Dear RC1,

Thank you very much for your thorough efforts to highlight these important aspects, which has helped us clarify the model description.

First, we will reply for your major concern:

"1. The Nfert problems suggest to me that MATCRO is very deficient in having, or totally lacking, a soil organic matter module and lacking in plant N balance. The authors need to come clean on this and state in the text that MATCRO either has or lacks a plant N balance module and soil N module. Soils were adequately described for water balance processes, but there was no mention of soil organic matter or soil N mineralization. Basing SLN and Vcmax on Nfert is a very limiting approach and suggests that soil N supply is ignored. The authors need to state those limitations and improvements even more strongly."

Reply: We thank the reviewer for emphasizing the importance of nitrogen balance module. We agree with these points and acknowledge that our earlier description did not sufficiently state this limitation. This model using the simplification of nitrogen representation in the leaf, where fertilization rate implicitly affects photosynthetic parameters (specific leaf nitrogen and maximum Rubisco capacity) without simulating soil nitrogen mineralization or plant nitrogen balance. We will clarify this in Section 4.3 of the manuscript:

"The model currently lacks explicit simulation of plant nitrogen balance. Nitrogen supply is represented by the effect of fertilizer rate to specific leaf nitrogen (SLN), which represents the leaf nitrogen content across a wide range of fertilizer levels (Muchow, 1988). This relationship is then used to adjust photosynthetic capacity (Vcmax). While this simplification enables global-scale application, it limits the model ability to capture nitrogen balance effects on yield. Future development could involve coupling MATCRO with a mechanistic soil nitrogen module to simulate soil nitrogen mineralization and dynamic plant nitrogen balance, thereby improving the model's capacity to represent nitrogen effects under diverse soil and management conditions."

"2. The authors use the term validation. Are Figures 5-10 independent data? But if so, then what data did you use for calibration? Was calibration only from literature for individual parameters? Need to indicate what data was used for calibration as that was never stated. Otherwise, readers will suspect you used this data for calibration."

Reply: Thank you for raising this important point. Pardon us for the confusion as our manuscript did not clearly state calibration and evaluation. Figures 5-10 are independent data. Calibration was limited to partitioning parameters (e.g. leaves, ear, and specific leaf weight toward developmental stage) derived from studies of Ciampitti et al. (2013a,b), since seasonal partitioning data were not available in the experimental datasets (Bassu et al., 2014). The comparisons of LAI, biomass, and yield in Figures 5– 7 for point scale, as well as yield in Figures 8–10 at the global-scale (spatial distribution from GDHY and country global-level from FAO), were used only for evaluation and not for calibration. However, we will replace the term "validation" with

"evaluation" to avoid misunderstanding and explicitly state which data were used for calibration and which were held out for evaluation.

"3. The statistics of Figures 5, 6, and 7 indicate quite poor performance of MATCRO-Maize and correlation statistics are weak tests. Can we recommend a model that performs that poorly for use by global gridded teams? Figure 7A and 7B are based on LAI and crop mass over time, but the high correlations there are misleading because of auto-correlation effects of time-series data (give high correlation because it uses time-series values)."

Reply: We agree that correlation based on time-series data lead to autocorrelation (e.g. LAI and biomass over time). To avoid misleading results, we will remove Figure 7A and 7B from the performance test (for LAI and total aboveground biomass). While site-level optimization would demand detailed information on local varieties and management, our approach emphasizes capturing global yield patterns. Hence, we can recommend this model for global scale simulation with the current parameterization. The model shows a moderate correlation at the global scale correlation (R = 0.54) and top 20 major producing countries (R = 0.58) compared with FAO data despite of data limitations. We are confidence that MATCRO-Maize is informative for global yield pattern, while acknowledging its limitations.

About your concern on technical correction:

1. "l. 83 – Says C-3 here. Should be C-4."

Reply: You are correct, thank you for noticing this error. We have corrected the text accordingly: "MATCRO-Maize calculates net carbon assimilation for the entire canopy (An) via the big-leaf model (Dai et al., 2004), where C4 leaf-level photosynthesis is separately calculated for sunlit and shaded leaves from the coupled photosynthesis–stomatal conductance model (Collatz et al., 1992)."

