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: Major revision

Comments from handling editor:

Dear Xiaodong Gao, dear Nana He, dear co-authors,

two reviewers have given feedback to your manuscript and both find that the presented topic is of substantial interest to the hydrological community. I agree with them, and would like to add that I am very impressed with the collected dataset. Both reviewers also have concerns and you have already responded to most of them in your final response in the discussion.

In fact, we used the withering humidity corresponding to different artificial forests here and hope to use Equation 11 to calculate the minimum soil water deficit of artificial forests.

In some instances I want to encourage you to have one more look at how you plan to implement the comments into the revision:

(1) Reviewer 2 comments that the connection between PWP and DSM is not easy to grasp, and I agree. Indeed, I am not able to follow your argumentation completely. I understand that you have high confidence in the PTFs for obtaining the local PWP, and I understand that you use PWP as a threshold to characterise severe plant water stress. I agree with this reasoning. I however do not understand how all this information is included in Eq. 11, where only one PWP value is mentioned. I am assuming it is the PWP of the control plot? In my reading therefore SMD_{PWP,k} shows how much plant available water is left in the control plot. It does not give as such information on the plantation. Can you please add the missing information to show how from this the soil water limitation in the plantation is found? Consider adding a sketch to illustrate and/or another equation.

Response: Thanks for your suggestion. As we argued in responses to the two reviewers, a relative soil moisture index, deep soil moisture deficit (DSMD) which is defined as the relative difference of deep soil moisture (DSM) under given trees and nearby grassland or cropland, is used for analysis in order to eliminate the effect of varying annual precipitation on DSM. And the Eq. 10 is used to calculate soil moisture deficit (SMD) under different tree plantations. In order to judge whether PWP is the degree limitation (changing to moisture limitation in the revised paper) for root water uptake in deep soil, PWP is also needed to be transferred to the form of relative soil moisture, i.e., soil moisture deficit corresponding to PWP (SMD_PWP). For a given tree plantation, SMD_PWP is calculated by subtracting soil moisture under the control plot from PWP under the tree plantation, as indicated in Eq. 11 which has been modified in the revised manuscript for clarity.

"$$SMD\_PWP_{j,k} = \frac{PWP_{j,k} - SMC_{0,k}}{SMC_{0,k}} \quad (11)$$

where $PWP_{j,k}$ and $SMC_{0,k}$ represent permanent wilting point in the *k*th layer of the *j*th plantations and soil moisture content in the *k*th layer of the control (cropland or grassland), respectively."

It should note that the data of soil moisture deficit in the 0-200 cm is meaningless according to the definition of deep soil moisture deficit. In this paper, we just focus on deep-layer soil moisture below 200 cm. Therefore, only data below 200 cm are shown in the Figures 3 and 4 in the revised manuscript.

(2) In the response to Reviewer 2's comment to Figure 2 you refer to the equation for RR, which is good. In the text explaining the variables you refer to tree age, but tree age does not appear in the equation. RR only shows whether it is moister/drier in plantation vs. control, correct? Can you remove the reference to tree age, to avoid confusion with the reader? Also, I am assuming that the soil moisture refers to the 2 m depth increments, mentioned in section 2.1.2? Can you please repeat here for clarity?

Also in the same section, I do not properly understand Lines 206-207. Can you revise them for clarity? Specifically, what is meant by the “significance of differences between soil moisture and RR”?

Response: The equation for response ratio (*RR*) shows the water relationship between plantations and their controls. First, we calculated the *RR*s corresponding to all ages of the two species plantations. Next, in order to determine the approximate age range of plantation trees for our subsequent sampling, and identify the ages at which dual limitations reached, we classified the *RR*s according to trees’ age. To avoid confusion, we have changed the description of tree age. During the calculation of *RR* effect size, we chose a soil depth interval of 200 cm as described in Section 2.1.2. In addition, 95% confidence interval (CI) was calculated for the overall data and for each tree species, the *RR* of soil moisture were considered statistically different from zero if the 95% CI did not include zero, and the differences were not considered significant if the 95% CI include zero. For clarity, we have supplemented this information as follows in Section 2.3.1. (Lines 221-226)

“where response ratio (*RR*) is a unit-free index with positive and negative values indicating either increasing or decreasing soil moisture in response to planted trees’ growth. X_e and X_c are values of soil moisture under trees and controls for each study, respectively. The soil depth interval analyzed was 200 cm as mentioned in section 2.1.2. We use a 95% confidence interval (CI) to test the statistical difference between the *RR* of soil moisture and zero (Deng et al., 2016), the method of calculating 95% CI showed as Eqs. (8) and (9).”

I have some more comments from my own reading of the manuscript:

(3) Similar to (1) for the root depth limitation: I do not fully understand the reasoning in section 2.3.3 explaining how depth limitation is obtained? The section says “analyze the significance of soil moisture between plantations and their controls”. Can you please add what measurement locations are compared, and what size is the statistical sample? Is it a statistical test comparing three soil water content samples per depth in the

planation with three samples in the same depth in the control? Also, next you state that you consider depth limitation, e.g. maximum rooting depth, is reached at the depth where the difference in soil water content between control and plantation is zero. I agree that this may be interpreted as the maximum root water uptake depth. But if this depth cannot be detected, this means it is located deeper than the deepest measurements? If this is correct, it would be good to state this explicitly in this section.

Response: Thank you for your comments. We compared the soil moisture content (SMC) of plantation and its' control (cropland or grassland) in each site, the straight-line distance between plantation and its' control is less than 500 m as described in Section 2.2.2. Three trees with the same age and similar growth status were selected as replicates in each plantation. Similarly, three control plots were selected as replicates. Therefore, as you mentioned, three SMC samples per depth in both tree plantation plot and control plot were used for statistical test. Due to the significant spatial variability of SMC and the multiple influencing factors, the difference of SMC in the plantation and its' control is hard to reach zero even without deep root absorption. In this study, we used the paired sample *t*-tests to judge whether the maximum root water uptake depth has been reached. It is considered that the depth limitation has been reached when the difference of SMC in the plantation and its' control is not statistically significant ($p>0.05$). However, if the difference is always significant ($p<0.05$), it indicates that the maximum root water uptake depth has not been reached. For clarity, we have revised the Section 2.3.3. (Lines 250-255)

"The paired sample *t*-test in SPSS was used to analyze the significant difference of soil moisture between plantations and their controls. Three duplicate values were taken for each plantation and its control per site, and the straight-line distance between them was less than 500 m. If the difference of soil moisture content in the plantation and its' control becomes not statistically significant ($p>0.05$) with the soil layer deepening, the consumption of DSM by plantations will be considered to have reached the depth limitation. Conversely, it indicates that the maximum root water uptake depth has not been reached when the difference is always significant ($p<0.05$)."

