

Manuscript Number: egusphere-2026-2303

Dear Reviewers,

Thank you very much for reviewing our manuscript. Please find our point-to-point responses below and the revisions/corrections in the changes-tracked version of the re-submitted manuscript. The comments are shown in normal text and our responses are in blue.

Reviewer#1

Major comments:

1. Apart from water stress, have the authors considered other critical factors affecting photosynthate allocation, such as nitrogen fertilization? In agroecosystems, water and nitrogen dynamics are tightly coupled and often interactively affect crop physiology. While I acknowledge the complexity of modeling this coupled process and understand the specific focus of the current study on water-driven partitioning, the impact of nitrogen cannot be overlooked. Could the authors elaborate in the Discussion section on how they plan to incorporate nitrogen effects, particularly water–nitrogen interactions, in future modeling efforts?

Response: Thank you for this valuable suggestion. We agree that nitrogen is another key factor regulating crop photosynthate allocation and that water and nitrogen often interact to influence crop growth and biomass partitioning in agroecosystems.

In Agro-C (Huang et al., 2009), nitrogen fertilizer application is included as one of the key management inputs, and in this study the recorded fertilizer application rates from each experimental site were directly used as the model inputs. The calibration and validation datasets encompass a wide range of nitrogen application rates as well as irrigation and water stress conditions, allowing the simulations to account for site-specific nitrogen management while focusing on the effects of water availability.

The primary objective of this study was to optimize the parameters governing

photosynthate allocation under water stress. The effects of nitrogen were represented using the existing Agro-C framework. Your suggestion of the nitrogen effects confirms our further study on the simulation of photosynthate allocation regulated by soil environmental factors beyond the water availability.

Following your suggestion, we added a brief discussion in the revised manuscript to note that our future work will investigate the coupled effects of water and nitrogen on photosynthate allocation and incorporate water–nitrogen interactions into the model to improve its representation of crop physiological responses under multiple environmental stresses. (Lines 581-587)

2. The manuscript highlights the importance of improved photosynthate allocation for estimating soil carbon inputs. However, this link could be discussed more clearly. The authors should briefly explain how improved AGB and BGB simulations may reduce uncertainty in residue and root carbon input estimates, while noting that long-term SOC sequestration would require further coupling with SOC turnover processes.

Response: Thank you for this helpful comment. We agree that the relationship between improved photosynthate allocation and soil carbon dynamics should be explained more clearly.

The Agro-C model originally developed by Huang et al. (2009) is a coupled Crop-C and Soil-C model rather than a crop growth model alone. In Agro-C, the Crop-C module first simulates aboveground and belowground biomass production. Subsequently, the simulated aboveground biomass is partitioned into harvested yield and crop residues according to the harvest index and straw return ratio, while belowground biomass is transferred entirely to the soil carbon module as root carbon input. These carbon inputs then drive SOC dynamics through the decomposition and turnover processes represented in the Soil-C module.

Therefore, improving the simulation of AGB and BGB directly reduces the uncertainty in residue and root carbon inputs to the Soil-C module, which is expected to improve the simulation of SOC dynamics. However, we agree that the present study mainly evaluates the improvement of the Crop-C module and does not independently assess long-term SOC simulations. Following the reviewer's

suggestion, we have added a brief discussion to clarify the linkage between the optimized photosynthate allocation scheme and the subsequent simulation of soil carbon inputs and SOC dynamics within the Agro-C framework. (Lines 489-493)

3. The empirical equations for ΔPR , ΔPL , and ΔYGR in Tables 1 and 2 contain relatively large polynomial coefficients, especially during the reproductive and maturity stages. The authors should briefly clarify whether physiological bounds were imposed on PR, PL, and YGR, and whether these equations are only applicable within the listed ΔW ranges.

Response: Thank you for this valuable comment. In the optimized Agro-C model, physiological constraints were imposed on the allocation coefficients based on crop physiological characteristics. Specifically, PR and PL represent the fractions of photosynthates allocated to roots and leaves, respectively. Therefore, the model constrains the allocation coefficients to satisfy $PR + PL \leq 1$ (Line 202), ensuring that the total carbon allocation remains physiologically reasonable.

The adjustment terms (ΔPR , ΔPL , and ΔYGR) are applied to the original parameter values (Table S1), and the magnitude of these adjustments is determined by the daily water deficit (ΔW). Consequently, the optimized parameters (PR_N , PL_N and YGR_N) remain within physiologically meaningful ranges. In addition, Section 4.2 has been expanded to further explain the physiological basis and rationale for the parameter optimization.