2. "L 101 – why bother with "co-limited" photosynthesis? That is a C-3 hold-over and probably does not apply to C-4."

Reply: Pardon us for the confusion, Thank you for pointing this out. We understand that "co-limited" photosynthesis mainly refers to C3 and is not appropriate for C4, hence we have removed it from the manuscript.

3. "l. 120 – Is "0.7μ" supposed to be "0.7μmol"? What am I missing?"

Reply: Thank you for noticing it. It is supposed to be 0.7 molm^{-2}s^{-1} and we have revised the text accordingly.

4. "l. 143 – Explain this better, is system solving iteratively for leaf temperature that satisfies…. "meet the following physical flux equations:" Is that what this does?"

Reply: Pardon for the confusion, we calculate the coupled photosynthesis and stomatal conductance system to find the value that satisfy Eq. (18) and (19), where we didn't iterate for leaf temperature. The intention in this text is to state the conditions that must be satisfied, while the

solution is defined in the following paragraph, Eq. (20) and Eq. (21). We will revise the text as follows: "Here, the leaf-level net carbon assimilation rate ($\overline{A}_{n,x}$), stomatal conductance for CO_2 ($G_{sc,x}$), and boundary layer conductance for CO_2 (G_{bc}) were calculated to satisfy the following physical flux equations".

5. "Eq 21 looks strange. "$Ca-Rd$", Rd is a rate in umol/m2/s, but Ca is CO2 concentration. Does "kp,xCa" make it a rate too."

Reply: Yes, you are correct, kp,xCa is also a rate. Pardon for the confusion, we have revised the unit in kp,x into $molm^{-2}s^{-1}$ for clarity.

6. "l. 176-177 Very strange. How can you know "maximum Rubisco carboxylation rate at the canopy level ($Vcmax25,x\ (l)$)"? Strangely worded. Not really a whole canopy trait at all, because your reference is $Vcmax25(0)$. I would think that Vcmax is a characteristic of specific leaf N concentration maybe for upper leaves. OK, as you describe for $Vcmax25(0)$ on line 186."

Reply: Pardon for the confusion, you are correct that Vcmax25,x(l) is characteristic for leaf. It is calculated from the maximum Rubisco carboxylation rate at a certain canopy depth, where depth is measured as the cumulative leaf area index (LAI) from the top of the canopy down to l. We have revised as follows: "$V_{cmax25,x}$ used in the photosynthesis module (Section 2.1) is obtained by dividing the maximum Rubisco carboxylation rate at a LAI depth of l ($V_{cmax25,x}(l)$) […]".

7. "l. 187-190 – This sentence implies conflict or difference, but in both cases $Vcmax25(0)$ is based on SLN for all three crops. Re-word to avoid that issue, or delete the whole sentence."

Reply: Thank you for the clarification. You're correct. We have revised as follow: "Here, while Bonan et al. (2011) uses the fixed value of $V_{cmax25}(0)$ value over time, $V_{cmax25}(0)$ in MATCRO is calculated dynamically […]"

8. "Eq. 27 – I don't like having two equations for $Vcmax25(0)$ from two sources. That does not make sense."

Reply: We agree that using two different sources may appear inconsistent and confusing. However, study from Bonelli and Fernando (2020) of Figure 1 shows the relationship between photosynthetic parameters and SLN varies considerably and decline photosynthetic activity is observed during the reproductive stage compared to the vegetative stage (Drouet and Bonhomme, 2004). We adopted stage specific parameterizations from this study to better capture this physiological difference since no single dataset adequately represents both growth phases. We will clarify this in the revised manuscript by adding this sentence: "Stage-specific parameterizations were applied to reflect the lower photosynthetic activity observed during the reproductive phase compared to the vegetative phase since no single dataset adequately represents both growth phases."

9. "l. 220-235 and Figure 2 – Where are the equations and figures for partitioning to stem? Missing. Not in Table 1 either. At least mention and say "not shown", or is stem "by

difference". Also ear is not the same as grain. Tell us how you get to grain yield. Very approximately, grain is 85% of ear at maturity, but grain growth starts later than ear, actually a few days after flowering. So Kyld is about 0.85??? You use 0.83. OK"

Reply: We thank the reviewer for this helpful comment. You are correct that we did not present the stem partition explicitly. In the model, partitioning to stem is represented as the remaining fraction after allocation to leaf and ear from the ratio to shoots/roots (line 256-257), and we will clarify this in the text.