(4) In Table 1 you give an overview of the soil profile information found in the literature. You mentioned you found 380 profiles, but Table 1 lists 129 pairs (=258 profiles) from the literature? Can you reconcile this?

Response: We agreed. We have modified the number of soil profiles to 258 in the text. (Line 106)

(5) The manuscript focusses on two types of limitation for plant transpiration, one of them related to reaching the maximum rooting depth, the other on reaching the permanent wilting point at a given depth. The first one was called intuitively "depth limitation", while the second one is much less intuitively named "degree limitation". Can you think of a more intuitive term? Maybe "soil limitation"?

Response: Thanks for your suggestion. The "degree limitation" here refers to the limitation of moisture in soil profile for plant transpiration. Therefore, we think "moisture limitation" may be a more suitable term to intuitively reflect the phenomenon that the soil moisture in the plantations reaches the permanent wilting point at a given depth. We have changed all statements about "degree limitation" to "moisture limitation" in the entire revised manuscript.

The revised version of the manuscript will once more be sent to peer review. Could you please submit a point by point response and a revised version with changes highlighted to support this next step?

Kind regards,

Anke Hildebrandt

Response: Thank you very much for your time and constructive comments on our paper. We have read through your and referees' comments carefully and responded to all comments point by point as above and follows. Concurrently, the relevant parts of the manuscript have also been modified and/or corrected in a revised version. We hope that the revisions in the manuscript and our accompanying responses will be sufficient to

make our manuscript suitable for publication in *Hydrology and Earth System Sciences*.

Comments of Anonymous Referee #1:

The paper by He et al. aimed to disentangle the degree and depth limitation of deep soil desiccation and its impact on tree's xylem hydraulic conductivity based on the published and sampled data from China's Loess Plateau. They argued that the degree limitation approached the permanent wilting point (PWP) and hence the PWP can be used to indicate the lower limit of root water uptake by different tree species. The depth limitation was also identified and varied between tree species and regions. Furthermore, they also reported that the loss of hydraulic conductivity was as high as 74.9-96.5% when both limitations were reached.

Overall, this paper is well motivated and mostly well structured and written. According to my knowledge, the research topic is less studies in the existing literature. The first conclusion seems not surprising that PWP is a good indicator of the degree limitation of deep-layer soil moisture (DSM) for the tree species examined because it is often used in this way. But I think this conclusion is interesting since PWP is usually determined using annual crops and more important, in that the deep-layer soil moisture reached the degree limitation while the shallow-layer soil moisture did not. Although this study has scientific merit and can be a scientific contribution potentially, I still have two major concerns about the method and discussion. (1) My first concern is about the definition of deep soil moisture deficit (DSMD). In this definition, they mentioned background soil moisture. The authors should clarify what does background soil moisture mean here, and why the DSM in adjacent control can reflect local annual precipitation. Moreover, in my opinion, the definition of DSMD should be moved to the method part. (2) The other concern is the discussion of the effect of limitation on xylem hydraulic conductivity. The discussion in this part seems not thorough and should be rewritten to improve the relevance.

Response: Thanks for your time and constructive comments on our paper.

About your first concern, below is our explanation. The deep-layer soil moisture (DSM) under planted trees with the same age can vary greatly in different sampling years if these years have very different annual precipitation. In order to eliminate the effect of varying annual precipitation on DSM, “deep soil moisture deficit (DSMD)” is defined as the relative difference of DSM under given trees and nearby grassland or cropland. In grassland/cropland, the rooting depth of plants is relatively shallow (<2 m) and hence does not influence DSM below 2 m (Gao et al., 2014; Zhu et al., 2016; Gao et al., 2022). Therefore, the magnitude of DSM in grassland/cropland is mainly determined by annual precipitation. In this way, it can be used to reflect local annual precipitation; i.e., the greater DSM in grassland/cropland, the bigger annual precipitation. Finally, the DSM in grassland/cropland is termed as background soil moisture here because it is not influenced by plants and can reflect local annual precipitation. In addition, the definition of DSMD have been moved to the method part in the revised manuscript. (Lines 233-239)

“The effect of different deep-rooted planted trees RWU on soil moisture was expressed as soil moisture deficit (SMD), which is the relative difference in soil moisture for given trees and adjacent cropland/grassland. Due to root distribution of the latter is too shallow (<2 m) to influence the change of DSM (Gao et al., 2014; Zhu et al., 2016; Gao et al., 2022), thus, the soil moisture of grassland/farmland measured simultaneously with that of plantation can be used as background value to eliminate the influence of climate difference, and its’ calculation method as shown in Eq. (10). Among them, the SMD of the soil layer below 2 m is the deep soil moisture deficit (DSMD).”

References:

Gao, X., Wu, P., Zhao, X., Wang, J., Shi, Y.: Effects of land use on soil moisture variations in a semi-arid catchment: Implications for land and agricultural water management, Land Degrad. Develop., 25, 163-172, 10.1002/ldr.1156, 2014.

Zhu, G., Deng, L., Zhang, X., Shangguan, Z.: Effects of grazing exclusion on plant

community and soil physicochemical properties in a desert steppe on the Loess Plateau, China, Ecol. Eng., 90, 372-381, 10.1016/j.ecoleng.2016.02.001, 2016.

Gao, X., He, N., Jia, R., Hu, P., Zhao, X.: Redesign of dryland apple orchards by intercropping the bioenergy crop canola (*Brassica napus* L.): Achieving sustainable intensification, Glob. Change Biol. Bioenergy, 14, 378-392, https://doi.org/10.1111/gcbb.12916, 2022.

