Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2020-266-AC3, 2020

Hydrology and Earth System Sciences
Discussions

Interactive comment on "Preferential water flow through decayed root channels enhances soil water infiltration: Evaluation in distinct vegetation types under semi-arid conditions" *by* Gao-Lin Wu et al.

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Received and published: 11 December 2020

Response to Reviewer #2

We thank the reviewers for arranging time to read and review our paper and providing suggestions and comments, which will help us improve the manuscript. We will try our best to modify and improve the manuscript following the reviewer's suggestions/comment.

Comment #2:

The manuscript compares the soil saturated infiltration capacity of different vegetation types (fruit tree, desert shrub and grassland) both in living and "degraded" state and relates the observed variation by size and area of root channels. The results indicate that degraded woody vegetation still provides for enhanced infiltration to deep layers due to root channels still providing for preferential flow to deep layers. I think the topic is overall relevant, because the decrease of soil water content by introduced woody vegetation is a pressing issue in semiarid areas in general and within the Loess Plateau and surrounding region specifically. I agree that learning how the degraded landscape behaves hydrologically may be of importance for understanding potential means for restoration. However, I find that the manuscript in the current form has substantial shortcomings and I recommend a very major revision of both the presentation and analysis. I think the introduction should give more background in the setting, e.g. the causes of vegetation degradation and depletion of the soil water storage. The methods need to be stated more clearly and the statistical analysis is not state of the art. The discussion is too narrow and e.g. leaves out some important alternative explanation of the observed patterns. Overall, the manuscript is premature for publication and I suggest rejection with invitation to re-submit.

Response: Thank you for your suggestion. Your suggestions were very helpful in making a better manuscript. We will try our best to modify and improve the manuscript following the reviewer's suggestions/comment.

In the introduction the focal term of the manuscript "dried soil layers" is introduced with a citation of Jipp et al., 1998. I find this citation misleading, as that reference focusses on the deeper soil layers whereas here the surface soil is of importance. Also, it would have been insightful to learn more about how slow depletion of soil water finally leads to vegetation degradation. A number of manuscripts and more recent ones have been published on this, e.g. on the Loess Plateau. This would also help to appreciate the relevance of the work. On the other hand, I am not sure how e.g. the "biomat bacterial layer" refers to this work. I suggest strongly revising the introduction.

Response: Thank you for your suggestion. Although we fully agree with this comment/suggestion, our aim was to focus on the impact of preferential flow formed by dead roots on soil moisture. Dried soil layers (DSL) are usually caused by excessive consumption of deep soil water by vegetation when there is not enough precipitation (Huang et al., 2018). DSL generally occurs below the depth of soil affected by rainfall infiltration, it greatly affects the growth of plants (Li, 2001; Jia et al., 2015). Previous studies have addressed the effects of root systems on soil water infiltration, butÂăthe effects of root channel formed by decayed roots after vegetation die off on soil water infiltration and soil water storage are still not clear. Meanwhile, most studies have concentrated the research on one plant type or species (Wu et al., 2016; Jiang et al., 2018; Guo et al., 2019), neglecting the comparison between different plant types. Therefore, this study explores the effects of decayed and alive roots on soil infiltrability in three common vegetation types (shrubs, fruit trees, and herbs) in semi-arid regions, and determines the contribution of the preferential flow to soil water. The results of this study indicate that macropores formed by decayed roots may ease soil water to move down to deep soil layers, especially in dried areas (Bogner et al., 2010). Hence, the preferential flow formed by decayed roots are conducive to the restoration of soil moisture in arid areas, thereby mitigating the aggravation of the dried soil layers. I am sorry for my carelessness. We will delete this sentence (Gerke et al. (2015) found that the biomat bacteria layer in thesoil can generate preferential flow paths in natural forests.) in the revised manuscript. The introduction part will add the required information and be rewritten following the reviewer's suggestion. (Additional reference) Huang, Z., Liu, Y., Cui, Z., Fang, Y., He, H. H., Liu, B. R., Wu, G. L.: Soil water storage deficit of alfalfa (Medicago sativa) grasslands along ages in arid area (China). Field Crops Res., 221, 1–6, 2018. Li, Y. S.: Effects of forest on water circle on the Loess Plateau. J. Nat. Resour., 6, 427–432, 2001. Jia, X. X., Shao, M. A., Zhang, C. C., Zhao, C. L.: Regional temporal persistence of dried soil layer along south–north transect of the Loess Plateau, China. J. Hydrol., 528, 152–160, 2015.

