinders of similar dimensions as our blocks as at hourly resolution**.**

Figure 6: Species codes should be explained in the main text, not only in the supplementary material.

We have specified the species code and name throughout the manuscript.

Discussion, L 303 ff:

The discrepancy between measured MC and predicted FMC is especially prominent at high moisture levels. Isn’t it most likely that this is explained by the geometry of the wooden elements. The effect of capillary water uptake must have been a multiple in the small (more or less cuboid wood block) compared to ‘normal’ deadwood forming long cylinders. Should eventually be included in the discussion.

We agree with the reviewer that there are many different aspects that could have led to a mismatch between measured and predicted wood moisture content. As indicated in Line 329, we did not want to include extra terms because it would only have increased the uncertainty of our simulations, which were already high. Nevertheless, we found that the reviewer’s suggestion is a valid point, so we added it as follows:

Lines 359-363: Wood moisture content was likely sensitive to other physical processes that are not included in the model. For example, our blocks were placed flat on the ground, which may have resulted in moisture uptake by capillary action, while our mechanistic model simulated a cylindrical log on its side without accounting for this process, which may have led to underestimates of wood moisture in our simulations (van Niekerk et al. 2021, Thybring et al. 2022)**.**

Lines 439-441: For example, mass loss in tree species with dense wood was not fully captured in our flux predictions (Figure 8: *Eucalyptus cullenii (EUCU), Eucalyptus chlorophylla (EULE), Terminalia aridicola (TEAR)*), likely due to the lower capacity of dense structures to hold water (Thybring et al. 2022)**.**

General comment / Discussion:
The link of the presented models/ simulations to the physiological needs of the decay organisms involved is somewhat lacking. Numerous decay models have been developed in Europe and Australia (e.g. at CSIRO) to describe the relationship between wood decay, climate, and a couple of other impact factors. How does all this relate to the findings of the recent study?

We have added citations to wood materials studies suggested by the reviewer and reformulated our conclusion section to include a comparison of our model results with current carbon models and wood material science decay models.

Lines 377-378: This result is consistent with wood thermodynamics in which wood is heated by incoming radiation during the day, and heat is stored and slowly released during the night. Sites with higher canopy cover experienced smaller temperature ranges, as shade buffers temperature extremes (Brischke and Rapp 2008b)**.**

Lines 386-389: We found a positive relationship between wood moisture and temperature and CO_2 fluxes across the precipitation gradient, and the strength of this relationship decreased at low precipitation sites. This result was expected as wood microclimate variables are known to be important drivers of deadwood degradation (Viitanen 1997, Mackensen et al., 2003; Brischke and Rapp 2008a, Kahl et al., 2015; Wang et al., 2023), influencing microbial and invertebrate-driven decay (Progar et al., 2000; Zanne et al., 2022).

Line 409: However, temperature variation can interact with moisture and cause CO_2 fluxes to be non-linear (Viitanen 1997**,** Wang et al., 2002; González et al., 2008; Forrester et al., 2012).

Lines 451-459: Ecosystem-scale carbon models like the YASSO model (Likski et al., 2005) and the CLM soil module (Lawrence et al., 2019) have already incorporated deadwood decomposition as a function of microbial activity affected by climate variables but have not yet explored the effects of wood moisture and temperature on microbial processes related to wood decay. More progress has been achieved in the field of wood material sciences, where the positive correlations between wood moisture and temperature and wood decay has been demonstrated (Brischke et al. 2006, Brischke and Rapp 2008a & 2008b, Niekerk et al. 2021). Our work extends these findings by quantifying the strength of the relationship between wood moisture and temperature and CO_2 fluxes from deadwood in response to precipitation and microbial and insect activities. Wood moisture and temperature alone are insufficient to predict the CO_2 fluxes, especially from diverse native woody species. Wood traits are likely ...