(2) Thanks for your comments. We have revised the part about the effect of limitations on xylem hydraulic conductivity as follows in the text. (Lines 423-438)

“The result showed that branches xylem of similar aged trees suffered embolism to different degrees when the moisture and depth limitations of DSD reached (Fig. 7). This is consistent with the hypothesis that the hydraulic conductivity of planted trees can be greatly reduced by severe DSD. The reason for this result is that dried soil seriously restricts the process of root water uptake, and water absorption of trees is difficult to meet the needs of aboveground metabolism, resulting in the interruption of the water column in the xylem vessels during prolonged dry periods, and thus *PLC* increases (McDowell et al., 2018; Yang et al., 2022). Subsequently, the leaf stomata close to prevent hydraulic failure as DSM approaches PWP. How long can the planted trees survive after this depends solely on the water pools of themselves and their tissues’ tolerance for drought stress (McDowell et al., 2022). Nevertheless, even though DSM of all regions both have been close to the local PWP, *PLC* varied greatly between different climate zones (Fig. 7), mainly caused by the difference of precipitation about time and amount for restoring shallow soil moisture. This suggests that the decrease in xylem hydraulic conductivity caused by the limitation of DSM may be repaired after entering the rainy season for the studied species plantations in Changwu and Yan’an. The *PLC* of black locust plantation in Mizhi, however, was significantly (p<0.05) higher than that of other regions, and restoration of embolism was more difficult due to limited rainfall supply. Thus, the embolism in the conduit accumulated continuously as the water pool became exhaustible causing the top tip of the distal water supply began

to die due to hydraulic failure of tissues (Fig. S4; Arend et al., 2021). This indicates that mature (>24 year) plantations on the LOP are already facing a great risk of dieback and even death in semi-arid regions similar to Mizhi."

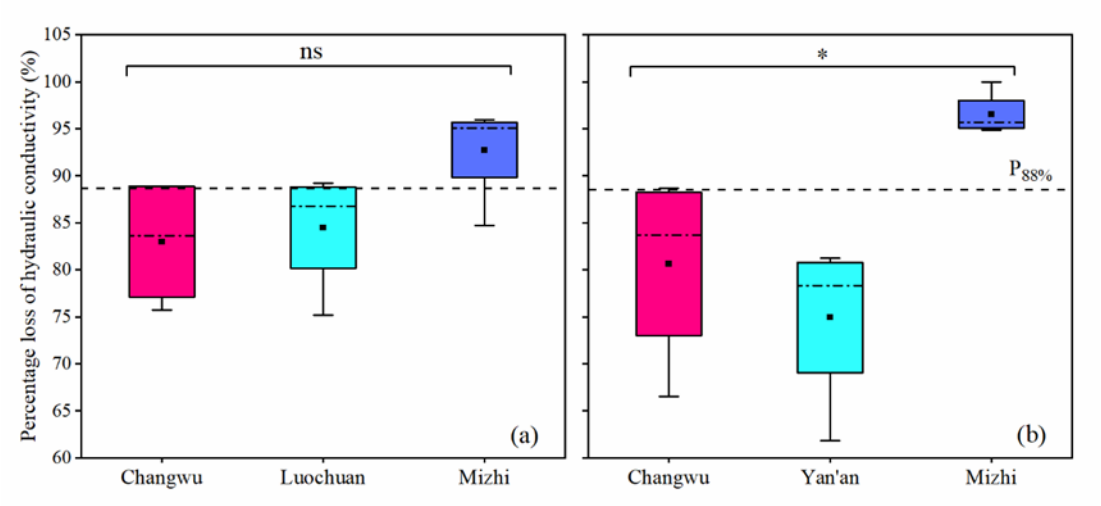

Figure 7: Differences in percentage loss of hydraulic conductivity of annual branches of apple (a) and black locust (b) in different regions (Changwu, Luochuan, Yan'an, and Mizhi). * and ns indicate that the significance level is $p<0.05$ and there is no significant difference, respectively.

Figure S4. Dieback of black locust (*Robinia pseudoacacia* L.) plantation in Mizhi.

References:

Arend, M., Link, R.M., Patthey, R., Hoch, G., Schuldt, B., and Kahmen, A.: Rapid hydraulic collapse as cause of drought-induced mortality in conifers, PNAS, 118(16), 10.1073/pnas.2025251118, 2021.

McDowell, N., Allen, C.D., Anderson-Teixeira, K., Brando, P., Brienen, R., Chambers, J., Christoffersen, B., Davies, S., Doughty, C., Duque, A., Espirito-Santo, F., Fisher,

R., Fontes, C.G., Galbraith, D., and Goodsman, D.: Drivers and mechanisms of tree mortality in moist tropical forests, New Phytol., 219 (3), 851-869, 10.1111/nph.15027, 2018.

McDowell, N.G., Sapes, G., Pivovaroff, A., Adams, H.D., Allen, C.D., Anderegg, W.R.L., Arend, M., Breshears, D.D., Brodribb, T., Choat, B., Cochard, H., et al.: Mechanisms of woody-plant mortality under rising drought, CO_2 and vapour pressure deficit, Nat. Rev. Earth Env., 3(5), 294-308, 10.1038/s43017-022-00272-1, 2022.

Yang, M., Gao, X., Wang, S., and Zhao, X.: Quantifying the importance of deep root water uptake for apple trees' hydrological and physiological performance in drylands, J. Hydrol., 606 (11), 127471, 10.1016/j.jhydrol.2022.127471, 2022.

The specific comments are given as follows.

Abstract

Line 20: Why use DSMD for analysis here?

Response: The deep-layer soil moisture (DSM) under planted trees with the same age can vary greatly in different sampling years if these years have very different annual precipitation. In order to eliminate the effect of varying annual precipitation on DSM, "deep soil moisture deficit (DSMD)" was defined as the relative difference of DSM under given trees and nearby grassland or cropland. In grassland/cropland, the rooting depth of plants is relatively shallow (<2 m) and hence does not influence DSM below 2 m (Gao et al., 2014; Zhu et al., 2016; Gao et al., 2022). Therefore, the magnitude of DSM in grassland/cropland is mainly determined by annual precipitation.

References:

Gao, X., Wu, P., Zhao, X., Wang, J., Shi, Y.: Effects of land use on soil moisture variations in a semi-arid catchment: Implications for land and agricultural water management, Land Degrad. Develop., 25, 163-172, 10.1002/ldr.1156, 2014.

Zhu, G., Deng, L., Zhang, X., Shangguan, Z.: Effects of grazing exclusion on plant community and soil physicochemical properties in a desert steppe on the Loess

Plateau, China, Ecol. Eng., 90, 372-381, 10.1016/j.ecoleng.2016.02.001, 2016.

Gao, X., He, N., Jia, R., Hu, P., Zhao, X.: Redesign of dryland apple orchards by intercropping the bioenergy crop canola (*Brassica napus* L.): Achieving sustainable intensification, Glob. Change Biol. Bioenergy, 14, 378-392, https://doi.org/10.1111/gcbb.12916, 2022.

Line 30: Do you have observational evidence of tree mortality in the study site?