Regarding the applicability of the empirical equations, the calibration datasets include multiple experimental sites covering a wide range of climatic conditions, soil types, irrigation regimes, and nitrogen application levels. More importantly, the optimized model was evaluated using independent validation datasets that were not involved in parameter calibration. As shown in Section 3.2.2, the optimized model consistently improved the simulation of both aboveground and belowground biomass, suggesting that the optimized allocation scheme is applicable across the listed ΔW range of -2 to 5 mm, which covers the reality conditions of crop fields. The extreme water conditions beyond the listed range are yet proved.

4. After model optimization, how is the effect of changing irrigation regimes on

photosynthate partitioning physically represented during the simulation? Please provide a clear description of this process.

Response: Thank you for this helpful comment. We have clarified the description of the optimized water module in Section 2.3.

Specifically, the original Agro-C model did not explicitly account for actual irrigation inputs. In the optimized water module, the daily irrigation amount ($Irr_{(i)}$) during the crop growing season is introduced as a model input. Soil moisture ($W_{(i)}$) is then calculated using the recorded precipitation and irrigation data for each study site, together with the crop water supply and water demand (Eq. 5). The calculated soil moisture is subsequently used to estimate the daily water deficit (ΔW), which drives the adjustment of the photosynthate allocation coefficients (ΔPR , ΔPL , and ΔYGR). In this way, changes in irrigation amount influence photosynthate partitioning through their effects on soil water availability. The revised manuscript now includes the following description in Section 2.3. (Lines 152-160)

In addition, we have further discussed the model's capability and limitations in representing different water management conditions in the newly added Section 4.3.2. We clarify that the current model can simulate different water conditions using site-specific irrigation amounts or relative available soil water (RAW), but it does not explicitly distinguish among different irrigation strategies (e.g., drip, sprinkler, and flood irrigation). We also discuss this limitation and outline future improvements to incorporate more detailed irrigation management practices. (Lines 596-602)

Some minor issues:

1. The abstract mentions “ecosystem carbon sequestration”, but the manuscript mainly evaluates crop biomass and soil carbon inputs rather than actual SOC stock changes. I suggest revising this phrase to “soil carbon inputs” or “potential implications for SOC dynamics.”

Response: Thank you for this helpful suggestion. We agree that the original expression could be misleading. We have revised “ecosystem carbon sequestration” to “soil carbon inputs” in the Abstract to better reflect the scope of this study.

2. In Tables 1 and 2, the fitted equations are useful but quite dense. The authors may

consider moving some detailed parameter information to the Supplement or adding a short explanation of how readers should interpret the equations and their applicable ranges.

Response: Thank you for this suggestion. Since Tables 1 and 2 contain the core parameterization of the optimized Agro-C model, we believe they are essential to the main text and therefore have retained them. Following the reviewer's suggestion, we have added a brief explanation describing how these equations should be interpreted and emphasizing that they are empirical parameterization functions developed from the calibration dataset and intended to be applied within the corresponding $\Delta W_{(i)}$ ranges.

“The equations in Tables 1 and 2 are empirical parameterization functions describing the responses of ΔPR , ΔPL , and ΔYGR to water deficit ($\Delta W_{(i)}$) at different DVI stages. The appropriate equation should be selected according to the crop type, DVI interval, and ΔW value during model simulation.” (Lines 278-282)

3. The figures are generally informative, but some captions could be improved. For example, Fig. 2 should more clearly explain the meaning of the fitted curves and whether PR/PL and YGR use different axes.

Response: Thank you for this helpful suggestion. Following the reviewer's recommendation, we have revised the caption of Fig. 2 to better explain the meaning of the fitted curves and the use of different y-axes.

“Fig. 2. Mean values and fitted curves of the leaf allocation coefficient (PL), root allocation coefficient (PR), and yellow-to-green leaf ratio (YGR) for maize and wheat at the jointing, silking/heading, and maturity stages under different soil moisture conditions, as simulated by the optimized Agro-C model. PL and PR share the left y-axis, whereas YGR is plotted on the right y-axis.” (Lines 329-333)

4. Some language polishing is needed. For example, “Up on the datasets...” should be revised to “Based on the datasets...”, and “Totally we collected...” could be changed to “In total, we collected...”.

Response: Thank you for your careful review. We have carefully checked the manuscript and revised the language throughout the text.

Reviewer#2

1. The manuscript claims to "improve the water module" by integrating root water uptake characteristics, but the actual implementation relies heavily on empirical constants and literature-derived parameters. The authors should clarify what constitutes the novelty beyond the empirical calibration.

Response: Thank you for this insightful comment. We agree that the optimized water module still contains empirical parameters and literature-derived constants. The novelty of this study does not lie in introducing new hydraulic parameters, but in improving the representation of crop responses to water stress.

