Authors' response to rewiever#1

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Title: Sensitivity of a Sahelian groundwater-based agroforestry system to tree density and water availability using the land surface model ORCHIDEE (r7949)

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Comment #1

This is a review for the manuscript "Sensitivity of a Sahelian groundwater-based agroforestry system to tree density and water availability using the land surface model ORCHIDEE (r7949)" submitted to Geoscientific Model Development by Gaglo et al. In this work, the authors introduce adjustments made to the ORCHIDEE model in order to simulate a PFT based on a dominant tree species in the Sahel region. The performance of the model is then compared against local flux measurements as well as tested with various scenarios to determine how sensitive it is to different conditions.

Overall, I was quite satisfied with the manuscript, as evidenced by the low number of line-by-line comments. It is a straightforward manuscript that focuses on a relatively simple implementation of a new model version with intentionally limited regional scope. Especially the calibration approach applied here is rather simplistic and carries its own effects that are not truly examined in the manuscript. However, since the examined system is in a semi-arid region that does not receive the appropriate amount of attention when discussing land surface modelling and touches on the various dynamics specific to these areas, I do consider it worthwhile contribution to the ecosystem model development discussion. As a sidenote, my apologies for that horror of a sentence there.

Now I am tempted to recommend acceptance with minor revisions as majority of the work here is easy to follow and comprehend, but the first section of the Discussion, specifically the realism/generality dichotomy here, makes me hesitate. I do comprehend the central idea of the matter and agree it is an important consideration when discussing model development. However, within the context of the work here, it came across as out of place considering that there isn't enough experimentation here to ground majority of the claims there. For example, the argument of limited applicability at other locations is hindered by the fact that there is no experimentation how this PFT performs at those places even with simplified assumptions compared to using the existing PFTs that are not set for environments like this. And that is not even going into how much assumptions already exist in the general ORCHIDEE soil moisture implementation, so using that as a generalist comparison is debatable in itself.

My suggestion is to just remove the majority of the first Discussion section and focus completely on what you have shown here and be more concrete in explaining what the challenges in the larger implementation of the model are here. I understand that is partially the attempt here, but this is muddled by the chosen realism/generality/accuracy approach. Because of this I do think my recommendation is technically return for major submissions, but I do think it should be a relatively minor rewrite here.

Response #1

We thank the reviewer for the positive assessment of our manuscript and we appreciate the constructive comment regarding the first section of the discussion section. Please see our detailed point-by-point

responses below. Reviewer comments and authors response are in black regular font and all revised manuscript text in bold with modified sections in blue.

Comment #2

Line 66: "In magnitude, the water use of Faidherbia albida trees at the plot scale was estimated to be less than 10 % of the annual amount of rainfall (Roupsard et al., 1999; Sarr et al., 2023). However, stable isotope tracing suggested a strong dependence of tree water use on groundwater (Roupsard et al., 1999)."

I was just a little bit confused by this pair of sentences. Is the argument here that the Faidherbia trees use little water, but also draw it from the deeper layers? As the current wording almost implies that the trees use approximately 10 % of the rain fall and in addition draw water from the deeper layers.

Either way, clarify the message here a bit.

Response #2

We thank the reviewer for pointing out this ambiguity. Our intention was to highlight that the overall water use of *Faidherbia albida* is relatively small at the plot scale, while the source of this water is largely groundwater rather than rainfall infiltration. To clarify this point, we have revised the sentences as follows:

Revised version lines 66 to 68

At the plot scale, the annual water use of *Faidherbia albida* trees was estimated to represent less than 10% of the rainfall input (Roupsard et al., 1999; Sarr et al., 2023). This modest total use was shown to rely strongly on groundwater by stable isotope tracing (Roupsard et al., 1999).

Comment #3

Line 366: "…with an r^2 between daily tree LAI simulation and observation of 0.81…"

Just to confirm that the correlation squared value was 0.81 between the observations and simulations? Which would indicate that the correlation itself was 0.9?

Nothing wrong with that, it is simply a staggeringly good fit. What caused me hesitations is that a few lines down the maximum measured LAI is also listed 0.81, which caused me a bit of confusion initially. Coincidences happen but still wished to check. Especially because that is a really high correlation to get when using the switch on phenological approach you seem to be using according to Figure 3.

Response #3

We thank the reviewer for his attention to details. Indeed, this is a coincidence, the maximum observed and simulated LAI is 0.8084 and 0.7331 respectively. We highlight that the calibration and validation are performed on different years but one single site explaining the high performance of the calibrated configuration. To prevent readers from being confused about this coincidence of numbers, we rephrased this sentence by only using the RMSE.

Revised version lines 385 to 386

For trees, the 'reverse phenology' of *Faidherbia albida* with its growing season in the dry season was reproduced by the model with an RMSE of 0.15.