Response: Yes, we observed withered trees during sampling. The photos depicting tree dieback in the study site have been given as Figure S4 above, which has been added to the supplemental file of the revised manuscript.

Introduction

Line 35: The range of loess thickness is often used as 30-200 m in the literature.

Response: It has been corrected as “30-200 m” in the text (Line 34).

Line 38: The citation in many parts is not mostly relevant. For instance, the citation of Gao et al., 2021 did not study the three-north shelter forest program.

Response: Thanks for your suggestion. The citation has been changed to “Cao et al., 2021” in the text. (Line 37)

Reference:

Cao, S., Xia, C., Suo, X., Wei Z.: A framework for calculating the net benefits of ecological restoration programs in China, Ecosyst. Serv., 50, 101325, 10.1016/j.ecoser.2021.101325, 2021.

Line 66: Several earlier studies have reported the dwarf aged trees. There studies should be cited here.

Response: Thanks for your comment. Zhu (2000) and Hou et al. (1991) also mentioned the dwarf aged trees, so we have cited the two references in the revised manuscript. (Line 65)

References:

Hou, Q., Huang X., Han, S., Zhang, X.: The status of soil moistures and nutrients in small-old-tree stands and impact on tree growth (In Chinese), 5(2), 75-83, Journal of Soil Water Conservation, 10.13870/j.cnki.stbcxb.1991.02.012, 1991.

Zhu, X.: Rescue the “soil reservoir” to control the ecological environment of the Loess Plateau (In Chinese), Bulletin of Chinese Academy of Sciences, 2000(04), 293-295, 10.16418/j.issn.1000-3045.2000.04.019, 2000.

Lines 70-71: This sentence is not clear and should be rewritten for clarity.

Response: This sentence has been revised as follows in the text. (Lines 69-71)

“They found that the canopy transpiration and the net photosynthetic rate of apple trees without deep-layer root water uptake was reduced, respectively, by 36% and 20% on average, compared with the trees with deep roots in a semiarid site on the LOP.”

Line 78: change disentangle to explore

Response: It has been done. (Line 80)

Line 81: Does any literature support this statement about the difference of drought-resistance capacity between tree species?

Response: Yes. Gessler et al. (2020) reported individuals have different abilities to persist and maintain their functions during drought to support this statement. Thus, it has been cited in here. (Line 83)

Reference:

Gessler, A., Bottero, A., Marshall, J., Arend M.: The way back: recovery of trees from drought and its implication for acclimation, New Phytol., 228(6), 1704-1709, 10.1111/nph.16703, 2020.

Materials and methods.

Line 86: Why does the literature begin in 1999?

Response: This is because the ecological project of the Grain-For-Green Program started in 1999. Thereafter, trees were planted extensively and intensively on the Loess Plateau.

Line 99: Why were only apple tree and black locust used for analysis?

Response: In the Grain-For-Green Program, trees of both ecological and economic objectives were planted extensively. The black locust is the most planted trees for ecological objective, while apple tree is the most planted trees for economic objective (Gao et al., 2021). Furthermore, these two tree species are the most studies and reported in the literature. Therefore, the two tree species are used for analyses because of they are mostly representative in the literature.

Reference:

Gao, X., Zhao, X., Wu, P., Yang, M., Ye, M., Tian, L., Zou Y., Wu Y., Zhang F., and Siddique K. H. M.: The economic-environmental trade-off of growing apple trees in the drylands of China: A conceptual framework for sustainable intensification, J. Clean. Prod., 296 (3), 126497, 10.1016/j.jclepro.2021.126497, 2021.

Line 130: Please give the full name.

Response: The full name of GPS is Global Positioning System, which has been added in the text. (Line 136)

Line 136: How do you judge whether the DSM reaches the degree limitation during sampling?

Response: In the soil sampling, soil moisture in the 0-10 m was measured gravimetrically under the selected tree age plantation as well as its' control cropland/grassland. Then, the relative soil moisture (i.e., soil moisture deficit (SMD)) was calculated to determine whether the DSM reached the degree limitation (changing to moisture limitation in the revised paper). If yes, soil moisture was continuously

measured in the 10-25 m.

Line 142: Soil moisture can be varied clearly at different directions around a tree. How do you address this issue?

Response: In the sampling, we chose three trees with same age and similar growth status as three replicates to diminish the difference in soil moisture. For reducing the effect of directions on soil moisture, the samples were collected at different direction for the three replicated trees. Here are the details. We collected soil samples in the due north direction of the first tree, a clockwise rotation of 120° around the second tree from the due north direction was used as the second sampling point, and a clockwise rotation of 240° around the third tree from the due north direction was used as the third sampling point, all replicates were located 1.5 m away from the trunk. And then the soil moisture of the three trees were averaged for analyzing. The accordingly text has been added as follows for clarity in the revised manuscript. (Lines 149-151)

"Collecting soil samples in the due north direction of the first tree, a clockwise rotation of 120° around the second tree from the due north direction was used as the second sampling point, and a clockwise rotation of 240° around the third tree from the due north direction was used as the third sampling point."

Table 3: Table 3 should be explained in more details. How do you classify soil texture fractions, i.e., the content of clay, silt and sand? What is the sampling depth? Are they mean values for different layers?

Response: According to the international standard for soil particle classification, we divided the soil particles into clay (<0.002 mm, %), silt (0.002~0.02 mm, %) and sand (0.02~2 mm, %). Sampling depth of soil particles was 10 m for each point, and Table 3 presents the average particle content value of all soil layers. These details have been added in the Note of Table 3. (Lines 202-206)

Table 3. Basic soil properties of field sampling sites.

