Response to Reviewers

Article Ref.: essd-2026-161

Mapping Plant Growth Index (PGI) over Australia from 1990 to 2024

Earth System Science Data

Reviewer #1

Retkute et al. introduce the Plant Growth Index (PGI), a continental-scale metric for Australia designed to quantify potential vegetation growth by integrating meteorological data from the BARRA-R reanalysis, ESA PFT layers, and MODIS EVI-derived C3/C4 grass fractions. The PGI is calculated as the product of light, moisture, and temperature indices to capture the spatiotemporal variability in vegetation status. The authors benchmark PGI against GPP, NDVI, SPEI, and Aussie-GRASS, demonstrating broad agreement and highlighting its utility for ecological modeling, rangeland monitoring, and climate-impact studies. Overall, the paper addresses a relevant topic, and the manuscript is generally well-structured. However, the theoretical justification for the index formulation, the lack of a rigorous baseline comparison, and the spatial scale of the validation present significant limitations. These aspects require substantial improvement before the manuscript can be recommended for publication.

Response:

We thank the reviewer for the insightful suggestions, feedback, and the time they have dedicated to review our manuscript. We have provided a point-by-point response below, addressing each specific comment and suggestion.

Major Comments

R1MC1

My primary concern lies in the justification of the PGI's added value. The authors validate the PGI by demonstrating its correlation with widely used proxies for vegetation growth and water availability (GPP, NDVI, SPEI, and Aussie-GRASS). While this confirms that the PGI behaves consistently with established metrics, it does not prove that the PGI is an improvement over them. The authors must provide evidence showing that the PGI performs better than, or at least provides distinct advantages over, previously used proxies. For example, does PGI predict GPP more accurately than SPEI across both spatial and temporal dimensions? Without a clear demonstration of its comparative advantage, the necessity of introducing a new index remains unsubstantiated.

Response:

We thank the reviewer for raising this important point and agree that demonstrating added value relative to existing proxies is essential. We acknowledge that showing consistency with established vegetation and hydroclimatic metrics alone is insufficient to justify a new index. In practice, however, no publicly available benchmark dataset exists that provides direct ground-based vegetation state observations with continental Australian coverage at compatible spatial and temporal resolution.

For this reason, we consider the OzFlux Gross Primary Productivity (GPP) dataset to be the most appropriate available benchmark. Although spatially limited (23 sites), OzFlux provides high temporal resolution observations across multiple Australian ecosystem types and therefore allows comparative evaluation of PGI against existing vegetation and climate proxies.

Action:

In the revised manuscript, we will perform a comparative benchmarking analysis of PGI, NDVI, SPEI and Aussie-GRASS against OzFlux GPP, including site-level and seasonal assessments where data availability permits. We will use these analyses to clarify the distinct advantages, limitations and intended application domain of PGI relative to existing approaches.

R1MC2

The inherent scientific and ecological meaning of the PGI requires deeper discussion. Equation (1) relies on a simple multiplicative formulation, but this approach feels arbitrary and lacks sufficient physical or empirical justification. The authors should clearly define what "growth" specifically means in the context of this index. Furthermore, they need to justify why Equation (1) is the optimal formulation.

Response:

We thank the reviewer for this important comment. We agree that the physical and ecological interpretation of the PGI formulation requires clearer justification. In this study, “growth” refers to potential meteorological suitability for vegetation growth, rather than realised biomass accumulation, carbon uptake, or observed ecosystem productivity. The multiplicative structure follows the ecological limiting-factor principle, whereby light, temperature and moisture act as partially independent constraints on plant growth potential, such that limitation in any one component reduces overall suitability. We acknowledge that alternative formulations are possible and that a multiplicative framework represents a simplifying assumption.

Action:

In the revised manuscript, we have expanded the Introduction and Methods sections to provide a clearer physical, ecological and historical justification for Equation (1). We now explicitly define the meaning of “growth” within the PGI framework, we explain the rationale for adopting a multiplicative limiting-factor formulation, we discuss its assumptions and limitations across different ecosystems, and we have clarified why this formulation was selected for a transparent, mechanistic, training-free continental index.

R1MC3

I highly recommend benchmarking this equation against standard data-driven models. If the authors were to use the same meteorological inputs to train a multiple linear regression (LR) model or a machine learning algorithm (e.g., Random Forest) to predict short-term plant growth, would the PGI outperform them? If the PGI cannot provide superior or equal performance to basic empirical models, its utility is questionable.

Response: We thank the reviewer for this suggestion. We agree that comparison with standard data-driven approaches is a useful consideration. However, a fundamental difficulty is defining an appropriate target variable for model training, as no direct ground-truth measure of plant growth exists at continental Australian scale with compatible spatial and temporal coverage. While OzFlux GPP provides an important benchmarking dataset, its spatial coverage is limited (23 sites), and it was not designed as a training dataset for continent-wide predictive modelling.

More broadly, PGI was developed as a mechanistic, training-free index based on meteorological forcing and predefined plant functional type responses, rather than as a statistical prediction model. Its intended purpose is to provide a transparent, interpretable and forecast-compatible measure of meteorological suitability for vegetation growth. We therefore view PGI and standard data-driven approaches (e.g. linear regression, Random Forest) as complementary rather than directly interchangeable methodologies.

