

Reviewer 1

Dear Reviewer,

We would like to thank you for your interest in our work, and for providing valuable comments that will significantly improve the quality of our publication. Below we provide a point-by-point reply to your comments, formatted in *italic*. Additions to the manuscript are formatted in **bold italic** and line references refer to the updated version of our manuscript.

Best regards,

On behalf of all authors,

Jette Elena Stoebke and David Wårlind

The authors have thoroughly revised the manuscript and addressed my concerns. I have no more questions.

However, I found a newly added sentence "Individual trees within a cohort do not compete among themselves for resources, as they are assumed to be perfectly aligned with the total crown area representing the sum of all individual trees in the cohort" (Lines 65~66, Page 3). I could not imagine how it would be "no competition" for individuals within a cohort. The individuals in a cohort (though maybe conceptually "individuals", with a metric of density or individuals) do compete with each other for soil resources (e.g., water and nitrogen). They may not compete light with each other because of the assumptions of PPA.

For example, in my model (BiomeE, or LM3-PPA), it does not specifically describe the competition of individuals within a cohort. I just let the plants in a cohort perform the same, such as absorbing the same amount of water and nitrogen from soil (they have to be like this by definition). I did not pay much attention to this simple and straightforward assumption at the beginning. Then, later, I found it represents an intense competition if soil nitrogen or water is limited when exploring the coexistence of N fixers vs non-fixer and drought-deciduous vs evergreen in seasonal tropical forests. And this mechanism is critical for coexistence.

So, I just want to remind the authors that the internal competition might have been implicitly included.

REPLY: Thank you for this thoughtful observation. Our original sentence referred specifically to light competition: individuals within a cohort do not self-shade because the cohort canopy is represented in aggregated form and only start increasing its self-mortality when its aggregated crown area exceeds its maximum available crown area (see eqn 2). However, we fully agree that competition for soil resources is implicitly present. All individuals in a cohort draw from shared water and nutrient pools, and when these become limiting, individuals within a cohort experience equal competition via reduced availability.

To make it clearer the section describing competition within a cohort has been updated as follows (line 62-66) ***“Individual trees within a cohort do not compete among themselves for light, as they are assumed to be perfectly aligned, with the total crown area representing the sum of all individual tree crown areas in the cohort. For resources such as water and nutrients, all individuals within a cohort are assumed to experience the same level of limitation, if any, and therefore do not compete among themselves. Competition for essential resources such as light, water, nutrients, and space only occurs between cohorts within the modelled area (patch).”***

Reviewer 2

Dear Reviewer,

We would like to thank you for your interest in our work, and for providing valuable comments that will significantly improve the quality of our publication. Below we provide a point-by-point reply to your comments, formatted in *italic*. Additions to the manuscript are formatted in **bold italic** and line references refer to the updated version of our manuscript.

Best regards,

On behalf of all authors,

Jette Elena Stoebke and David Wårlind

I appreciate the authors' responses. Many of my comments are well addressed. However, several major concerns remain outstanding to me, which unfortunately limits the contribution of this study to the vegetation modeling community.

1. Conceptually it is hard to make sense of a 'spatially explicit cohort model'. For instance, a cohort is given a coordinate of (x_0, y_0) with a plant density N_0 in the model. Does it mean there are N_0 trees growing at the specific location of (x_0, y_0) ? Physically it does not make sense. I understand the motivation to find a mid-ground between individual model and spatially implicit cohort model. But I feel simply turning cohort as spatially explicit is not the right way. A potentially valid approach is to have spatially explicitly patches/stands (represent horizontal heterogeneity) paired with spatially implicit cohort.

REPLY: Cohort models exist because they are a compromise between the complexity of reality and the realities of computational limits. Here we have simply adjusted that compromise to incorporate some more of the complexity. The coordinate used in the model is not an (x, y) position of a cohort, nor does it imply that all individuals in a cohort occupy a single point in space. In fact, SEC does not use Cartesian coordinates at all. Instead, each cohort is assigned an angular position (Θ) along a circular ring, representing the centroid of its individuals aggregated crown area (line 155-156). This centroid is used solely to distribute crown area in horizontal space and to calculate light competition among cohorts. The cohort itself occupies an aerial footprint around this centroid, it is not located at a single point.

*To make it clearer the section describing cohort's position has been updated to the following (line 151-156) **"In SEC (Fig. 1b), the centroid of a cohort's aggregated crown area, representing the combined crown area of all individuals within the cohort, is assigned a fixed position within the patch, enabling gaps created by tree mortality to persist over time. These gaps provided optimal light conditions at the forest floor, promoting the establishment of shade-intolerant PFTs. Over time, the size of the gap decreased as overstory cohorts grew, occupying more space as their crown area increased. The***

centroid of each cohort was defined in a one-dimensional space $\Theta \in [0,2\pi]$, representing its placement on a circle.”

2. Pragmatically, the new SEC model does not show big difference than PPA (from Fig. 3 and other figures). So, why does LPJ need to introduce an extra layer of complexity (spatially explicit cohort) while spatially implicit PPA predicts the same results? The model comparison results are compelling to show that the vanilla LPJ does not work well but this is not surprising to the modeling community given the advances in vegetation demographic modeling in the past decades.