Sites	Plant species	Soil type	Clay	Silt	Sand	Soil organic	Bulk density	pH

						metter (g kg^{-1})	($g\ cm^{-3}$)	
Mizhi	Apple	Cultivated loessial soils	15.5	24.3	60.2	2.94	1.28	7.64
	Cropland	Cultivated loessial soils	14.9	25.1	60.0	2.33	1.29	8.44
	Black locust	Cultivated loessial soils	13.6	25.0	61.4	3.09	1.28	8.03
	Grassland	Cultivated loessial soils	13.8	25.4	60.8	2.35	1.29	8.36
Luochuan	Apple	Dark loessial soils	21.5	37.1	41.4	4.62	1.31	7.54
	Cropland	Dark loessial soils	22.2	38.5	39.3	4.38	1.33	8.17
Yan'an	Black locust	Cultivated loessial soils	18.1	33.1	48.8	4.87	1.29	8.07
	Grassland	Cultivated loessial soils	19.6	31.5	48.9	4.43	1.30	8.53
Changwu	Apple	Dark loessial soils	24.6	38.7	36.7	4.76	1.31	7.35
	Cropland	Dark loessial soils	25.8	38.7	35.5	4.35	1.32	8.21
	Black locust	Dark loessial soils	22.9	38.2	38.9	5.01	1.29	7.96
	Grassland	Dark loessial soils	22.7	38.4	38.9	4.26	1.31	8.23

Note: Sampling depth of basic soil properties, including soil particles (which was divided into clay (<0.002 mm, %), silt (0.002~0.02 mm, %) and sand (0.02~2 mm, %) according to the international soil particle classification standard), soil organic metter, and pH was 10 m for different vegetation types, and the average values of these parameters on different soil layers are presented here. The soil bulk density presents the average value of 1 m soil profile.

Line 215: The index here can not represent degree limitation of soil desiccation, but just a relative soil water content.

Response: The relative moisture content (i.e., soil moisture deficit) here was used to characterize the moisture limitation of soil desiccation. Therefore, we have changed the title to "Quantitative index for moisture limitation of soil desiccation" in the text. (Line 232)

Line 231: The manufacture of the Canoco 5 should be added in the text.

Response: The manufacture of Canoco 5 is Microcomputer Power Ithaca, New York, USA, which has been added in the text. (Line 260)

Results

Line 235: The analysis in 3.1 seems not closely connected with the following analyses in 3.2 and 3.3.

Response: The analysis in 3.1 indicated that the tree age at which the plantation had a biggest effect on DSM appears to be between 20 and 30 years. The analyses in Sections 3.2 and 3.3 were based on this finding. This information has been emphasized in the

revised manuscript. (Lines 270-272)

“And then, plantations between this age range were regarded as the main subjects when analyzed the moisture and depth limitations of DSD for planted trees in Sections 3.2 and 3.3.”

Line 240: Please change extreme to the biggest.

Response: It has been changed in the text. (Line 270)

Line 260: Are these data used in the section 3.2.1 from published literature or your field sampling or the combination? Please clarify.

Response: Data in Figure 4(a) and (b) were extracted from literature, while data in Figure 4(c)-(f) belonged to the measured data. We have emphasized the data source before the analysis of the results as follows in the revised manuscript. (Line 297)

“Combined with literature extraction (Fig. 4a and b) and measured (Fig. 4c-f) data to reveal the moisture limitation of the DSD.”

Line 265: This sentence is not clear. Please rewrite this sentence.

Response: We have rewritten the sentence as follows in the text. (Lines 304-305)

“Namely, the lowest values of DSM consumption were same as that of APO in different regions.”

Line 268: What does extreme rainfall mean here? How much precipitation?

Response: The mean annual precipitation (MAP) of Changwu and Yan’an is 575 mm and 530 mm, respectively (Wang et al., 2022). In 2021, however, the annual precipitation is 910 mm and 704 mm, respectively (Table 1), which increased by 58.3% and 32.8% over MAP, respectively. Thus, we considered that the Changwu and Yan’an experienced an extremely wet year in 2021.

Reference:

Wang, S., Gao, X., Yang, M., Zhang L., Wang X., Wu, P., Zhao, X.: The efficiency of organic C sequestration in deep soils is enhanced by drier climates, Geoderma, 415, 115774, 10.1016/j.geoderma.2022.115774, 2022.

Figure 5: The yellow line in the Figure 5a is not clear. Please change it to another color.

Response: Thanks for your suggestion. It has been changed to a clear color in the revised manuscript.

Line 298: Soil texture can largely affect soil moisture. But, how can it lead to the degree and depth limitation of deep soil desiccation? The results here should be explained in a more sense way.

Response: Soil texture determines the adsorption force of the soil to the water molecules. The more clay content in soil, the more energy needed by plants to extract water from soil. Therefore, for tree species with the same water uptake capacity, soil clay content and its' spatial distribution characteristics mainly determine the lower limit of available soil water, thus indirectly affecting the limitation of deep soil desiccation to plants. To eliminate concerns, we have changed the text as follows in the revised manuscript. (Lines 345-347)

"The clay content determines the lower limit of water that plants can uptake through its adsorption of water molecules. Thus, soil texture and climatic conditions were the main factors leading to the limitations of DSD in different regions."

Discussion

Line 340: Please add a citation here.

Response: Wu et al. (2015) has been cited here. (Lines 393-394)

Reference:

Wu, Y., Huang, M., Warrington, D.: Black Locust Transpiration Responses to Soil Water Availability as Affected by Meteorological Factors and Soil Texture, Pedosphere, 25(1), 57-71, 10.1016/S1002-0160(14)60076-X, 2015.

Line 347: Please delete "reference".

Response: It has been deleted. (Line 400)

Line 349: please change to soil water use.

Response: It has been changed to “soil water use” in the text. (Line 402)

Line 354: Keep the decimal places consistent.

Response: It has been edited in the text. (Line 407)

Line 355: Use the full name of SPAC.

Response: Thanks for your comment. The full name of SPAC is soil-plant-atmosphere continuum. It has been added in the text. (Line 408)

Line 378: Are the trees examined in your study site dieback?

Response: Yes, we took photos (as shown in the Figure S4 above) to record the black locust plantation of Mizhi where obvious dieback occurred with the help of digital camera at the same time of sampling.

Comments of Anonymous Referee #2:

This is a very interesting that focuses on the analysis of deep soil desiccation and its effect on soil moisture supply and tree hydraulic conductivity in tree plantations. This is a topic that fits the scope of this journal and that is of interest for its readership. Overall, the manuscript is well written and organized, and the motivation, scientific gaps, and objectives are clear. However, there are some confused methodological descriptions that make unclear most of the results, weakening the strength of the work. Moreover, data interpretation is not always straightforward, leaving the reader with

doubts about the effective role of PWP. Please, find my main concerns and some minor corrections and suggestions below. In the end, I recommend a major revision of this work.

Response: Thanks for your time and constructive comments on our manuscript. Corrections have been made based on the recommendations, with detailed response to each comment presented below.

Specific comments

- As far as I know, the approach of mixing data extracted from the literature with those collected in the field is quite unusual. Still, I welcome this approach because the two distinct datasets can corroborate each other. However, the presentation of the two dataset is quite confusing and it was hard for me to understand which results refer to data collected in the field and which were extracted by the literature. This holds true for the tables, the figures, and the results presented in the text. All this creates some confusions. I think it's important to well explain this difference for the sake of clarity and to allow the reader understanding where the findings come from.