Action:

In the revised manuscript, we have clarified the intended role of PGI relative to standard data-driven approaches and explicitly discuss the benefits and limitations.

R1MC4

Finally, the manuscript lacks an analysis of how much each individual component (i.e., light, moisture and temperature indices) drives the final index. It would be helpful if the authors include a sensitivity analysis quantifying the relative contribution of each component in Equation (1) to the final PGI across different biomes or seasons.

Response:

We thank the reviewer for this important suggestion and agree that understanding the relative influence of the Light, Moisture and Temperature indices on PGI is important, particularly across contrasting Australian environments and seasons.

Action:

In the revised manuscript, we now include a sensitivity analysis quantifying the relative contribution of LI, TI and MI to PGI variability. Consistent with the multiplicative structure of Equation (1), we use log-transformed sensitivity analyses. Analyses are conducted at continent, seasonal and bioregion scales to assess how the dominant drivers of PGI variability vary across ecosystems and times of year.

R1MC5

The current validation is conducted primarily at the bioregion scale. This aggregated approach masks localized variability and fails to explicitly demonstrate the power of the PGI as a fine-scale proxy. To make a persuasive case for the index's resolution, the authors must validate the performance of the PGI at finer scales (e.g., pixel-level comparisons), rather than solely relying on smoothed bioregional averages.

Response:

We thank the reviewer for this important comment and apologise for not describing the methodology clearly enough. We do not perform smoothing or averaging prior to the benchmarking analyses. Rather, all correlations are calculated using **pixel-level data**, and the resulting correlation values are subsequently aggregated within bioregions to summarise the distribution of relationships across the full 35-year period.

Action:

In the revised manuscript, we have revised the Methods and Results sections to make the benchmarking framework clearer, explicitly emphasising that the analyses are based on pixel-level comparisons, with bioregional summaries used only for synthesis and interpretation of the spatial distributions.

Minor Comments:

R1mC1

Equation (1): There is an extraneous comma in the equation that needs to be removed.

Action: Corrected.

R1mC2

Table 1: Are the temperature thresholds obtained from the cited literature genuinely applicable to the highly adapted and often endemic vegetation of Australia? This requires an in-depth discussion to ensure the thresholds are ecologically valid for the study region.

Response:

We thank the reviewer for raising this important question. The temperature thresholds were derived from literature either conducted in Australia (Hattersley, 1983; Bennett et al., 2023; Teckentrup et al., 2023) or from global studies that included Australian ecosystems and species (Kumarathunge et al., 2019; Liu et al., 2024). We agree that the ecological applicability of these thresholds to Australia's highly adapted and often endemic vegetation warrants clearer discussion.

Action:

We have expanded the Discussion to further clarify the ecological basis and limitations of the adopted temperature thresholds for Australian vegetation and now briefly discuss how the framework could be adapted for application to other regions.

R1mC3

Line 100: The temperature index is highly dependent on the classified vegetation types. What is the inherent accuracy of the ESA PFT classification product over Australia? The authors must discuss how classification errors propagate through the model and impact the reliability of the final PGI.

Response:

We are not aware of any published study that have formally evaluated the ESA PFT classification product over Australia. To provide context, we compared the ESA PFT product against the widely used JULES GL7 PFT maps (Wiltshire et al., 2020), which are static and available at coarser (~200 km) spatial resolution. We found broad agreement between the spatially aggregated ESA PFT maps and the JULES GL7 maps. We agree that uncertainties in vegetation classification and their implications for the PGI framework warrant clearer discussion.

Action:

We have expanded the Discussion to briefly discuss uncertainties associated with the ESA PFT product, their potential implications for PGI, and include a comparison between the ESA PFT and JULES GL7 maps in the SI

R1mC4

Line 135: The description of the Aussie-GRASS data is vague. Please explicitly detail which specific variables or outputs were extracted and utilized.

Action:

The revised manuscript includes a clearer description of the specific Aussie-GRASS variables used, their derivation/extraction, and the preprocessing steps applied prior to benchmarking.

R1mC5

Line 195: The PGI time series exhibits significantly stronger temporal amplitude/variations compared to the observed GPP time series. This mismatch is a notable flaw. The authors should investigate whether the PGI formulation needs refinement to dampen this over-sensitivity, or explicitly explain why this divergence occurs physically.

Line 255: The discussion should be expanded to explicitly address the temporal variance discrepancy noted in my comment for Line 195.

Response:

We agree that this discrepancy requires clearer explanation. PGI responds directly and immediately to meteorological forcing, whereas GPP reflects integrated physiological and ecological responses, including buffering, acclimation, phenology and other lagged processes. In addition, the multiplicative PGI formulation may amplify variability under strongly limiting or rapidly changing conditions.

Action:

In the revised manuscript, we have expanded the Discussion to explicitly address the stronger temporal variability of PGI relative to GPP, including the physical and ecological factors contributing to this divergence.

References

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