The following line numbers refer to the track-changes file.

Reviewer #1:

Thank you for the positive feedback and for the valuable and constructive comments! We have carefully revised the manuscript to address the suggestions. Below, we provide detailed responses to each of the reviewer's remarks and outline the corresponding revisions made to the manuscript.

General Comments

The manuscript could benefit from a more explicit discussion of the assumptions made in the model, particularly those related to the root architecture and soil-root interface potentials. A dedicated section summarizing these assumptions and their potential impacts on the results would enhance clarity.

We added more explicit description of our model assumptions when we introduce the root architecture model (L191-196), more explicit equations and assumptions about the root hydraulic model (L198-230) , and the perirhizal zone potential (L281-282). Furthermore, we added a section dedicated to model limitations to the discussion (L664-673).

Consider adding a table summarizing all model parameters and their units. This would help readers understand the variables used and ensure consistency throughout the manuscript.

We added a table summarizing all model parameters and variables in alphabetical order (Table 1).

Provide more detailed derivations and explanations of key equations. For instance, equations related to perirhizal resistance and root water uptake should be thoroughly explained, including the assumptions and approximations involved.

We added the continuum equations for the root hydraulic model and improved the explanations of the key equations (L198-230), in particular the derivation of the root hydraulics (Eqns 4-8) and added the derivation of the geometry parameter B (SI, L1-31).

Specific Line-by-Line Comments

Line 32-34: Do the authors know of any attempts to solve the Navier-Stokes Equation across root tissue? Do the authors consider radial or axial flow here? The radial flow seems to be challenging, especially if the cell-cell pathway needs to be considered. On the other hand, will the average flow correlate with the average potential gradient? Averaging schemes seem to depend on the arrangement of cells and the composite structure of root tissue, and they are not simple averaging schemes. I suggest that the authors clarify these points in the text.

To our knowledge, radial flow across tissue is not simulated using Navier-Stokes Equation due to the laminar nature of the flow. To explain the derivation of the effective radial flow *from root anatomical features, we now cite the MECHA model of Couvreur et al. (2018). We now added the following paragraph to this section (L34-36): "For porous media, Darcy's law can be derived from the Navier-Stokes equations using homogenisation \citep{Hornung1996}. Also in plants, water flow is generally laminar. \cite{couvreur2018going} describe water movement within root cross sections, numerically calculating effective radial conductivity from root anatomical features."*

Line 36: What do the authors mean by "in this way"? Do they refer to 3D architectural models or Navier-Stokes equations?

we rephrased: "In summary, Darcy-type flow equations are used to simulate water flow in both the soil and the root domains as well as the water exchange between them." (L 39-42)

Line 37: Replace "potential difference" with "water potential difference".

done (L51)

Line 56: Replace "we" with "they". Not all the authors of the mentioned work are co-authors of this manuscript.

we rephrased that sentence: "In order to obtain water potentials at the soil root interfaces, which are used by the root model, a perirhizal model around the root segments is employed that incorporates nonlinear soil conductance based on \cite{Schroeder2008}." (L61-62)

Line 87: Replace "Vanderborght et al. (2021) showed that it reproduced the uptake by 3D root architectures quite well" with "Vanderborght et al. (2021) demonstrated that this approach well reproduced the water uptake by 3D root architectures".

done

Line 108: What do the authors mean by individual potential? Make it clear that here you are referring to soil water potential.

We rephrased the paragraph: "The way the root hydraulic system (left green column): The surrounding soil of the root system is characterised by soil water potentials at the soil root interface for each root segment (Figure 1A,)…" (L120-124).

Line 131-138: It is not clear what the authors mean by Axx, Bxx, xAx, and xBx. Provide clear definitions and explanations of these terms in the text. See also the suggestion for Figure 1.

We described this new nomenclature in more detail (L133-137) and included colored columns in Fig.1 to make it easier to follow.