Response: Thanks for your comment, we have provided a detailed description as shown below for the data sources of the tables, the figures and the results presented in the text, and explained these contents in the title of themselves in the revised manuscript. (Lines 125-126; 158-159; 202; 274-278; 292-293; 311-314; 329-330; 352-353; 366-367; 416-417)

Lines 125-126

Table 1: Sample information used in this study. Data marked with NEP and NSP represent the number of data pairs from the literature and field sampling, respectively.

Lines 159-160

Table 2: Basic information for the trees reaching the moisture limitation (lowest deep soil moisture deficit) of each site sampled in the field.

Line 202

Table 3: Basic soil properties of field sampling sites.

Lines 274-278

Figure 2 contains 11980 literature extraction data and 4200 field sampling data.

Lines 292-293

Figure 3 involves literature extraction data of soil moisture from 15-year-old apple orchards obtained in 2002, 2010, 2016 and 2019.

Lines 311-314

Figure 4 (a) and (b) belong to literature extraction data, and (c)-(f) belong to field measurement data.

Lines 329-330

Figure 5: The data of 22-year-old apple and cropland (dark green) in Changwu belong to literature extraction data, and other data are field measured data.

Lines 352-353

Figure 6: Both extracted data from literature and field measured data participate in the redundancy analysis.

Lines 366-367

Figure 7: The percentage loss of hydraulic conductivity of annual branches of apple (a) and black locust (b) are field measured data.

Lines 416-417

Figure 8: Regulatory mechanism of the extreme influence of root water uptake (RWU) on deep soil moisture based on both the extracted data from literature and field

measured data.

- Moreover, there are some unclear explanations and definitions that hamper a complete understanding of the work and of its' results. See below the specific comments.

Response: We have carefully considered the below comments and made revisions one by one in the revised manuscript as follows.

- Sometimes, there are too many acronyms. Some are used several times in the text and become familiar to the reader, and some are very well knows. However, some are not, and an excessive use of acronyms can fragmentate the reading flow and hamper understanding. Moreover, sometimes acronyms are used for the entire term and sometimes not: please be consistent throughout the entire manuscript.

Response: We have completed the full names of all acronyms, such as GPS (Line 136) and SPAC (Line 408) that appear only once; reduced the unnecessary use of acronyms, such as SM (Lines 322-323, 341-345) and SD (Lines 146-147) for the readability of the article; and deleted redundant acronym such as ECMWF (Lines 208-209) in the revised manuscript.

Line 136

"Geographic coordinates (altitude, longitude, and latitude) for each site were obtained using a Global Positioning System."

Lines 146-147

"The straight-line distance between the planted trees and their control was controlled at less than 500 m, and the average straight-line distance of the three replicates was shown in Table 2."

Lines 208-209

"The precipitation, air temperature, and relative humidity of different regions were from the European Centre for Medium-Range Weather Forecasts ERA5-Land reanalysis."

Lines 322-323

“We calculate the difference significance of soil moisture between the plantations and control using the paired sample *t*-test.”

Lines 341-345

“The RDA showed that the explanatory variables (soil properties, meteorological variables and plant characteristic) account for 67.7% of the total variation of soil moisture and SMD. SMD was significantly (p<0.01) positively correlated with VPD, and negatively correlated with clay, silt, RH, MAT, and MAP (Fig. 6a). The clay, VPD, silt, RH, and FRDWD provided statistically significant (p<0.01) explanations for the distribution of SMD and soil moisture (Fig. 6b).”

Line 408

“Probably because the hydraulic path of water transport in the soil-plant-atmosphere continuum is too long.”

- The Authors insist a lot on the role of the PWP as an indicator of the degree of moisture limitation for plants. However, the PWP was not directly measured, it can be very variable according to different locations and depth, and DSM is used as a proxy. I suggest making the connection between PWP and DSM clearer and stronger. As far as I understand, the main message of the manuscript lays on this aspect which should be crystal clear to the reader.

Response: Large-scale permanent wilting point (PWP) measurements are infeasible because obtaining undisturbed soil from deep soil is difficult and time-consuming. Soil pedotransfer functions (PTFs) are widely used for PWP estimation (Balland et al. 2008), Studies have established the PTFs for the Loess Plateau based on a large number of measured data and verified its estimation accuracy (Wang et al. 2012; Yang et al., 2020). Therefore, the estimation of PWP based on the PTFs in this study has high accuracy and reliability. PWP is the soil moisture content causing plants wilt, so we use soil

moisture content to represent it, and deep soil moisture content (DSM) here is mostly directly measured as either mass or volumetric moisture content. In this study, the relationship between PWP and DSM is mainly reflected in whether the lowest value of DSM is PWP in plantations. Specifically, we calculated the soil moisture deficit value ($SMD\_PWP_{j,k}$) corresponding to the PWP of each plantation sample plot using formula 11, as the degree limitation (changing to moisture limitation in the revised paper) of water uptake by the artificial forest roots. Then, we calculated the moisture deficit value ($SMD_{j,k}$) corresponding to the DSM of artificial forest with different tree ages using Eq. 10, and compare it with the $SMD\_PWP_{j,k}$ to determine the specific age of the artificial forest when the consumption of DSM reaches the moisture limitation. For clarity, we have supplemented it in Section 2.3.2. (Lines 241-242)

"When the $SMD_{j,k}$ corresponding to DSM is very close to $SMD\_PWP_{j,k}$ suggests that the consumption of DSM by trees has reached moisture limitation."

References:

Balland, V., Pollacco, J., Arp, P.: Modeling soil hydraulic properties for a wide range of soil conditions. Ecol. Model., 219 (3-4), 300-316, 2008.

Wang, Y., Shao, M., Liu, Z.: Pedotransfer functions for predicting soil hydraulic properties of the Chinese Loess Plateau. Soil Sci., 177 (7), 424-432, 2012.

Yang, M., Wang, S., Zhao, X., Gao, X., Liu, S.: Soil properties of apple orchards on China's Loess Plateau, Sci. Total Environ., 723, 138041, 2020.

- The language is sometime not appropriate, some sentences are not linear and a bit hard to follow. There are sparce grammar mistakes. I made a few suggestions only (below). I suggest a language review by a native (or very proficient) English-speaker.

Response: Thanks for your help in language. We have revised the manuscript one by one according to your suggestions, and asked native English speakers to edit the language of the revised manuscript.

