Review "Developing an eco-physiological process-based model of soybean growth and yield (MATCRO-Soy v.1): Model calibration and evaluation"

General remarks

The manuscript presents the MATCRO-Soy model. MATCRO-Soy is an extension of MATCRO which was developed to simulate rice. The authors describe the necessary changes to the model and present an evaluation against multiple data sources showing moderate agreement.

Overall, the manuscript is well structured and provides detailed explanations of MATCRO-Soy but requires a thorough language check. Additionally, I have several concerns regarding the representation of symbiotic nitrogen fixation (major comment 1) and water stress (major comment 3) and the role of CO_2-fertilization (major comment 6). Additionally, some of their equations as well as methods used for calibration and evaluation need to be described in more detail (major comments 2, 4 and 5).

I hope that the specific comments below help to improve the quality of the manuscript.

Major comments

1. The authors' reparametrize an existing crop model for rice to extend its usage to soybean. However, soybean is a legume and therefore capable of symbiotic nitrogen fixation. It is my understanding that neither symbiotic nitrogen fixation nor nitrogen uptake are explicitly simulated in the model but are implicitly captured by the nitrogen limitation (SLN see also major comment 2). Even if symbiotic nitrogen fixation is captured implicitly reducing nitrogen stress, the respiratory costs of symbiotic nitrogen fixation are not considered. Yet, these costs are essential when determining the pathway of nitrogen uptake a plant follows depending on environmental conditions. For example, Fischer et al. (2006) show that the simulation of N uptake requires the optimization of the respiration costs of different uptake paths to reduce respiration losses. Neglecting these respiratory costs may lead to an overestimation of NPP and in turn crop yield under nitrogen limited conditions. When assessing Fig. 5 and 6 a), MATCRO-Soy indeed shows a systematic overestimation of FAO yields. It would be interesting to assess whether this overestimation is stronger in countries with lower fertilization rates which could indicate that the missing representation of the cost of N fixation contributes to the overestimation. Additionally, I would ask the authors to explain why they do not consider respiratory costs of biological nitrogen fixation and the implications of this assumption and also considers this when discussing the limitations of their model. What would be potential solutions to solve this issues in future model versions?

2. The explanations of Eq. 8, 9 17, 18 and 19 are incomplete. For example the explanation of eq. 8 and 9 is missing the explanation of SLN_{Y0}, SLN_{Y1}, SLN_{Y2} and SLN_{Y3}, $SLN_{Y3,h}$, $SLN_{Y3,l}$ and $N_{fert,max}$. All of these seem to be parameters that are listed in tables later on but this is not clearly explained. In addition I think that the assumption that biological nitrogen fixation (BNF) is captured through SLN needs a thorough explanation. Do the authors assume that BNF is captured by N_{fert}? If so this should be stated and its implications need to be discussed. This is also related to major comment 1 regarding the assumption to not represent the respiratory costs of BNF.
Similar in eq. 17, 18 and 19 P_{leaf0}, P_{leaf1}, P_{leaf2}, P_{pod1} and P_{pod2} are only listed in the tables but not explained.

3. Eq. 25 and 26: Water stress is a factor to reduce the yield at harvest. It is not clear whether only the value for the water content of each soil layer at the day of harvest is used to calculate water stress or if this is integrated over the entire growing season but only applied at harvest. In both cases only applying water stress at harvest has its limitations (e.g. such an approach misses propagation effects of early season water stress as well as drought mortality) which should be discussed.

4. The authors use segmented linear models to estimate several parameters in different developmental stages (DVS). However, they do neither provide the software they used to create these models nor how the models were trained. Therefore, I think the answers to the following questions need to be added to section 3.2: How where the initial breakpoints estimated? What kind of optimization method was used?

5. Detrending: It looks like the authors apply linear detrending which removes both the slope and intercept of the linear regression from the observations and simulations respectively. This should at least be explained when the term "detrending" is introduced. In addition, I think the authors should highlight that the detrended comparison is useful to evaluate interannual variability and sensitivity to climate variability but mention that linear detrending removes important signals from the data.

6. L622-627: The authors describe the role of CO_2-fertilization effects for simulations results and hypothesize that this is the reason for the positive bias compared to observations. I would appreciate a more thorough explanation how the authors come to this conclusion. What is their explanation for the models ability to capture the temporal trend of the yield increase well but systematically overestimate yields? If this is all explained by CO_2-fertilization, this indicates that the model captures the temporal development of the effect well (slope) but not the overall magnitude of the role of CO_2 (bias) for yield formation. Additionally, while the CO_2-fertilization is one possibility, I do not think that this is the only possible explanation that is supported by their results. As stated in major comment 1 and 3, underestimation of respiratory costs for symbiotic nitrogen fixation and water stress are also likely explanations that should be discussed.

