Author's response on "Modelling the artificial forest (*Robinia pseudoacacia* L.) root-soil water interactions in the Loess Plateau, China" by Li et al.

*Reviewer comments are typed in **black** color, whereas the responses are typed in **blue** color.*

Anonymous Reviewer #1

General comments:

This article develops a root growth model which adjusts root distribution and rooting depth in the root water uptake model based on the cost-benefit theory, and the model verified by observational data is used to simulate the root depth and distribution from 1971 to 2020 to analyze and study the drying soil layers (DSLs), but this article is not thorough enough in some respects. It is of great practical significance for artificial afforestation to analyze the changes of the root system over water-scarce areas such as the Loess Plateau, and the regional analysis chart formed in the article has certain significance for various arid and semi-arid areas to carry out the regional ecological restoration.

As one of the important issues that this research focuses on, although DSLs have been extensively reported in artificial forest land, the issue should be introduced with a certain background in the introduction part.

We are thankful for the valuable comments and suggestions.
First, we expanded the introduction to the drying soil layer in the revised manuscript. Please see lines 96-103. Then, we revised the manuscripts following the comments and suggestions. The point-to-point explanation to the revisions are as follows.

Specific comments:

Line 46: "complicated morphological distribution" should be "a complicated morphological distribution".
We made the correction in the revised version.

Line 331: "imply" should be "implies".
We made the correction in the revised version.

Line 352 and 353: "a NSE" should be "an NSE".

We made the correction in the revised version.

Line 361: “non-availability” should be “the non-availability”.
We made the correction in the revised version.

Line 462: “the dynamic approach resulted in root uptake of 24 mm” should be “the dynamic approach resulted in a root uptake of 24 mm”.
We made the correction in the revised version.

Line 500-502: “Comparisons between the static and dynamic rooting depth approaches also determined that the former was incapable of reproducing the occurrence and evolution of the drying soil layers that have been widely reported in this region (Fig 12).” How this conclusion was obtained needs a more detailed and in-depth explanation.
Your suggestion is appreciated. The observations indicate that the occurrence, the upper and lower boundaries, and the soil water status within the drying soil layer change with time. The static rooting depth approach pre-sets a fixed root depth over the simulation period, which does not capture the hydraulic traits of roots that may advance to use water from the wetter zone beneath the pre-set root depth. We added the explanation in the revised manuscript. Please see lines 487-488 and 517-523.

Line 509-511: “Exploration of water from wetter but deeper soil is also an adaption strategy when it is more profitable, usually with more cost when coarse root growth requires additional biomass investment.” please provide evidence or reference for how this conclusion was obtained.
Appreciated. These understanding comes from literatures. We cited some of these literatures in the revised version., e.g., Pierret et al. (2016) and Germon et al. (2020). Please see lines 530-532.

References:

Pierret, A., Maeght, J.-L., Clément, C., Montoroi, J.-P., Hartmann, C., and Gonkhamdee, S.: Understanding deep roots and their functions in ecosystems: an advocacy for more unconventional research, Ann. Bot., 118(4), 621-635, doi:10.1093/aob/mcw130, 2016.

Germon, A., Laclau, J.P., Robin, A. and Jourdan, C.: Tamm Review: Deep fine roots in forest ecosystems: Why dig deeper? Forest Ecol. Manag., 466, 118135, doi:10.1016/j.foreco.2020.118135, 2020.