Line 142: Replace the unit of soil water content with cm^3/cm^3 to indicate that volumetric water content is considered here. Replace "soil total potential" with "total soil water potential" here and elsewhere in the text.

done

Line 152: What does it mean radial hydraulic conductivity with a unit of 1/day? Typically, it has a unit of a gradient in water potential inside.

Yes, typical unit are [cm2/day] being a volumetric flux per gradient [cm3/day 1/cm]. For root radial uptake we divide this value by the segment surface (this is sometimes called intrinsic root radial conductivity). We added the term 'intrinsic' for clarification (L172)

Line 157: Did the authors neglect the osmotic potential gradient between soil and root xylem? Comment on this assumption.

We now added the fact that we neglect the osmotic potential in the effective radial pathway of water between soil and root: "As \cite{DOUSSAN1998}, we consider that the soil water is a dilute solution as is the sap and therefore we neglect the osmotic potential in the xylem and the soil." (L205-207). Please note that in the derivation of the effective radial conductance as described in the MECHA model (Couvreur et al. 2018), osmotic potential is considered.

Line 247: The authors use the concept of matric flux potential to derive the average hydraulic conductance in the perirhizal zone. Why did they not consider the radial nature of root water uptake in this derivation?

The derivation uses a cylindrical model, we now clarify this (L289).

Line 237-255: The set of questions described here is hard to follow, particularly Equation 18. Explain the derivation of these equations. To what extent is Equation 19 similar to those presented in Schröder et al. (2008) and Van Lier et al. (2006)? If they are based on similar concepts, I suggest referencing these works.

Based on the analytical solution of Schröder et al. (2008), and using an average soil hydraulic conductivity in the perirhizal zone, defined as $K_{prhiz}=(\Phi(h_s)-\Phi(h_{sr})) / (H_s-H_{sr})$ *we can derive old Equation 18 (now 22). We now added the derivation of this equation as well as the geometry factor B in the SI Section 1. The idea of using an average matric flux potential was also introduced by de Jong van Lier et al. (2006). Because they derive the root water uptake term per soil layer and not per root segment, and because they use a mixed-type boundary condition at the root-soil interface, their final equation looks slightly different than the one in our manuscript.*

Line 410-413: Do the estimated root-soil hydraulic conductance and particularly the difference between two selected plants correspond to any literature values?

We did not compute the root-soil hydraulic conductance as in serially combining soil and root resistances. Our values of root system conductance Krs are in range with literature values for maize (Meunier et al. 2020) and cereals (Baca Cabrera et al., 2024). We now added this information to the discussion, (L612-613).

Félicien Meunier, Adrien Heymans, Xavier Draye, Valentin Couvreur, Mathieu Javaux, Guillaume Lobet, MARSHAL, a novel tool for virtual phenotyping of maize root system hydraulic architectures, in silico Plants, Volume 2, Issue 1, 2020, diz012

Juan C. Baca Cabrera, Jan Vanderborght, Yann Boursiac, Dominik Behrend, Thomas Gaiser, Thuy Huu Nguyen, Guillaume Lobet, bioRxiv 2024.10.10.617660; doi: https://doi.org/10.1101/2024.10.10.617660

Line 451-454: The reported differences are compared to what? Provide a clear reference for the comparison.

It is an inter-model comparison, the coarser 1D model is compared to the 3D model, we clarified this in the text (L506).

Line 251 & 264: Replace “troug” with “through”.

done

Figures and Visualizations

Figure 1: Label subplots as A1, A2, and A3 instead of referring to the first, second, and third columns in the caption. This will make it easier for readers to follow the discussion.

We decided to use numbering (1-3) for the subplots and additionally use colors to make it easier to follow.

Figure 2: Is this really a loop? This figure would benefit from sequential numbering of the steps to clarify the process flow.

We included the numbering.

