HESS-2023-12
Title: The degree and depth limitation of deep soil desiccation and its impact on xylem hydraulic conductivity in dryland tree plantations
Author(s): Nana He et al.
MS type: Research article
Iteration: Minor revision

Public justification (visible to the public if the article is accepted and published):

Dear Xiadong Gao, Nana He, and co-authors,

thank you for implementing further changes in the document as to my previous comments. I have had another careful look at the revision and still, the problem is not resolved. As mentioned previously, accommodating, the issue probably requires adaptation elsewhere in the manuscript, e.g. discussing how gradients of aridity may affect root water uptake depth.

Response: Thank you very much for your great patience and constructive comments on our paper. Difference degrees of drought across various sites adjust the root water uptake depth of *Robinia pseudoacacia* and *M. pumila* trees mainly by altering their growth characteristics of the aboveground part, for example plant height in Table 2, and underground part, for example the fine root dry weight density in Fig. S5, which have been provided in the Supplement file. Correspondingly, we have made the following modifications in the Discussion section (Lines 398-417 in the track-changed version) as follows.

Lines 398-417:

"Our results indicated that for the sampled trees, the maximum RWU depth reached 18.0-22.0 m for *M. pumila* orchards across different sites, and 18.4-18.8 m for *R. pseudoacacia* forests in Changwu and Yan'an, while in Mizhi it was more than 25 m (Fig. 5). These depth ranges are similar to the maximum RWU depth of the artificial *Caragana microphylla* forest discovered by Wang et al. (2009). Divergence in the maximum RWU depth of the same tree species examined at different sites mainly due to tree adopting different biomass allocation strategies to adapt to varying drought aridity (Mayoral et al., 2016; Valverdi et al., 2019; Zhao et al., 2022). This was mainly manifested as the fine root dry weight density distributed at greater soil depth for *R. pseudoacacia* plantation examined in Mizhi than that in Changwu and Yan'an (Fig. S5), while the plant height of *R. pseudoacacia* trees in Mizhi was lower than that in Changwu and Yan'an (Table 2). Due to the longer flow path, the greater hydraulic resistance for upward water transfer (Mencuccini, 2003; Zweniecki et al., 2003), thus *R. pseudoacacia* trees examined in Changwu and Yan'an were taller, making it relatively difficult to absorb water from deeper soil layer. In contrast, due to substantial human intervention such as canopy pruning, the maximum RWU depth of *M. pumila* plantations across different sites both were between 18.0-22.0 m. This differences between tree species were consistent with the hypothesis. In addition to human management factors, the inconsistency in the maximum RWU depth examined for *M. pumila* and *R. pseudoacacia* in Mizhi is in that, the early-stage water consumption of the latter is higher (Wu et al., 2021), leading to lower deep soil moisture (>2 m) across different sites than *M. pumila* plantations (Fig. S3). Furthermore, the larger VPD and the coarser soil texture (Fig. 8), helps *R. pseudoacacia* trees to absorb water by growing deeper roots (>25 m) in this site.

References:

Wang, Z., Liu, B., Liu, G., and Zhang, Y.: Soil water depletion depth by planted vegetation on the Loess Plateau, Sci. China Ser D-Earth Sci, 52(6), 835-842, https://doi.org/10.1007/s11430-009-0087-y, 2009.

Mayoral C., Pardos M., Sánchez-González M., Brendel O., Pita P.: Ecological implications of different water use strategies in three coexisting mediterranean tree species, For. Ecol. Manage., 382, 76–87, https://doi.org/10.1016/j.foreco.2016.10.002, 2016.

Valverdi NA., Cheng L., Kalcsits L.: Apple scion and rootstock contribute to nutrient uptake and partitioning under different belowground environments, Agron. J., 9(8), 415, https://doi.org/10.3390/agronomy9080415, 2019.

Zhao, L., He, N., Wang, J., Siddique, K. H. M., Gao, X., and Zhao, X.: Plasticity of root traits in a seedling apple intercropping system driven by drought stress on the Loess Plateau of China, Plant Soil, 24

(1), 273, https://doi.org/10.1007/s11104-022-05603-1, 2022.