Comment #4

Line 369: “However, 2 out of 3 years…” -> “However, during 2 out of the 3 evaluation years…”

Just to ease the reading a bit, although now I am wondering if I got the preposition right there.

Response #4

We thank the reviewer for this suggestion. We agree that adding *“during”* improves the readability, and the preposition is indeed correct. The revised sentence now reads:

Revised version lines 388 to 389

However, during 2 out of the 3 evaluation years, the maximum tree LAI was overestimated by the model by 11% and 13% in 2020–2021 and 2022–2023, respectively (Fig. 3e).

Comment #5

Line 570: “As in our case study, their comprehensive evaluation of 13 models revealed that improving one dimension often compromises another, underscoring the difficulty of achieving optimal performance across all three.”

This is connected to my general comment, but the discussion preceding this does not really establish anything indicated here.

Response #5

We thank the reviewer for this insightful observation. We agree that, despite our intention to situate our study within the broader model evaluation framework of Levins (1966) and subsequent works (e.g. Mahnken et al., 2022), the proposed framing around realism, generality, and accuracy introduced a level of abstraction not fully supported by the scope of our experiments. We also agree with the reviewer that this section risked diverting attention from the concrete results and limitations demonstrated in our analysis.

To address this, we revised Section 4.1 following the reviewer’s suggestions by removing the theoretical realism/generality/accuracy arguments and instead highlighting the specific strengths and limitations of our configuration. In particular, we now focus more directly on (i) the limited capture of interannual LAI and day to day GPP variability, (ii) the site-specific calibration that constrains transferability, and (iii) the challenges for scaling this configuration to other regions. The revised text now reads:

Revised version lines 544 to 575

A configuration of the ORCHIDEE r7949 model was developed to represent the phreatophytic behavior of Faidherbia albida trees in Sahelian agroforestry systems. Model evaluation was conducted by comparing simulated LAI, carbon, and energy fluxes with site observations, a standard approach for assessing model performance (Collins et al., 2011; Li et al., 2016; Vuichard et al., 2019).

The model reproduced average LAI values reasonably well for both trees and crops, though interannual variability was not fully captured. For trees, simulated maximum LAI matched measured values but failed to reflect the observed year-to-year fluctuations (Fig. 3a and 3e). This limitation is primarily due to lack of realism in the allocation of carbon in this ORCHIDEE’s configuration, which

subsequently limits the interannual plasticity of leaf biomass. Additionally, simplified tree phenology (MacBean et al., 2015) represents a secondary contributing factor. Similarly, crop LAI dynamics compared well with simulations from the process-based model LandscapeDNDC (Rahimi et al., 2021), yet interannual variability remained underrepresented, primarily due to lack of realism in the allocation of carbon in the model, alongside simplified crop phenology and the use of a single crop PFT without accounting for species rotation.

Eddy-covariance-derived GPP is inferred from empirical models fitted to the net ecosystem exchange (NEE) rather than measured directly. Only NEE represents the full semi-hourly variability of the flux, whereas GPP and ecosystem respiration (Reco) are estimated from moving-window fits of light- and temperature-response functions (Lasslop et al., 2010; Reichstein et al., 2012). This procedure inherently smooths short-term fluctuations, leading to a reduction of day-to-day variability in the partitioned components. Unlike EC-derived GPP, the simulated GPP shown stronger day-to-day variability, particularly during the dry season (Fig. 3c and 3g). This reflects the role of vapor pressure deficit (VPD) computed from the meteorological forcing (air temperature, specific humidity and surface pressure; Fig. S2) which limits assimilation via the stomatal scheme (Yin and Struik, 2009). Consequently, short-term changes in atmospheric dryness are transmitted directly to GPP (Fig. S3). The effect is stronger for trees than for crops, consistent with higher stomatal sensitivity in the tree parameterization.

The introduced configuration increased the process realism of the model by explicitly linking tree phenology to groundwater availability, in line with observations of Faidherbia albida water use (Roupsard et al., 1999; Sarr et al., 2023). At the same time, this came at the cost of reduced transferability. The use of exogenous groundwater forcing and parameter calibration based on three years of data at a single site limits the broader applicability of this setup. For example, the current approach is unlikely to capture crop dynamics in regions with different rainfall regimes, soil conditions, or crop management practices. Similarly, the assumption that trees rely exclusively on groundwater omits the possibility of mixed water sources, which may help explain the interannual variability of LAI observed at the site. The configuration improves representation of phreatophyte-driven phenology in ORCHIDEE at the case study site, but its wider applicability remains constrained by data availability and site-specific calibration. Extending the approach to other contexts will require the integration of a dynamic groundwater module coupled with surface water processes, as well as crop and species-specific parameterizations that account for local management and phenological diversity.