For ear and grain, pardon us for the misleading statement. Ear is the storage organ which is not grain. We have parameterized Kyld from observation data and got the value of 0.83, hence we will use this value in the study. We will revise in the manuscript: "The term "ear" in maize represents the reproductive organ to store the grain. The grain developed later than the ear with approximately 83% of ear at maturity in this study (Table 1, kyld)."

10. "Table 1 –SLW could be somewhat related to SLN. Please give Tb, Th, To in Centigrade."

Reply: We have revised Tb, Th, and To into Celcius

11. "l. 260 – You call this validation. OK, if independent. But then, what data did you use for calibration? I suspect you used this data for calibration. Line 288-292 indicates that you calibrated life cycle to AgMIP data."

Reply: We thank the reviewer for this important clarification. We will replace term "validation" to "evaluation" in order to avoid confusion. Calibration in this study was limited to phenological parameters (sowing, flowering, harvest) from AgMIP data (Table 2, Bassu et al., 2014) and biomass partitioning (leaf and ear) from Ciampitti et al. (2013 a,b). We then compare the simulation at the point-scale for phenology (flowering and maturity) and evaluated with LAI, aboveground biomass, and yield with AgMIP data (Table 2).

12. "l. 278-279 – Confusing to go elsewhere for soil data, when you give the soil types of AgMIP study in the Table 2. Re-write."

Reply:Thank you for noticing this. We will rewrite it into "We identified the soil texture from the gridded soil texture dataset of ISIMIP (Volkholz and Müller, 2020)".

13. "l. 308-309 – You indicate N fertilization rates. What about N mineralization rates of each soil?"

Reply: We thank the reviewer for this comment. In the current version of MATCRO-Maize, soil N mineralization is not explicitly simulated. Instead, its effect is represented implicitly through an empirical function of specific leaf nitrogen (SLN) and nitrogen fertilizer (Nfert) in Eq. (29) and Eq. (30). We acknowledge that this simplification limits the model's ability to capture the nitrogen dynamics in the soil, the limitation of this factor in the model will be written in the model limitation (the same as major concern point one).

14. “l. 340-341 – I am confused. Here you reduced rubisco “rate” and SLN? On what basis? How was this justified (was it based on the validation data)? Apparently, you did calibrate to the data or thought about a possible reason.”

Reply: Thank you for raising this topic. We mentioned in the response to technical correction point 8, study of Bonelli and Fernando (2020) compared photosynthetic parameter varies across SLN from multiple studies. In MATCRO-Maize, we used the reduction in Rubisco activity based on experimental data of Drouet and Bonhomme (2004) with the intention to test the lower photosynthetic rate observed in this study as we have done in Figure 12. We understand writing this sentence in l. 340-341 may have caused confusion, hence we will move this sentence to the result section to explain about Figure 12.

15. “Figure 6 for Brazil and others would indicate a problem with temperature parameterization for Vcmax(0), because you have a To that is too low, and even a Th is too low. You have values typical of a C-3 temperate warm-season crop.”

Reply: Wagree that site-specific varieties, such as those cultivated in Brazil may have higher optimum temperature and tolerances for photosynthesis than represented in our parameterization. In MATCRO-Maize, To and Th is not directly related to Vcmax but for phenological development. We used cardinal temperature for growing period as reported by Osborne et al. (2015) as a generalized representation of maize photosynthesis. While this approach does not capture potential variation in heat tolerance across regions or cultivars in site-scale, it provides a universal parameter for global-scale.

16. “l.355-364 – These statistics and Figures 5, 6, and 7 indicate quite poor performance of MATCRO-Maize. Can we recommend a model that performs that poorly, for use by global gridded teams? Figure 7A and 7B use LAI and crop mass over time which is not warranted because of auto-correlation effects of time-series data (gives high correlation because it uses time-series values).”

Reply:You are correct, we acknowledge Fig. 5, 6, and 7 indicate weak correlations. However, we will remove Fig. 7A and 7B (we also stated the same in reply for major concern point 3). In this study, Fig. 8, 10, and 11 demonstrate moderate and statistically significant correlations at country and global scales. While we recognize the limitations at site level, we consider MATCRO-Maize useful for global yield estimation, particularly in major producing regions, and will revise the text to highlight both strengths and limitations transparently.