REPLY: We respectfully but firmly disagree with the reviewer’s assertion that our study has “limited contribution.” Our work offers a novel canopy structure scheme for LPJ-GUESS that broadens the modelling landscape rather than reinforcing the emerging dominance of a single approach (i.e., PPA). Many groups have implemented PPA (e.g., via FATES), and reliance on a single conceptual framework risks narrowing methodological diversity in vegetation demographic modelling.

Although some aggregate ecosystem metrics appear similar across PPA and SEC, this similarity arises from different mechanisms, and the underlying representation of canopy dynamics differs substantially. SEC provides a distinct and scientifically valuable alternative that both matches and, in some respects, outperforms PPA, while also addressing known limitations of PPA such as:

Automatic elimination of canopy gaps once total crown area equals patch area (unless special corrections are added). SEC maintains persistent gaps without special rules.

Instantaneous cohort promotion/demotion between canopy layers, a structural feature of PPA that does not reflect gradual ecological processes. SEC avoids this behaviour entirely.

By enabling spatially explicit canopy gaps, more realistic understory light environments, and different competitive interactions, SEC opens opportunities for studying regeneration niches, gap dynamics, and demographic coexistence using a different conceptual foundation. This distinction became clear in the recent demographic vegetation model intercomparison (Eckes-Shephard et al. 2025), which showed that PPA models do not initiate thinning at canopy closure because subcanopy layers can continue to “fill up” until the light environment is fully exploited, whereas gap-based approaches begin inducing mortality in suppressed trees as soon as canopy closure reduces understory light. Thus, the value of SEC is not diminished by the fact that certain aggregate outcomes resemble those of PPA; rather, SEC captures gap-like mortality dynamics without requiring explicit individuals, thereby expanding methodological options and increasing robustness in the modelling community.

*To make this clearer the following sections have been added (line 412-419) “**By enabling spatially explicit canopy gaps, SEC produces more realistic understory light environments and competitive interactions, opening new opportunities to investigate regeneration niches, gap dynamics, and demographic coexistence within a different conceptual framework. While SEC itself was not included in the demographic vegetation model intercomparison of Eckes-Shephard et al. (2025), the study demonstrated that PPA-based models delay thinning until the light environment is***

fully saturated, whereas gap-based approaches induce mortality in suppressed cohorts as soon as canopy closure reduces understory light. This highlights the type of dynamics that SEC captures without requiring explicit individuals, thereby expanding methodological options for bridging individual-based and cohort-based forest modelling frameworks.”, (line 529-531) “The development of the new canopy structure scheme, SEC, marks a significant advancement in the representation of forest patch horizontal heterogeneity within LPJ-GUESS and provides an important alternative to the growing dominance of PPA-based frameworks.”, (line 523-525) “Moreover, in contrast to PPA, SEC avoids the instantaneous promotion and demotion of cohorts between canopy layers that occur when the total crown area exceeds the patch area, thereby providing a more gradual and ecologically consistent representation of canopy reorganization.”, (line 529-531) “The development of the new canopy structure scheme, SEC, marks a significant advancement in the representation of forest patch horizontal heterogeneity within LPJ-GUESS and provides an important alternative to the growing dominance of PPA-based frameworks.”, and in the abstract (line 21-24) “By capturing these dynamics without requiring explicit individuals, the scheme expands methodological options for bridging individual-based and cohort-based models, enhancing the model’s capacity to explore regeneration niches, forest management effects, and functional coexistence, while improving alignment with observational data.”

3. Not including solar zenith angle is rather problematic to me since it has been a standard practice in the modeling community (e.g. Fisher et al. 2018; Bonan's modeling book, etc.). This simplification can greatly bias the PAR, photosynthesis-stomata, and plant carbon dynamics in my opinion. If the input PAR is already zenith-angle adjusted, this might be relatively less an issue.

REPLY: This concern is based on a misunderstanding. Our model explicitly includes zenith-angle-adjusted PAR.

To make this clearer the following sections have been added (line 513-519) “Additionally, none of the schemes account for the angle of the sun, assuming instead that all solar radiation comes directly from the zenith. Therefore, the PAR used in this study is adjusted for the solar zenith angle. Under this assumption, LPJ and LPD are unaffected with respect to gap dynamics, as neither scheme represents canopy gaps explicitly, whereas in both PPA and SEC the solar angle would influence the amount of direct light reaching the forest floor through canopy gaps, with lower solar elevations reducing understory direct light availability (e.g. Sato et al., 2007). This effect is not represented in the present study but will be examined in future work. In SEC, gaps are spatially explicit, while in PPA gap availability is constrained once total crown area exceeds the patch area.”

4. The zenodo code link shows "The record is publicly accessible, but files are restricted to users with access." I am not sure whether this conforms to GMD policies.

REPLY: This has been updated and now the zenodo files are publicly accessible.

In addition to the specific responses detailed above, we have made minor editorial refinements throughout the manuscript to improve clarity, flow, and grammatical consistency. While these changes are not individually itemized here, a complete record is provided in the latexdiff document for reference.