Most importantly: What were the details of the selection of the measurement loca-

tions? How far from stems were the located? Were they randomly selected and what procedure was used for that? Were they (as Fig. 1 suggests) located on top of the root collar of the perished plant in the decayed areas? If the latter was the case, the differences between living and decayed groups will have to be re-evaluated. This is because the infiltration reservoir would directly connect to the decaying rooting network of one precise stem, and the result is only representative for the exact former locations of the stem and not the more representative area surrounding the stems.

Response: Thank you for your suggestion. The operation steps of the entire infiltration process of the study are based on Zhang et al. (2017). The above-ground parts of trees and shrubs were carefully removed to make them flush with the ground before the infiltration experiment. Meanwhile, the litter layer was carefully cleaned so that the soil surface was exposed. For reducing the influence of artificial disturbance on soil structure, the infiltrometer were gently and vertically inserted into the soil about 5 cm. And, the insertion position ensured that the root collar was located in the center of the infiltrometer. The prepared water is poured into the double-ring as fast as possible until the water depth reaches 5 cm, and the water level lines of the inner ring and the outer ring are kept consistent. We use the falling head method to measure the soil infiltration process. And, the time durations for the water line to drop 1 cm in the inner ring were recorded with a stopwatch until the infiltration time remains stable for three consecutive measurements. Then, water was refilled into the ring until the water depth reaches 5 cm whenever the water level dropped to a depth of 1 cm. We will add some relevant information about the infiltration process in the revised version of the manuscript.

Using double ring infiltrometers for assessing infiltration capacity has the disadvantage that introducing the rings causes substantial disturbance which affects the soil properties. I assume the data are worth publishing regardless, but I expect this to be mentioned in the discussion, along with an evaluation why you believe the results can be interpreted regardless. Please give also more details of the infiltration measurement. How deep was the infiltrometer introduced to the ground and how?

Response: Thank you for your suggestion. The operation steps of the entire infiltration process of the study are based on Zhang et al. (2017). The above-ground parts of trees and shrubs were carefully removed to make them flush with the ground before the infiltration experiment. Meanwhile, the litter layer was carefully cleaned so that the soil surface was exposed. For reducing the influence of artificial disturbance on soil structure, the infiltrometer were gently and vertically inserted into the soil about 5 cm. We use the falling head method to measure the soil infiltration process. And, a more detailed description will be added to the revised manuscript.

Soil water content was measured precisely where? From the methods section it sounds like it was assessed within the infiltration area, but I am note sure whether this makes sense? I am also not sure, why the soil water content is important for interpretation? Also why give the soil water content in gravimetric units, if the soil was collected in cylinders and volumetric soil water content could be assessed.

Response: Thank you for your suggestion. Studies have shown that soil water content is also key factor determining soil infiltration capacity in semi-arid regions (Archer et al., 2002; Zehe and Blöschl, 2004; Alaoui, 2015; Cui et al., 2019). Soil gravimetric water content was measured by using a soil drilling method before infiltration measurement. And, we will add the required in formation in the revised version of the manuscript. (Additional reference) Alaoui, A.: Modelling susceptibility of grassland soil to macropore flow. J. Hydrol., 525, 536–546, 2015. Zehe, E., Blöschl, G.: Predictability of hydrologic response at the plot and catchment scales: role of initial conditions. Water Resour. Res., 40, 497–518, 2004. Cui, Z., Wu, G. L., Huang, Z., Liu, Y.: Fine roots determine soil infiltration potential than soil water content in semi-arid grassland soils. J. Hydrol., 578, 124023, 2019.

The explanation of how root channel sizes and area are measured is unclear. Were the assessed within the infiltration area after the experiment or before? Why is the diameter of the stubbles required for root channel diameter, or are roots the origin are the “stubbles”?