Mencuccini M.: The ecological significance of long-distance water transport: short-term regulation, long-term acclimation and the hydraulic costs of stature across plant life forms, Plant Cell Environ., 26,163–182, https://doi.org/10.1046/j.1365-3040.2003.00991.x, 2003.

Zwieniecki, M. A., Thompson, M. V., & Holbrook, N. M.: Understanding the Hydraulics of Porous Pipes: Tradeoffs Between Water Uptake and Root Length Utilization, J. Plant Growth Regul., 21(4), 315–323, https://doi.org/10.1007/s00344-003-0008-9, 2003.

Wu, W., Li, H., Feng, H., Si, B., Chen, G., Meng, T., Li, Y., and Siddique, K. H. M.: Precipitation dominates the transpiration of both the economic forest (*Malus pumila*) and ecological forest (*Robinia pseudoacacia*) on the Loess Plateau after about 15 years of water depletion in deep soil, Agr. Forest Meteorol., 297 (1–4), 108244, https://doi.org/10.1016/j.agrformet.2020.108244, 2021.

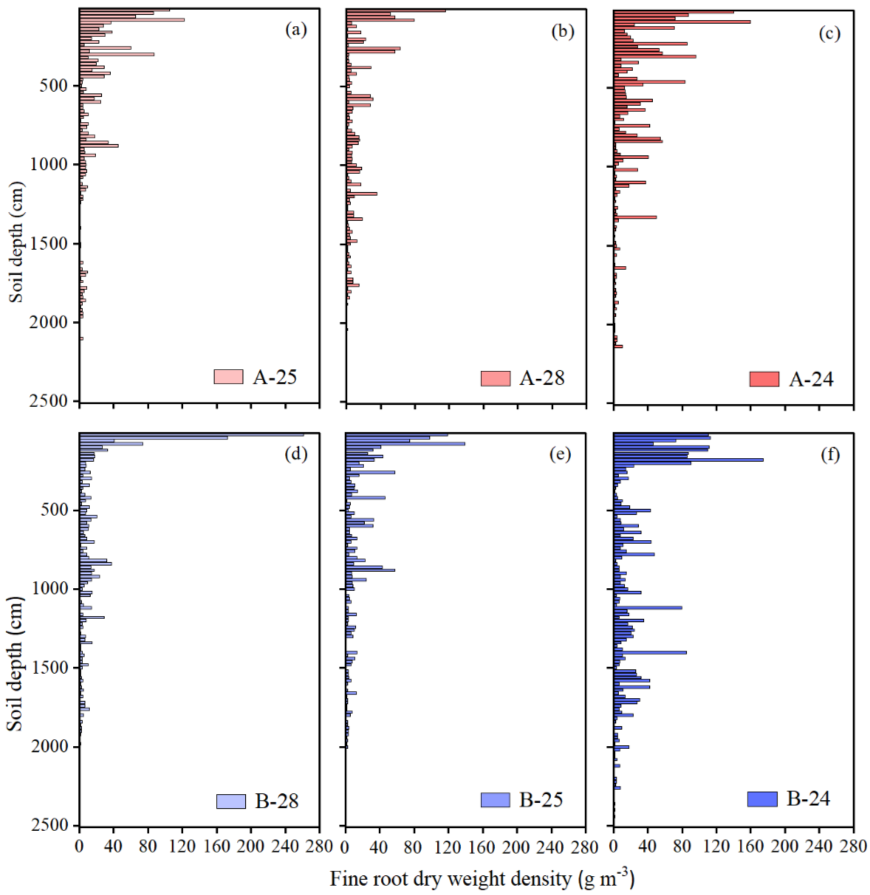

Figure S5: Dynamic distribution of fine root dry weight density after reaching the moisture limitation of deep soil desiccation. All data are field measurements obtained simultaneously with soil moisture in Figure 5. The capital letters A and B in the legend represent *M. pumila* and black locust (*R. pseudoacacia*), respectively, and the numbers after the letters represent tree age, for example, A-25 represents 25-year-old *M. pumila*. (a) and (d) indicate Changwu; (b) and (e) indicate Luochuan and Yan'an, respectively; (c) and (f) indicate Mizhi."