17. Figure 8 and 9 really seem to be “blind” evaluation because MATCRO is so much above the observed. Something is seriously missing here that causes the mis-match. Figure 8 shows MATCRO doing much better than warranted in drought-prone regions such as West Africa or Mexico or southwestern USA, so is the soil water balance failing or is stomatal conductance effect excessively conserving soil water? Or is it the “big-leaf” photosynthesis approach, very incomplete handling of N-fert effect on Vcmax, or something else? Figure 10 could point out issues with the soils for each country and stated N-fert that you used.”

Reply: We acknowledge that overestimations are evident in drought-prone regions as reviewer have mentioned or West and Southern Africa, central Brazil, and northern Argentina, where maize is mainly rainfed and exposed to drought with limited fertilizer inputs. This mismatch of the overestimation is likely linked to limitations in the soil water balance module, which may not fully capture soil variability and water stress. The soil water balance module in MATCRO perform poorly in representing the soil water balance in different soil depth. However, due to the limited availability of observational data on soil water dynamics, this explanation cannot be fully confirmed within the scope of this study. Other factors such as the big-leaf photosynthesis approach, the empirical treatment of nitrogen effects on Vcmax, and stomatal conductance responses, may also play a role. While these weaknesses highlight areas for future improvement, we believe the model remains informative for global-scale yield estimation.

18. "Figure 11 (MATCRO usually over-estimates) differs from Figure 7 (where MATCRO under-estimates). Any reasons for this?"

Reply: Thank you for pointing them out. The apparent contradiction arises because Figure 7 shows site-level yield, it uses experimental conditions with no nitrogen fertilizer and no irrigation led to low yield. While Figure 11 shows country-scale, yields are averaged across many grid cells where management inputs are different. The Brazil site in the experimental data shows underestimated value, while the country-scale shows overestimated value. Most maize grown in Brazil is rainfed, with some irrigated areas summarizes country-level averages across grid cells. Moreover, the universal parameterization can result in overestimation when applied under these heterogeneous conditions.

19. "l. 414 and 417 – what do you mean by "changed parameters". Be more specific, is it what you mentioned on lines 340-341 without justification?"

Reply: Thank you for pointing this out. We will replace the term "changed parameters" with "test of the SLN–Vcmax relationship" to avoid ambiguity.

20. "Figure 13 – indicate source of N-fert values used for x-axis"

Reply: We used Nfert values from gridded dataset (ISIMIP; Volkholz and Ostberg, 2022) and will put it in the revised manuscript.

21. "l. 428 – replace "were statistically significant" with "showed statistically significant correlations" I also challenge "relatively well", as performance was not very good."

Reply:Thank you for your suggestion, we agree with your point. We have replaced it in the revised manuscript.

22. "l. 433 – "One reason" not "the reason"

Reply: Thank you for your suggestion, we have adopted it in the revised manuscript.

23. "l. 450 – Many maize models have LAI growth relatively uncoupled from photosynthesis and C balance. Carbon-driven LAI growth may cause problems."

Reply: Thank you for the comment. We agree that driving LAI directly from carbon balance can create feedbacks that cause overestimation. To address this, should incorporate constraints on LAI development and leaf partitioning when LAI becomes unrealistically large. We will add this point explicitly in the limitations section: "A limitation of the current model is that LAI development is directly driven by carbon balance, which may create feedbacks leading to overestimation. Future improvements should incorporate constraints on LAI expansion and adjust leaf partitioning when LAI exceeds realistic levels."

24. "Go back and confirm that is really how the Brazilian experiment was handled as $Nfert = 0$. OR, this indicates that you have problems with getting soil N mineralization simulated. I did not see a word about SOC of soils."

Reply: Pardon for the confusion. The Brazilian experiments relied on soil nitrogen mineralization rather than applied fertilizer, and this effect is implicitly represented through the SLN parameterization in MATCRO. We have revised sentences to clarify this point and explicitly note the lack of a mechanistic soil organic carbon and nitrogen mineralization module as a limitation.