Minor comments
1. L35f: "[…] represent physiological processes influenced by key climate factors on the long-term impacts of climate […]" the double use of climate seems redundant to me. Suggestion: "[…] represent the long-term climate change impacts on yield productivity via the influence of key climatic factors on implemented physiological processes."

2. L37: Missing "the" before crucial.

3. L39: I am not sure if "mechanistic crop model" is the best term to use because the radiation use efficiency approach is (semi-)empirical and I would define mechanistic as based on first principles (e.g. foundational laws of physics). Therefore, I would argue that models using a radiation use efficiency approach as well as models using a biochemical approach like Farquhar can be process-based depending on how other processes are implemented. I suggest to rephrase the sentence to distinguish biochemical approach to simulate photosynthesis from (semi-)empirical instead of distinguishing mechanistic and process-based.

4. L46: I believe it should be "AgMIPs efforts" instead of "AgMIP efforts". Also […] the simulated impacts of environmental factors on crop yields using a GGCM […]" instead of "[…] the estimated impacts of environmental factors using a GGCM on crop Yields […]".

5. L49: remove "due".

6. L51: "[…] the development of new soybean models […]" instead of "[…] the development of the new soybean model […]" because MATCRO-Soy has not been introduced yet.

7. L54f: A verb is missing in the first part of the sentence. I suggest to add "exist" after parameters.
8. L57: Remove "remains".
9. L64: Is Masutomi et al., 2019 referring to the ozone implementation? If yes this is not clear from the current sentence structure.
10. L82: It is not clear to me what the authors mean by carbon allocation driven by photosynthetic activity. To me carbon allocation is the distribution of carbon between different plant organs – here called carbon partitioning – while photosynthetic activity drives carbon assimilation. Please clarify.
11. L83: I do not understand what is meant by "The phenology module serves as a time dimension […]" I assume that it is time dependent but this is not the same. Please clarify.
12. L87f: NPP is not primary production not product. Please correct.
13. L88: I suggest to simply to "The NPP is stored in […]" instead of "These photosynthesis products are stored in […]".
14. L90: Is de Vries et al., 1989 the reference to "school of De Wit" or MACROS? Also the acronym MACROS has not yet been introduced.
15. L99: Either "The output of the MATCRO model […]" or "The output of MATCRO […]".
16. Eq. 2: Add the subscript t to GDD to highlight that it the GDD until the current timestep t.
17. Eq. 4: Add the subscript t to DVR to express that it is the DVR of the current timestep t. Also, here m is used as the index for time while it is used for maturity in Eq. 1, 2 and 3. This is confusing. Why not use t for time. Similarly why are b, h and o used for minimum, maximum and optimum? Why not use min, max and opt which are far more intuitive?
18. L137: Replace "net primary product" with "NPP".
19. L140: Add "the" before Ball-Berry.
20. L144: I think it needs to be "$V_{cmax,top}$ instead of V_{cmax}
21. Eq. 17: How can the developmental stage (DVS) be negative? I would assume it starts at 0.
22. Eq. 22 I am a bit confused by the specific leaf weight parameter, this seems to be the same as leaf mass per area (LMA) trait. If so why not use the common definition? Or this not per leaf area but per agricultural area? If this is the case this should be mentioned. There also seems to be a discrepancy regarding the units in Table 3 are per area (m^{-2}) whereas they are per area squared in the text (ha^{-2}).
23. Fig. 2a): How is the first segment fitted to the data if there are only values for DVS of around 0.2 or larger?
24. L374-378: The abbreviation MSD is used twice for mean standard deviation as well as mean squared deviation.
25. L431f: Why does the model have a higher accuracy for countries with high production levels? Are fertilization levels in these countries higher and water stress levels lower? If so this should also be discussed in the context of N-fixation (major comment 1) and water stress (major comment 3).
26. L436: Reference is not displayed correctly.
27. L540: Change "[…] highlights the model capacity of the model" to "[…] highlights the capacity of the model".
28. L578-587: This paragraph is very general and I am missing the connection to the MATCRO-Soy's strengths and application.
29. L599: Change "[…] number of grids" to "[…] number of grid cells".