Also, the revised manuscript still includes instances, where the discussion or conclusions are not supported by the presented data. Those are partly in the revised text and partly have not been found yet. There are still instances that strongly suggest that a maximum root water uptake depth has been reached, and this is not in line with the methods. I give a non-conclusive list below.

Line numbers refer to the tracked-changed version of the manuscript

Lines 405-407: „the root water uptake in other regions reached their maximum depth during the sampling period“

As mentioned previously, this sentence suggests that a temporal maximum root water uptake depth has been reached. The addition „during the sampling period“ does not cure the problem, but worsens it.

Response: Because this sentence repeats the words in the second sentence in this paragraph (Lines 398-400 in the track-changed version), we have deleted this sentence in the latest version. Furthermore, we have revised other misleading statements in the manuscript as follows.

Line numbers refer to the track-changed version of the manuscript.

Lines 25-27:

“The corresponding depth of soil moisture use reached 18.0-22.0 m for these old planted trees at different sites while it was more than 25 m for black locust in the drier site of Mizhi.”

Lines 73-75:

“The effect of deep-layer soil desiccation on xylem hydraulic conductivity of planted trees, however, is still unclear, particularly in relation to the two dimensions.”

Lines 247-249:

“If the difference of soil moisture content in the plantation and its’ control becomes not statistically significant (p>0.05) at a given layer, it is defined that this depth corresponds to the maximum RWU depth for the planted trees sampled in this study."

Lines 315-317:

"treating the points with no significant (p>0.05) soil moisture difference as the maximum RWU depth for the planted trees sampled in this study. The maximum RWU depth reached 18.0-22.0 m for *M. pumila* orchard at different sites"

Lines 363-364:

"Although DSM (>200 cm) decreased with an increase of planted trees age, and even reached the lowest limitation, shallow soil moisture (<200 cm) did not change significantly (Figs. 2 and 4)."

Lines 367-369:

"DSM of various sites was depleted to the lowest limitation, seriously threatening the sustainability of tree growth under future climate conditions."

Lines 398-400:

"Our results indicated that for the sampled trees, the maximum RWU depth reached 18.0-22.0 m for *M. pumila* orchards across different sites, and 18.4-18.8 m for *R. pseudoacacia* forests in Changwu and Yan'an, while in Mizhi it was more than 25 m (Fig. 5)."

Line 408-411: This assertion is not supported by the presented results. The root-to-shoot ratios have not been presented and have not been discussed. Therefore, they cannot be used here to support the observed differences in root water uptake depth.

Response: Thank you very much for your suggestion. We have removed this section of the description.

Line 419-420 & 457-459: The new addition „in the plantations …“ is confusing and potentially misleading in the direction that some maximum has been observed. You could replace with „in the plantations sampled in this study.“

Response: Thank you very much for your constructive comments. We have revised the statement as follows.

Line numbers refer to the track-changed version of the manuscript.

Lines 27-29:

"Furthermore, the mean values of native percentage loss of hydraulic conductivity of planted trees' branches xylem reached 74.9-96.5% in the plantations sampled in this study."

Lines 438-439:

"The result showed that branch xylem of similar aged trees suffered embolism to different degrees in the plantations sampled in this study."

Lines 482-484:

"Furthermore, the trees suffered serious embolism of which the degrees were dependent on tree species and sites of the plantations sampled in this study."

Lines 495-497:

"Furthermore, the native percentage loss of hydraulic conductivity of planted trees' branches was between 74.9% and 96.5% in the plantations sampled in this study."

Minor comments

Lines 400-402 of the tracked changed version: Ahmed et al., 2014 is not a very good reference for this. If you refer to the length of the flow path, you can for example check Zweniecki et al., 2003, and follow-up work.