Line 503-513: “Notably, the development of the drying soil layers is predominantly due to water utilisation by the deep fine roots, which accounts for approximately only 5% of the total profile uptake (Fig. 11). Although minor compared with the total, it caused a 505 sustained negative soil water balance in the deep soil due to difficulties in receiving recharge, as described in the results section. The continuous development of the lower boundary of the drying soil layer implies that its recovery is critically difficult. This is because of the large thickness and vast storage capacity of loess soil (Huang and Shao, 2019). Plants tend to develop more fine roots in the topsoil and use more soil water due to lower costs but higher benefits, that is, a more profitable adaptation strategy when experiencing water stress. Exploration of water from wetter but deeper soil is also an adaption strategy when it is more profitable, usually with more cost when coarse root growth requires additional biomass investment. This explains why the top 2.0 soil was the most active zone of water uptake in this study. Depletion of topsoil always vacates the storage for infiltration, making it difficult for the rainfall to replenish the deeper dried soil layer or groundwater (Turkeltaub et al., 2018)." Please supplement the significance of this research from a practical perspective in combination with the actual vegetation restoration situation on the Loess Plateau.

We appreciate this suggestion very much. As a matter of fact, Huang and Shao (2019) reviewed the studies on soil water in the Loess Plateau of northwest China. In this paper, the research progresses in the drying soil layer of the artificial forestation and their practical significance have been discussed in depth. In our manuscript, we focus on discussing mechanisms of the occurrence and evolution of the drying soil layer on basis of the mathematical simulation. In the revised version, we enhanced the discussion about the practical significance of this study by referring to the earlier review work by Huang and Shao (2019). Please see lines 539-545.

References:

Huang, L., & Shao, M. (2019). Advances and perspectives on soil water research in China's Loess Plateau. Earth-Science Reviews, 199, 102962. https://doi.org/10.1016/j.earscirev.2019.102962

Figure 8: Since the circles on Figures 8b and 8c represent observation values, please explain what their different colors mean in the caption.

We added the explanations to the colors in the caption of Figure 8.

Figure 10b: The DD symbol has a black edge but the SD symbol does not. Please unify the style.

We updated the Figure 10b.

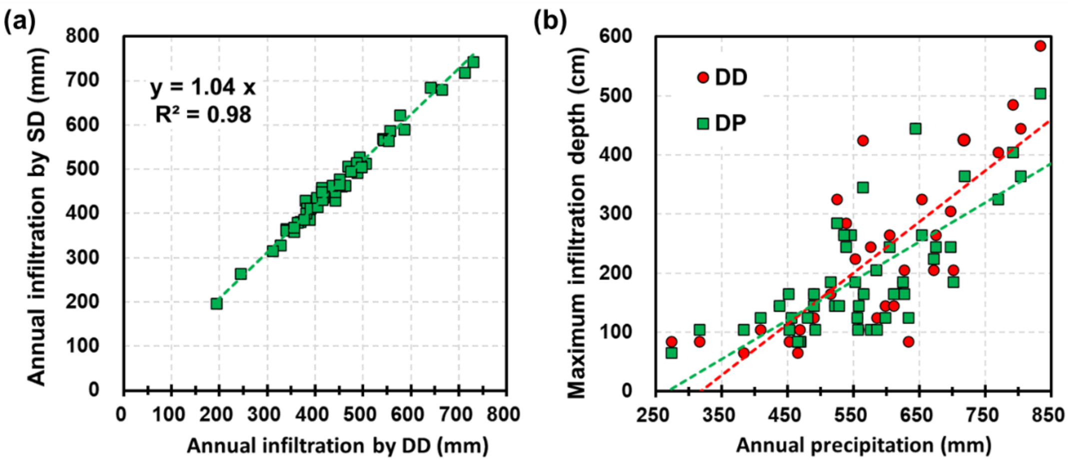

Figure 1: Comparisons of (a) infiltration amounts and (b) maximum infiltration depths between the static rooting depth (SD) and dynamic rooting depth (DD) approaches

Anonymous Reviewer #2

General comments:

Based on the in situ observations, the manuscript proposes a root growth model that simulates both the dynamic rooting depth and fine root distribution. Subsequently, the model was used to simulate the forest-soil water relationships, including soil water availability and the temporal–spatial dynamics distribution of the dynamic rooting depth and fine root distribution in the Loess Plateau (LP) of China. Further, a long-term simulation was performed to address the drying soil layers issues in the region. The results show that incorporating the dynamic rooting depth into the currently available root growth models is necessary for accurately reproducing the drying soil processes. The manuscript is well-written and innovative. The proposed provides a much needed and powerful tool to address the drying soil layer issue than in situ sampling techniques. The findings on the thickness of the drying soil layer and the difficulties in recovery offer insight and strong implications for forest–water management in this region. The manuscript is of interest to the readers of the journal as well the wider ecohydrology community. I only have the following minor suggestions for the authors to consider:

We thank that the reviewer thinks the paper is well-written and innovative. We appreciate all the useful suggestions that will improve the overall quality of our paper. We revised the manuscripts following the comments and suggestions. The point-to-point explanation to the revisions are as follows.

Specific comments:

Yes, it is true how the black locust roots and soil water interact has not been addressed in previous modelling studies in the Loess Plateau of China, a brief and precise of similar findings/studies for other tree species in other regions/countries would help readers understand the current research gap and strengthen the innovative nature of the manuscript.

Thanks for the crucial comment and suggestion.
Fortunately, we accessed the latest work of Sakschewski et al. that is published on Biogeosciences on 12 July 2021, which is closely related to our work.
Sakschewski et al. (2021) reviewed the root growth approaches in the current Earth system models and concluded that "none of those studies have acknowledged resource investment, timing and physical constraints of tree rooting depth within a competitive environment". To deal with this issue, they proposed a variable rooting depth approach for the LPJ model. Their results indicate that "variable tree rooting strategies are key for modelling the distribution, productivity and evapotranspiration of tropical evergreen forests".

In this work, it is assumed that the maximum rooting depth is related to the tree height by a logistic growth function (Sakschewski et al., A5) and the vertical distribution of the fine roots follows a shape function (Sakschewski et al., A2).

In our work, the rooting depth and fine root distribution are constrained by the soil water distribution over the soil profile. The rooting depth and fine root distribution are finally determined by an optimization function that takes account of the ratio of water uptake and connections between the coarse and fine roots.

The variable root approach by Sakschewshi et al. (2021) deals with the trade-off of biomass allocation between the above- and below-ground parts. Our work of dealing the similar issues is still on-going. It is hoped that better understandings of vegetation – water interactions in the semi-humid and semi-arid Loess Plateau can be achieved soon.

We incorporated the latest information into the revised manuscript. Please see lines 68-75, 86-88, 103, and 571.

References:

Sakschewski, B., von Bloh, W., Drüke, M., Sörensson, A. A., Ruscica, R., Langerwisch, F., Billing, M., Bereswill, S., Hirota, M., Oliveira, R. S., Heinke, J., & Thonicke, K. (2021). Variable tree rooting strategies are key for modelling the distribution, productivity and evapotranspiration of tropical evergreen forests. Biogeosciences, 18(13), 4091–4116. https://doi.org/10.5194/bg-18-4091-2021

P7 Eq. 6 defines the relationship between the coarse and fine roots. An addition of the definition of coarse and fine roots in the introduction would also clarify the potential confusion about the distinction of the two.

The suggestion is appreciated. The definition of coarse (>2 mm diameter) and fine roots (<2 mm in diameter) in the classic approach is used in this study, and we clarified this in introduction part of the revised version. Please see lines 76-78.

References:

Smithwick, E. A. H., Lucash, M. S., McCormack, M. L., & Sivandran, G. (2014). Improving the representation of roots in terrestrial models. Ecological Modelling, 291, 193–204. https://doi.org/10.1016/j.ecolmodel.2014.07.023

Jackson, R. B., Mooney, H. A., & Schulze, E.-D. (1997). A global budget for fine root biomass, surface area, and nutrient contents. Proceedings of the National Academy of Sciences, 94(14), 7362–7366. https://doi.org/10.1073/pnas.94.14.7362

P3, Line 79, “potentially beneficial…” should be “potentially benefit..”

We made the correction in the revised version.