Specifically, the original Agro-C model estimated water stress using relative available soil water (RAW), whereas the optimized model explicitly incorporates root water uptake by coupling soil water potential, root hydraulic conductivity, root surface area density, and root water potential to calculate the actual root water uptake. Based on the difference between crop water demand and actual root water uptake (ΔW), the photosynthate allocation coefficients (ΔPR , ΔPL , and ΔYGR) are dynamically adjusted according to crop developmental stage. Therefore, the main novelty of this study is the integration of a process-based root water uptake module with a dynamic photosynthate allocation scheme, rather than the introduction of new empirical parameters. We have revised the Introduction and Discussion to better clarify this point. (Lines 90-96, 566-572)

2. There are several minor errors and inconsistencies in the equations and text. Please check them.

Response: Thank you for your careful review. We have thoroughly checked the equations, variable definitions, and the entire manuscript for consistency. Several minor typographical, grammatical, and formatting errors have been corrected, and the notation has been revised where necessary to ensure consistency throughout the manuscript.

3. The manuscript does not describe how soil hydraulic parameters were obtained for each site. Were these derived from the reported soil texture using pedotransfer

functions, or were they directly measured? This affects the reproducibility of the model results.

Response: Thank you for this valuable comment. We apologize that the description of the soil hydraulic parameters was not sufficiently clear in the original manuscript.

The site-specific soil input data, including bulk density, sand content, clay content, and total nitrogen content, were obtained from the corresponding experimental site descriptions, as described in Section 2.5. Based on these soil properties, the soil hydraulic parameters used in the water module, including the wilting moisture (W_p) and the lower (W_l) and upper (W_{upper}) optimum soil moisture thresholds, were calculated following the original Agro-C model developed by Huang et al. (2009). Therefore, these parameters were neither directly measured nor assigned as fixed values across all sites. (Lines 130-132)

In addition, the newly introduced hydraulic parameters in the optimized water module mainly refer to root hydraulic parameters. Specifically, the root water potential ($\Psi_{r,(i)}$) was treated as an empirical constant derived from the literature (Munns and Tester, 2008; Novák et al., 2005). The soil water potential $\Psi_{s,(i)}$ can be calculated using the van Genuchten water retention function (van Genuchten, 1980)(Eq. 9).

$$\Psi_{s,(i)} = \frac{1}{\alpha} \left[\left(\frac{\theta_s - \theta_r}{W_{(i)} - \theta_r} \right)^{1/m} - 1 \right]^{1/n}, \quad m = 1 - \frac{1}{n} \quad (9)$$

where θ_s denotes the saturated soil moisture content ($\text{cm}^3 \text{ cm}^{-3}$), θ_r denotes the residual soil moisture content ($\text{cm}^3 \text{ cm}^{-3}$). The α and n represent the empirical parameters of van Genuchten related to soil texture. These parameters were derived according to the parameterization scheme of the original Agro-C model (Huang et al., 2009). (Lines 177-184)

The intrinsic root hydraulic conductance (L_p) was obtained from published studies. The root hydraulic conductivity (C_r) was calculated dynamically from root biomass and specific root surface area (Eq. 11). We have revised the manuscript to

clarify the sources of both the soil and root hydraulic parameters, thereby improving the transparency of the model.

4. The Introduction packs excessive information into single sentences, making it difficult to follow the logical thread. For example, lines 36–51. I suggest the author to refine the statements.

Response: Thank you for this helpful suggestion. We have revised the Introduction, particularly Lines 36–51, by breaking several long sentences into shorter ones and reorganizing the text to improve the logical flow. The revised version presents the effects of water availability on crop carbon allocation in a clearer and more coherent manner. (Lines 38-49)

5. The authors use multiple terms interchangeably: “photosynthetic allocation,” “assimilate partitioning,” “carbon allocation,” and “photosynthate allocation.” While these are closely related, the lack of consistent terminology may create confusion.

Response: Thank you for this helpful suggestion. We agree that consistent terminology improves the readability of the manuscript. Following your recommendation, we have replaced the terms “photosynthetic allocation” and “assimilate partitioning” with “photosynthate allocation” throughout the manuscript to ensure consistency. We retained the term “carbon allocation” only where it refers to the broader process of carbon partitioning within the plant or in the context of the terrestrial carbon cycle, as it has a broader meaning than photosynthate allocation. We have carefully checked the manuscript to ensure that the terminology is now used consistently and appropriately.

6. Although limitations in the present study are mentioned sporadically, they are scattered rather than consolidated. A dedicated, clearly headed subsection in Discussion would improve transparency and provide a clear roadmap for future research.

Response: Thank you for this constructive suggestion. We agree that presenting the limitations in a dedicated subsection improves the clarity and transparency of the discussion. We have changed the Section 4.3, in which the current limitations of the

model are discussed in a consolidated manner. This subsection also outlines several directions for future model development, including the incorporation of dynamic water–nitrogen interactions and more detailed representations of root processes. We believe this revision provides a clearer roadmap for future research and improves the overall organization of the Discussion.