Response: Thank you for your suggestion. I am sorry for my unclear description. The root channel diameter and root channel area in the manuscript are root diameter and root area respectively. According to formula 3, the root area can be calculated by root diameter. And, the root diameter is determined by the measured diameter of the stubbles on the soil surface in the inner ring. We will modify the relevant information about the root channels in the revised version of the manuscript. We used a digital camera to record the vertical profile to determine the extent of the wetted area after the experiment. Meanwhile, the lateral width and vertical depth of the wetted volume were measured with a 1000 mm steel ruler with precision of 1 mm. We will add the required in formation in the revised version of the manuscript.

When were the measurements conducted? We learn that two different measurements campaigns were merged. Soil properties can change with time and therefore the length of the period between merged datasets is relevant.

Response: Thank you for your suggestion. The infiltration experiment of Herb (Medicago sativa) was carried out in August 2018, and the infiltration experiment of scrubland (C. korshinskii) and the fruit tree (A. vulgaris) was carried out in July 2019. Although the soil properties will change over time, we set a control group (bare land) for each infiltration experiment. Therefore, we can compare the influence of different vegetation types (scrubland, fruit tree, and herb) on soil infiltration rate by calculating the difference in infiltration rate between the experimental group and the control group. And, a more detailed description will be added to the revised manuscript.

Some variables are presented but it is unclear why and how they are supposed to be interpreted. For example, how is the initial infiltration or soil water content of importance for the interpretation?

Response: Thank you for your suggestion. I am sorry for my unclear description. Studies have shown thatÂăsoil water content is also key factor determining soil infiltration capacity in semi-arid regions (Archer et al., 2002; Zehe and Blöschl, 2004; Alaoui,

2015; Cui et al., 2019). The initial infiltration rate largely determines the start time of runoff on the soil slope. Therefore, studying the change of initial infiltration rate is more conducive to understanding the influence of different root systems (decayed and alive roots) on slope runoff. And, we will add the required in formation in the revised version of the manuscript. (Additional reference) Alaoui, A.: Modelling susceptibility of grassland soil to macropore flow. J. Hydrol., 525, 536–546, 2015. Zehe, E., Blöschl, G.: Predictability of hydrologic response at the plot and catchment scales: role of initial conditions. Water Resour. Res., 40, 497–518, 2004. Cui, Z., Wu, G. L., Huang, Z., Liu, Y.: Fine roots determine soil infiltration potential than soil water content in semi-arid grassland soils. J. Hydrol., 578, 124023, 2019.

How were the sites managed? Is there grazing of animals are the fruit trees approached for harvest? In other words, are there any land management procedures that affect soil compaction.

Response: Thank you for your suggestion. In order to eliminate the influence of human trampling on the soil properties during fruit harvesting, we selected an abandoned fruit tree plantation for experimentation. There are no grazing animals in the fruit tree plantation (A. vulgaris). Therefore, the experimental site does not have any land management procedures that affect soil compaction. And, we will add the required in formation in the revised version of the manuscript.

The statistical analysis is not state of the art. The overall goal of the manuscript is to reveal differences in infiltration capacity between the groups and explain them with supplemental information, like root channel diameter and bulk density. This would be a classical application for a statistical model, like ANOVA, mixed effects models or structural equation models. This would reduce the statements of the individual correlations and improve the interpretation.

Response: Thank you for your suggestion. We fully agree with this comment and we will try to improve the statistical analysis part in the revised version of the manuscript

tacking into account the aforementioned suggestion.

Also, it looks like root channel diameter and root channel area are related? If yes, it is enough to present only one of them.

Response: Thank you for your suggestion. Yes, root channel diameter and root channel area are related. We will modify the text following the reviewer's suggestion.

The results section is extremely short. It would have been nice to see boxplots of the root channel diameter, bulk density etc. for the different groups.

Response: Thank you for your suggestion. We will add boxplots of the root channel diameter and bulk density for the different groups in the revised version of the manuscript.

It is good to see charts of the infiltration rates over time, but this can only be one representative measurement? It is not stated so in the figure description.

Response: Thank you for your suggestion. We will add the required in formation in the revised version of the manuscript.

Figure 3: I think the initial infiltration rate is not required? There are no error bars for the steady infiltration rate - is the variation so small that it does not show up? It would be more insightful, to show the results as boxplots.