81. What is the drought-resistance related to? Water use strategy? Root depth? It is important to define this here, I believe.

Response: The drought-resistance refer to the ability of a plant to maintain favorable water balance and turgidity even exposed to drought conditions there by avoiding stress and its consequences. Thus, it related to the water use strategy of different tree species under drought conditions. Of course, shifting the root depth is sometimes also a water use strategy for trees to adapt to arid environments. We have modified this sentence in the revised manuscript. (Lines 80-83)

"Our hypotheses were that the moisture and depth limitations of DSD depends on tree species, as they differ in drought-resistance capacity, which relies on themselves water use strategy under drought stress (Gessler et al., 2020)."

89. What kind of bias? Please explain.

Response: The bias here refers to the phenomenon that the obtained literature cannot serve the research subject well according to a single screening criterion when selecting the literature. We have amended the statement here as follow to correct it in the revised manuscript. (Lines 91-92)

"To avoid bias in the literature selection, the following criteria were set to filtrate 718 articles obtained."

111. What does the Authors mean hear with "random errors", and how can they be avoided? Please, explain.

Response: Random error here refers to accidental or indeterminate error, which is a mutually compensating error caused by small random fluctuations in a series of related factors during the measurement process. Due to the different sampling years of apple orchards in Changwu and Luochuan from literatures, which may lead to random error in the process of comparative analysis of soil moisture data among tree ages. In order to avoid these random errors affecting the results of this study, we divided them into

tree age segments for analysis.

141. This sounds unbelievable to me. I have used a hand auger to get soil samples down to a couple of meters, and only occasionally to 4-5 through a driller. Here the Authors report 25 m! How is that possible? Please, explain.

Response: In order to explore the maximum water consumption depth of the plantation, we insisted on using 15 drill pipes (to reduce the weight of the tool itself, choose a hollow steel pipe) with a length of 2 m to form an auger that could be disassembled on demand. Each 25 m deep soil column required four people to work together and continuously for four days to complete (As shown in the following photographs of sampling process). We have added these photographs as Figure S1 in the supplement to demonstrate the sampling process.

Figure S1. The process of collecting soil samples with the auger.

Figure 2. This is supposed to be an important figure for the “story” the Authors tell but it is not very clear to me. What is the response ratio? I did not find any definition.

Without understanding the RR meaning it's difficult to grasp the importance of the figure. What do negative and positive values of RR mean? In the caption: what are the "effect sizes". Please, clarify all this.

Response: Thanks for your comment. Response ratio (*RR*, the calculation formula is as below) is a unit-free index with positive or negative values indicating either increasing or decreasing soil moisture in response to planted trees' growth. Thus, a negative value of *RR* indicates that plantation growth decreases soil moisture, and vice versa increases soil moisture. In addition, the effect size indicates the value of *RR*. To dispel this confusion, we have carefully illustrated this information in the revised manuscript. (Lines 220-223; 274-279)

Lines 220-223

" $RR = Ln(X_e / X_C)$

where *RR* is a unit-free index with positive and negative values indicating either increasing or decreasing soil moisture in response to planted trees' growth. X_e and X_c are values of soil moisture under trees and controls for each study, respectively."

Lines 274-279

"Mean effect sizes indicating the mean value of response ratio (*RR*, a unit-free index with positive or negative value means soil moisture increases or decreases with the older of plantations) of soil moisture response to planted trees' growth on the Loess Plateau are divided into: (a) tree age <10 year, (b) 10 year ≤ tree age<20 year, (c) 20 year ≤ tree age<30 year, and (d) tree age ≥ 30 year. The vertical black dotted lines indicate *RR*=0. Blue and red dots, which involves 11980 literature extraction data and 4200 field sampling data, represent black locust forests and apple orchard *RR*s, respectively; diamonds and circles represent the mean *RR* of black locust and apple orchard, respectively; and the error bars represent 95% CI."

Paragraph 3.2. I have some doubts about the definition of SMD and DSMD. I assume

that SM is highly variable in space…so, how can we use a control tree as a real control? Should we measure the SM in several control trees? Can you use a more pedological definition of deficit, such as the difference between the actual water content and saturation? The Authors have the soil samples and therefore could perform a lab analysis to determine the porosity of the samples. Moreover, I intuitively understand the difference between SMD and DSMD but this difference was not analytically define. This rises some issue on the use of this metric and the interpretation of the data subsequently presented. Please, clarify well this part.

Response: In our study regions, the age of planted trees is a major factor that affects the moisture and depth limitations, but there may be significant differences in the deep soil moisture content (DSM) under the same age of trees in different sampling years. For example, there is a significant difference in DSM between apple orchards aged 15 years in 2005 (rainfall 470 mm) and apple orchards with the same age in 2013 (rainfall 760 mm). In order to minimize this difference, we need to remove the impact of annual rainfall. Considering crops or grasses do not utilize deep soil moisture below 2 m due to their shallow roots (Gao et al., 2014; Zhu et al., 2016; Gao et al., 2022), they can reflect differences in annual rainfall between different sampling years. Thus, we have used the deep soil moisture deficit (DSMD), which is defined as the relative difference of DSM under given trees and nearby cropland or grassland to better analyze the moisture limitation of plantations. For clarity, we have defined them in Section 2.3.2. (Lines 233-239)

"The effect of different deep-rooted planted trees RWU on soil moisture was expressed as soil moisture deficit (SMD), which is the relative difference in soil moisture for given trees and adjacent cropland/grassland. Due to root distribution of the latter is too shallow (<2 m) to influence the change of DSM (Gao et al., 2014; Zhu et al., 2016; Gao et al., 2022), thus, the soil moisture of grassland/farmland measured simultaneously with that of plantation can be used as background value to eliminate the influence of climate difference, and the $SMD_{j,k}$ calculation method as shown in Eq. 10. Among them, the SMD of the soil layer below 2 m is the deep soil moisture deficit (DSMD)."

References:

Gao, X., Wu, P., Zhao, X., Wang, J., Shi, Y.: Effects of land use on soil moisture variations in a semi-arid catchment: Implications for land and agricultural water management, Land Degrad. Develop., 25, 163-172, 10.1002/ldr.1156, 2014.

Zhu, G., Deng, L., Zhang, X., Shangguan, Z.: Effects of grazing exclusion on plant community and soil physicochemical properties in a desert steppe on the Loess Plateau, China, Ecol. Eng., 90, 372-381, 10.1016/j.ecoleng.2016.02.001, 2016.