25. "L, 466 – and soil fertility"

Reply: We will incorporate this into the manuscript, as soil fertility is also an important source of model error and contributes to spatial variation.

26. "Table 4 – I am surprised that the other gridded global models for maize are performing that poorly. Correlation is a weak test."

Reply: Thank you for raising this. We agree that correlation is a weak test at the grid scale. However, the moderate level of correlation is typical in global-scale evaluation for crop model due to the noise in yield data and uncertainty in management inputs. We will clarify this point in the manuscript.

27. "l. 535-544 – Nfert problems suggest to me that MATCRO is very deficient in having, or totally lacking in a soil organic matter module and lacking in an semblance of a plant N balance. The authors need to come clean on this and say they lack a plant N balance module and lack a soil N module."

Reply: We agree that MATCRO-Maize does not include a soil organic matter module or a plant nitrogen balance (as we also stated in major concern point 1). We mimic the relationship between Nfert and SLN from other studies (Muchow, 1988). The model does not simulate nitrogen cycling in soil or plants, and we will add this sentence: "Nitrogen effects are represented indirectly via SLN as a function of fertilizer rate and developmental stage, which constrains the model ability to capture nitrogen cycling in soils and plants."

28. “l. 550 – replace “would be” with “are”

Reply:We have adopted it in the manuscript.

References:

- *Bassu, S., Brisson, N., Durand, J. L., Boote, K., Lizaso, J., Jones, J. W., Rosenzweig, C., Ruane, A. C., Adam, M., Baron, C., Basso, B., Biernath, C., Boogaard, H., Conijn, S., Corbeels, M., Deryng, D., De Sanctis, G., Gayler, S., Grassini, P., Hatfield, J., Hoek, S., Izaurralde, C., Jongschaap, R., Kemanian, A. R., Kersebaum, K. C., Kim, S. H., Kumar, N. S., Makowski, D., Müller, C., Nendel, C., Priesack, E., Pravia, M. V., Sau, F., Shcherbak, I., Tao, F., Teixeira, E., Timlin, D., and Waha, K.: How do various maize crop models vary in their responses to climate change factors?, Glob Chang Biol, 20, 2301–2320, https://doi.org/10.1111/gcb.12520, 2014.*
- *Ciampitti, I. A., Murrell, S. T., Camberato, J. J., Tuinstra, M., Xia, Y., Friedemann, P., and Vyn, T. J.: Physiological dynamics of maize nitrogen uptake and partitioning in response to plant density and N stress factors: I. Vegetative phase, Crop Sci, 53, 2105–2119, https://doi.org/10.2135/cropsci2013.01.0040, 2013a.*
- *Ciampitti, I. A., Murrell, S. T., Camberato, J. J., Tuinstra, M., Xia, Y., Friedemann, P., and Vyn, T. J.: Physiological dynamics of maize nitrogen uptake and partitioning in response to plant density and nitrogen stress factors: II. reproductive phase, Crop Sci, 53, 2588–2602, https://doi.org/10.2135/cropsci2013.01.0041, 2013b.*
- *Drouet, J. L. and Bonhomme, R.: Effect of 3D Nitrogen, Dry Mass per Area and Local Irradiance on Canopy Photosynthesis Within Leaves of Contrasted Heterogeneous Maize Crops, Ann Bot, 93, 699–710, https://doi.org/10.1093/aob/mch099, 2004.*
- *Muchow, R. C.: Effect of nitrogen supply on the comparative productivity of maize and sorghum in a semi-arid tropical environment I. Leaf growth and leaf nitrogen, Field Crops Res, 18, 1–16, https://doi.org/10.1016/0378-4290(88)90055-X, 1988.*
- *Osborne, T., Gornall, J., Hooker, J., Williams, K., Wiltshire, A., Betts, R., and Wheeler, T.: JULES-crop: a parametrisation of crops in the Joint UK Land Environment Simulator, Geosci. Model Dev, 8, 1139–1155, https://doi.org/10.5194/gmd-8-1139-2015, 2015.*
- *Volkholz, J. and Ostberg, S.: ISIMIP3a N-fertilizer input data (v1.2). ISIMIP Repository., https://doi.org/10.48364/ISIMIP.311496.2, 2022.*