Zwieniecki, M. A., Thompson, M. V., & Holbrook, N. M. (2003). Understanding the Hydraulics of Porous Pipes: Tradeoffs Between Water Uptake and Root Length Utilization. Journal of Plant Growth Regulation, 21(4), 315–323. https://doi.org/10.1007/s00344-003-0008-9

Response: The hydraulic path of water transport described here not only refers to the root zone, but also to the distance from the root system to the canopy, which is more affected by tree height. Mencuccini (2003) mentioned that the higher tree, the greater resistance to transfer upward water due to it must cross the longer path and increased number of internodes and conduit connections. Thus, we have added the two references as follows.

Lines 407-411:

"Due to the longer flow path, the greater the hydraulic resistance for upward water transfer (Mencuccini, 2003; Zweniecki et al., 2003), thus *R. pseudoacacia* trees examined in Changwu and Yan'an were taller, making it relatively difficult to absorb water from deeper soil layer.

References:

Mencuccini M.: The ecological significance of long-distance water transport: short-term regulation, long-term acclimation and the hydraulic costs of stature across plant life forms. Plant Cell Environ., 26,163–182, https://doi.org/10.1046/j.1365-3040.2003.00991.x, 2003.

Zwieniecki, M. A., Thompson, M. V., & Holbrook, N. M.: Understanding the Hydraulics of Porous Pipes: Tradeoffs Between Water Uptake and Root Length Utilization. J. Plant Growth Regul., 21(4), 315–323, https://doi.org/10.1007/s00344-003-0008-9, 2003."

Lines 449-453: „Our …" I believe this sentence misses a verb, please check.

Response: We have revised the expression of this sentence as follows.

Lines 473-475:

"Our study showed that, except for *R. pseudoacacia* plantation in Mizhi, 24-28-year-old *M. pumila* and *R. pseudoacacia* plantations across different sites both reached the soil moisture limitation and the maximum RWU depth."

Please note that although the revision is tagged as „minor" by the HESS system, this is an automatic tag for all manuscripts not submitted for further review. I request that you have a thorough look at how you discuss the results, and invite you to revise substantially the discussion section. Especially after the changes implemented in the previous revisions, the latter does not have much substance and is not up to standard for publication and it also does not do justice to the interesting results. One option could be to refer to existing modeling work on how root water uptake depth is expected to depend on aridity in natural ecosystems. You also have interesting data on root density that are barely presented or discussed.

I am looking forward to the revised version of your manuscript,

Anke Hildebrandt

Response: Based on your constructive comments, we have carefully revised the Discussion sections. The following are the two key modifications, one regarding the maximum root water uptake depth of plantations (Lines 397-429 in the track-changed version), and the other regarding the second hypothesis (Lines 438-464 in the track-changed version). Other modification details were presented in the tracked-changed version of the manuscript. We hope that the revisions in the manuscript will be sufficient to make our manuscript suitable for publication in *Hydrology and Earth System Sciences*.

Lines 397-429:

"After soil water in the profile becomes limited, plants extend their roots into the deep soil to expand their water-hunting range during the dry season (Fig. 8; Ivanov et al., 2012). Our results indicated that for the sampled trees, the maximum RWU depth reached 18.0-22.0 m for *M. pumila* orchards across different sites, and 18.4-18.8 m for *R. pseudoacacia* forests in Changwu and Yan'an, while in Mizhi it was more than 25 m (Fig. 5). These depth ranges are similar to the maximum RWU depth of the artificial *Caragana microphylla* forest discovered by Wang et al. (2009). Divergence in the maximum RWU depth of the same tree species examined at different sites mainly due to tree adopting different biomass allocation strategies to adapt to varying drought aridity (Mayoral et al., 2016; Valverdi et al., 2019; Zhao et al., 2022). This was mainly manifested as the fine root dry weight density distributed at greater soil depth for *R. pseudoacacia* plantation examined in Mizhi than that in Changwu and Yan'an (Fig. S5), while the plant height of *R. pseudoacacia* trees in Mizhi was lower than that in Changwu and Yan'an (Table 2). Due to the longer flow path, the greater hydraulic resistance for upward water transfer (Mencuccini, 2003; Zweniecki et al., 2003), thus *R. pseudoacacia* trees examined in Changwu and Yan'an were taller, making it relatively difficult to absorb water from deeper soil layer. In contrast, due to substantial human intervention such as canopy pruning, the maximum RWU depth of *M. pumila* plantations across different sites both were between 18.0-22.0 m. This differences between tree species were consistent with the hypothesis. In addition to human management factors, the inconsistency in the maximum RWU depth examined for *M. pumila* and *R. pseudoacacia* in Mizhi is in that, the early-stage water consumption of the latter is higher (Wu et al., 2021), leading to lower deep soil moisture (>2 m) across different sites than *M. pumila* plantations (Fig. S3). Furthermore, the larger VPD and the coarser soil texture (Fig. 8), helps *R. pseudoacacia* trees to absorb water by growing deeper roots (>25 m) in this site. Although the maximum RWU depth of *R. pseudoacacia* trees in Mizhi exceeded the measurement depth, the findings from both field observation (Li et al., 2019) and model simulation (Li et al., 2022) indicate that plantations face challenges in extracting substantial amounts of water from deep soil due to deep-layer soil desiccation. Instead, they primarily rely on shallow soil water replenished by rainfall. Thus, the low precipitation exacerbates the drought stress for plantations in semi-arid region, considering the projected increase in both the intensity and duration of future drought events (Miller et al., 2023)."

Lines 438-464:

“The result showed that branch xylem of similar aged trees suffered embolism to different degrees in the plantations sampled in this study (Fig. 7). This was consistent with the hypothesis that the xylem hydraulic conductivity of the planted trees varies among tree species and sites. The variations across different sites are mainly attributed to the degree of deep soil desiccation and the disparities in shallow soil moisture influenced by precipitation. Dried soil seriously restricts the process of RWU, and water absorption of trees is difficult to meet the needs of transpiration, resulting in the leaf stomata close to prevent excessive reduction of water potential (Yang et al., 2022). Subsequently, the water column in the xylem vessels is interrupted as the continuous decrease in soil moisture availability (McDowell et al., 2018), and thus *NPLC* increases during prolonged dry periods (McDowell et al., 2018). Even though DSM of all sites was depleted to close to the local *PWP*, *NPLC* varied greatly between different climate zones (Fig. 7), mainly due to the difference of precipitation as well as about time and amount for restoring shallow soil moisture. This suggests that the decrease in xylem hydraulic conductivity caused by the deep-layer soil desiccation may be repaired after entering the rainy season for the studied plantations in Changwu and Yan’an. The *NPLC* of *R. pseudoacacia* trees in Mizhi, however, was significantly (p<0.05, Fig. 7(b)) higher than that of other regions. This precisely confirmed that even if the water absorption range was deeper, it couldn’t buffer the negative effects of limited precipitation and extremely dry soil moisture profile on water transport in tree bodies. Thus, the embolism in the conduit accumulated continuously as the water pool became exhaustible causing the severe and large-scale canopy die-back (Fig. S4; Arend et al., 2021). It should be note that the *NPLC* value of *R. pseudoacacia* plantation may be higher due to the sample length (3-5 cm) in the XYL’EM measurement is shorter than the maximum vessel length, but the result is consistent with trees with most, or all, of their foliage dead exhibited high rates of native embolism (78–100%) (Nolan et al., 2021). However, although the *NPLC* of *M. pumila* trees in Mizhi was also high (Fig. 7(a)), there was no significant degradation in the plantation, and this interspecific difference may be mainly caused by differences in tree height (Table 2) and the capacitance within their tissues and water loss (McDowell et al., 2022). The results indicate that mature (>24 year) *R. pseudoacacia* plantations on the LOP are already facing a great risk of dieback and even death in semi-arid regions similar to Mizhi.”