Response: Thank you for your suggestion. The initial infiltration rate largely determines the start time of runoff on the soil slope. Therefore, studying the change of initial infiltration rate is more conducive to understanding the influence of different root systems (decayed and alive roots) on slope runoff. The error bars for the steady infiltration rate will be added to the revised version of the manuscript following the reviewer's suggestion. And, the result of Figure 3 will be presented in the form of a boxplot.

Figure 4: The figure description is missing. There must be an error with the units of the average root channel diameter, which ranges from 1 to 16 cm.

Response: Thank you for your suggestion. I am sorry for my carelessness. The result

description of Figure 4 is placed in section 3.3 (3.3. Correlation between root channel properties and soil water infiltration rates) of the result. We will add the required in formation in the revised version of the manuscript. And, the error bars for the average root channel diameterÂăwill also be added to the revised version of the manuscript following the reviewer's suggestion.

The reference to Fig. 5 is only given in the discussion (L 233-235), and should be shifted to results. I would expect that the infiltration depth depends also on how much water had to be infiltrated before the steady state was reached in each location. Also here a statistical model would be extremely useful, which can test the influence of several variables like vegetation type, vegetation state and total infiltration together on infiltration depth.

Response: Thank you for your suggestion. We fully agree with this comment and we will add the relevant content of Figure 5 to the results section in the manuscript. In addition, we will use other statistical models to examine the effects of several variables such as vegetation type, vegetation status, and total infiltration on the infiltration depth. And, we will modify the text following the reviewer's suggestion.

Please add a discussion on the reliability of the methods, especially the infiltrometer, but also root channels.

Response: Thank you for your suggestion. Water infiltration processes were evaluated by using a double-ring infiltrometer in the selected sites. The device (double-ring infiltrometer) is composed of a 16-cm diameter inner ring and a 32-cm diameter outer ring. It was made by using 1-cm wall thickness and 20-cm height PVC pipes. The purpose of the outer ring is to have the infiltrating water act as a buffer zone against infiltrating water straining away sideways from the inner ring. The above-ground parts of trees and shrubs were carefully removed to make them flush with the ground before inserting the infiltrometer. For reducing the influence of artificial disturbance on soil structure, the infiltrometer were gently and vertically inserted into the soil about

5 cm (Fig. 1). And, the insertion position ensured that the root collar was located in the center of the infiltrometer. Then, simultaneous and rapidly addition of water to the inner (with methylene blue) and outer (without methylene blue) rings was done up to 5 cm height. We use the falling head method to measure the soil infiltration process. The root channel diameter (ARCD) and root channel area (RCA) in the manuscript are root diameter and root area respectively. According to formula 3, the root area can be calculated by root diameter. And, the root diameter is determined by the measured diameter of the stubbles on the soil surface.ÂăWe will modify the relevant information about the root channels in the revised version of the manuscript. Although we did not accurately measure the absolute value of the root channel in different treatments, we can compare the relative difference of the root channel. Because the root channel formed by the decay of the root system in this experiment is the main influencing factor of the preferential flow change. Preferential flow could promote the flow of water to deep soil layers, thereby increasing the soil infiltration rate. Therefore, we can compare the difference in root channel between different root systems (decayed and alive roots) of the same species by calculating the difference in infiltration rate. And, we will add the required in formation in the revised version of the manuscript.

I am surprised the authors do not refer or discuss alternative mechanisms to the role of root channel diameter and root area for enhancing infiltration capacity. Alternatively, bulk density (modulated by soil organic carbon or compaction if applicable) could potentially be related to infiltration capacity. Also, depending on the location of the infiltration areas and of Fig. 1 (see also comments above), the stem flow literature in semiarid areas may be relevant, like the double funneling in desert shrubs by Li et al (2009).

Response: Thank you for your suggestion. We fully agree with this comment. In order to eliminate the influence of human trampling on the soil properties during fruit harvesting, we selected an abandoned fruit tree plantation for experimentation. There are no grazing animals in the fruit tree plantation (A. vulgaris). Therefore, the experimental site does not have any land management procedures that affect soil compaction. This

section will be rewritten following the reviewer's suggestions/comment. And, we will try our best to modify and improve the manuscript.

I think detailed comments would only be useful for a later version of the manuscript.

Response: Thank you for your suggestion. Your suggestions were very helpful in making a better manuscript. We will try our best to modify and improve the manuscript following the reviewer's suggestions/comment.

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