Gao, X., He, N., Jia, R., Hu, P., Zhao, X.: Redesign of dryland apple orchards by intercropping the bioenergy crop canola (*Brassica napus* L.): Achieving sustainable intensification, Glob. Change Biol. Bioenergy, 14, 378-392, https://doi.org/10.1111/gcbb.12916, 2022.

Fig. 8. Is this based on the results of this study or is a more general conceptual figure deriving from what we already know? This is not clear to me. Please, specify.

Response: Fig. 8 is based on the results of this study (parameters in the box on a white background) and concepts from the literature (parameters in the box on a gray background). We have specified this as follows in the revised manuscript. (Lines 383-384)

"Based on the results of this study and opinions from literature, Fig. 8 shows the mechanism by which plants regulate the moisture and depth limitations of DSD."

Minor comments and technical corrections

18. I'd add "water" or "moisture" before "limitation".

Response: Due to the limitation here including the moisture limitation and depth limitation of deep soil desiccation (DSD) mentioned in the text, we therefore have modified the text as follows in the revised manuscript. (Lines 16-17)

"The limitation in relation to both moisture and depth of deep soil desiccation (DSD) beyond which root water uptake ceases remains unclear."

21. "minimize the effect…": this is not clear without reading the manuscript. Please explain it or skip it.

Response: Thank you for your suggestion. We have deleted "to minimize the effect of climate differences in various sampling years", and supplemented the complete concept of deep soil moisture deficit (DSMD) as follows in the revised manuscript. (Lines 233-239)

"The effect of different deep-rooted planted trees RWU on soil moisture was expressed as soil moisture deficit (SMD), which is the relative difference in soil moisture for given trees and adjacent cropland/grassland. Due to root distribution of the latter is too shallow (<2 m) to influence the change of DSM (Gao et al., 2014; Zhu et al., 2016; Gao et al., 2022), thus, the soil moisture of grassland/farmland measured simultaneously with that of plantation can be used as background value to eliminate the influence of climate difference, and the $SMD_{j,k}$ calculation method as shown in Eq. 10. Among them, the SMD of the soil layer below 2 m is the deep soil moisture deficit (DSMD)."

36. Remove "there".

Response: It has been removed. (Line 35)

45. Move "in drylands" at line above, after "tree planting".

Response: It has been moved in the revised manuscript. (Lines 43-44)

74. Typo/language issues.

Response: Thank you for your suggestion. We have rewritten this sentence as follow in the revised manuscript. (Lines 75-76)

"The effect of DSD on xylem hydraulic conductivity of planted trees, however, is still

unclear, when moisture and depth limitations of DSD are reached."

105. Why "intuitively"? Please, explain.

Response: We mean collecting data directly from the intuitive figures of soil moisture. We have reorganized this sentence as follows in the text. (Lines 108-110)

"The original data were either clearly obtained from tables in the selected papers or directly extracted from the intuitive figures in those papers using GetData Graph Digitizer."

143. Replace "was" into "were".

Response: We have done. (Line 153)

Table 2, caption: Why only those, and not all? Please, explain.

Response: Because these trees with specific age cause the lowest deep soil moisture deficit, namely reach the moisture limitation of deep soil desiccation in different regions. Thus, we used them as the focus of this study to obtain results related to the depth limitation of deep soil desiccation and the percentage loss of xylem hydraulic conductivity, and presented their basic information.

225-228. "significance": do you mean the possibly significant difference? Please explain. In general, these three lines are not very clear, please explain better.

Response: Yes, the "significance" means the significant difference. To make this section clearer, we have rewritten it as follows in the revised version. (Lines 250-255)

"The paired sample *t*-test in SPSS was used to analyze the significant difference of soil moisture between plantations and their controls. Three duplicate values were taken for each plantation and its control per site, and the straight-line distance between them was less than 500 m. If the difference of soil moisture content in the plantation and its' control becomes not statistically significant ($p>0.05$) with the soil layer deepening, the

consumption of DSM by plantations will be considered to have reached the depth limitation. Conversely, it indicates that the maximum root water uptake depth has not been reached when the difference is always significant (p<0.05).”

231. Canoco 5. What is this? Please, explain.

Response: Canoco 5 is software for redundant analysis with production information of Microcomputer Power Ithaca, New York, USA. We have added this information in the revised manuscript. (Lines 259-260)

“Redundancy analysis (RDA) was performed to evaluate the contributions of environmental factors to SMD and soil moisture using Canoco 5 (Microcomputer Power Ithaca, New York, USA).”

240. Which plantation? Only one of them or both?

Response: Both the two plantations had a biggest effect on DSM appears to be between 20 and 30 years. We have revised the description as follow in the revised manuscript. (Lines 269-270)

“Thus, the tree age at which the two plantations had a biggest effect on DSM appears to be between 20 and 30 years.”

274. What do the Authors mean by “randomness”? Please, clarify.

Response: Due to the apple orchards in Changwu (Fig. 4(a)) and Luochuan (Fig. 4(b)) are collected from literature, we divide them into tree age segments for analysis to avoid errors caused by different sampling years and locations between the data. We have clarified this information as follows in the revised version. (Lines 314-316)

“In order to reduce the randomness caused by different sampling years and locations between the extracted data, the data for apple trees with similar ages in Changwu (a) and Luochuan (b) were combined.”

Fig. 4, 5, 6 and 7. Are these figures based on field data or extracted data only? Please, specify.

Response: Thanks for your suggestion. Figure 4 (a) and (b) belong to literature extraction data, and (c)-(f) belong to field measurement data; the data of 22-year-old apple and cropland (dark green) in Figure 5(a) belong to literature extraction data, and other data are field measured data; both extracted data from literature and field measured data participate in redundancy analysis of Figure 6; and the percentage loss of hydraulic conductivity of annual branches of apple (Figure 7(a)) and black locust (Figure 7(b)) are field measured data. We have indicated the data sources in these figures' title of the new version.

307. Here again, "limitations" is vague…I would add "water" or "moisture".

Response: Due to the limitations here including the moisture and depth limitations of deep soil desiccation (DSD) mentioned in the text, we have modified the text as follows in the revised manuscript. (Line 358)

"Effect of the DSD limitations on hydraulic conductivity"

320-321. Language issues.

Response: We have rewritten this sentence as follows in the revised manuscript. (Lines 372-373)

"This is ascribed to surface or shallow layer soil moisture, which is usually greatly influenced by rainfall infiltration and evapotranspiration."