Figure 5: Increase the font size to improve readability.

done

Figure 6: Make the subplots larger and increase the font size to enhance clarity.

done

Figures 10, 13, 16, 19: These figures are very crowded and hard to distinguish between different lines. I suggest removing the legend from within the subplots. If they share the same legend, specify it once below or at the top of the subplots. Use different colors to separate the variables more clearly.

done

Figures 11, 12, 17, 18, 21: It is hard to distinguish between solid and dashed lines. Make the x-axis values in Figure 11 more readable.

Done

Reviewer #2:

Thank you for your encouraging feedback and insightful comments! We have thoroughly revised the manuscript to incorporate the suggestions. Below, we offer detailed responses to each of the reviewer's points and highlight the corresponding changes made.

RC: I find the organization of the different models hard to follow. In particular, I'm not sure if I fully understood the definition of the AAA vs AAB vs ABA vs CBB etc. I think there could have been a better naming convention for these that more explicitly state which assumptions are being undertaken in the text. It's really a cosmetic issue, but I think it would really improve the readability of the manuscript. For example, I'm not sure if I've understood very well what the purpose was of the 2D macroscopic grid.

We revised the presentation of the nomenclature to make it easier to follow by including colours and extending the description (L114-L137).

RC: There were minor details regarding the theoretical section that I think could use a bit of elaboration on. I suppose Richards' equation is also being solved for in order to determine soil matric potential, however, it became a bit confusing whether you needed to after some of the equilibration equations come in (i.e. equilibration between the soil matric potential and the xylem potential). It would be useful to know what boundary conditions are considered for this. I assume that there is some kind of resupply of soil water, but it's again unclear whether this is the case. This specificity would be useful.

As a steady rate model, the perirhizal model is independent of time, but only depends on the rate which is determined by the bulk soil total potential Hs and the root xylem potential Hx. Specifically, we use a zero-flux outer boundary condition for the individual perirhizal models. However, the resupply enters the simulation trough the macroscopic model. We now clarified this in L281-282.

RC: The matrix notation for the root zone radial and xylem water transport is nice, but I think it would be useful to include the differential equations to make it clear what physical phenomena is being considered. I think it's just an extra two lines to show the equation in and around the plant, the surface Dirchlet and the no-flux at the bottom. Something that makes it easy to follow for the reader. Then, I think matrix manipulations are all great.

On top of the already existing continuum equations for the soil model, we added the continuum equations for the root hydraulic model in the beginning of Section 2.3, and show their discretization. We state the boundary conditions of the soil domain in the scenario descriptions, lines (L451-453).

RC: Getting into some aesthetics, there are so many figures in this manuscript, and I wonder if some of them could be moved to an SI. I would say that 11, 12, 14, 15, 17, 18, 20, and 21 all look quite similar and aren't adding a lot to the main text. They're hard to read, and they aren't really doing a lot of heavy lifting. As such, I would recommend maybe keeping 11 and 12 and then tucking the others into SI if the readers want to see other plots that look similar, but slightly different. Unfortunately, the transpiration figures are all really too important to move to SI. Figure 9 is amazing. I would only recommend to generate a mean value at each given depth for the full model in order to compare it with A and B. This would really show how representative the simplification actually is at capturing the mean behaviour of the full model and how much information we're loosing by looking at simplifications.

We agree and moved 14, 15, 17, 18, 20, and 21 to SI

As a last point, I couldn't help but read this and think, "couldn't one apply an empirical or semi-empirical factor to get the reduced models to match the full models?" I don't think that's work that needs to be done here (there's more than enough in this paper). I just think that it might be useful to think about. In my mind, the discussion about the crop distributions seems to allude to a potential remedy for the discrepancies between the different models. In my mind, I think that there might be some kind of asymptotic homogenization approach that could capture those geometric details and simplify them down to better estimate the dimensionally reduced model. Of course, if you're certain that this can't be done, it would be good to include these details in the discussion. I think it would be a strong point to make as well.

The authors completely agree. We added a section on model limitations to the discussion and mention homogenisation approach as valuable tool for model development (L664-672).