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Discussions

# *Interactive comment on* "New measures of deep soil water recharge during vegetation restoration process in semi-arid regions of northern China" *by* Yiben Cheng et al.

**Yiben Cheng et al.**

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We thank anonymous reviewer for their constructive comments. The manuscript has been significantly improved by addressing the comments. The following are our point-to-point responses to their comments.

Responses to the Comments from Reviewer #1 1) The author claims that the DSR measurement performed in this study, being a task never reported before. On the other hand, the explanation on the DSR measurement and relevant principles/details were not presented. For example, it is understood a lysimeter installed at the depth of 3.2 meter, to enable the measurement of DSR as being below the deepest root c.a.



100cm. However, the length and width of this lysimeter is only 0.3m*0.3m, while the root distribution can reach a 200cm diameter horizontally. This makes this reviewer questioning the reliability of DSR measurements. Also within the deep soil, the relative humidity is rather hight(e.g., 99.9%), which will lead to vapor condensation on lysimeter device, how this vapor condensation effect is removed also needs some explanations.

Response: Thank you for the comment. The explanation of this new type of Lysimeter has been published in HESS in details before (Cheng et al, 2017), so that is why it is only briefly explained in this article. The conventional Lysimeter uses an impermeable container (constructed all the way from ground surface downward) to wrap the soil column, blocking the horizontal flow of the soil layer, thus there is inevitable water potential difference existing inside and outside the container of the Lysimeter. It is notable that horizontal soil moisture flow in the active root zones in arid and semi-arid regions could be significant as the roots prefer to grow horizontally to intercept the maximum infiltrated water. In arid and semi-arid regions, the roots usually do not grow vertically to great depths because the regional groundwater table is so deep that it is almost impossible for roots to tap groundwater(especially in our research area). Below the active root zones, horizontal movement of water moisture will be substantially reduced and vertical movement of water moisture starts to prevail. The new Lysimeter has an upper water balance part(different from the inclusions of conventional Lysimeters) and a lower measurement part which can directly measure the water flux. Specifically, the flux infiltrating into the balance part at the depth of the measurement face should equal the flux exiting the balance part and entering the measurement part. There is no need to build an impervious container to wrap the vegetation tested for the new Lysimeter above the measurement face. The 0.3 m*0.3 m is the planar view size of the new Lysimeter, and the height of the Lysimeter is 1.2 meters. Because the measurement face of the Lysimeter is at a depth of 2 meters, the installation of the instrument requires downward excavation to a depth of 3.2 meters. After this step, lateral excavation will be conducted (under a 2 m undisturbed soil) to generate a cave with the size of 0.3 m of width, 0.3 m of length, and 1.2 m of height to host the Lysimeter. After the installation of the Lysimeter, the excavation will be backfilled using the native soil. The experimental site was flat sandy land before ASK was planted for sand control 40 years ago. After 40 years of development, the region is dominated by ASK, scattered Rhamnus parvifolia, Chenopodium glaucum, Setaria viridis and the field average vegetation coverage has reached 80%. In order to investigate the distribution of the roots of ASK, five ASK plants with the same growth and age were excavated on the adjacent plots of the experimental site to conduct the analysis of roots layer by layer up to 1.2 m below ground surface. The average root of these five ASK plants at a particular depth is regarded as the representative root of ASK plants in this area at that depth. The condensate of the soil layer in the semi-arid area is indeed an important source, but the groundwater level in this area is about 7 meters deep, so the groundwater replenishment on soil moisture for shallow soil layers less than 2 m deep is essentially negligible. Therefore, the source of condensate at a depth of 2 meters comes solely from precipitation, and we can still use the water balance principle to calculate the distribution of precipitation-induced infiltration in each soil layer.

2) The author claims that the direct measurement of ET is not reliable, but the current approach deployed to measure DSR combined with water balance equation will give accurate estimation of ET. This is a very strong statement while way beyond the reality. If one looks back the point one about the reliability of DSR measurement in this study.

Response: Implemented. According to the literature review conducted by the authors, the methods of directly measuring ET include Lysimeter, Eddy correlation method, Bowen ratio method, Large aperture scintillation method, etc. Taking the most advanced Eddy correlation method as an example, the measurement error may be 20% or higher and the required monitoring conditions are quite demanding. Furthermore, it is difficult to avoid the influence of human factors on the experimental results. This study provides an inexpensive measurement method that directly measures the water flux at the lower interface of the target layer (the deep soil recharge or DSR), and combine DSR with a few factors that can be accurately measured in real applications (such



as precipitation and soil water storage) to calculate ET from the law of conservation. The deficit of this method is that it measures the ET at the point where the Lysimeter is located, thus it may not be the representative ET value over a large scale. Upscaling of the point ET value to large-scale ET value is an important issue and should not be overlooked in the future.

3) The way the author investigate the soil texture change is too much data-limited (e.g., only one plot, and the averaged mixed information was used), which renders the reliability of relevant analysis.

Response: First of all, we need to point that this study does not consider the exact spatial distribution of soil size distribution that is often important for conducting a precise unsaturated flow simulation (which is not the focus of this investigation). Instead, the purpose of measuring the soil particle sizes is to estimate the capillary rise based on the “average” grain sizes of sand. The capillary rise height is an important parameter for designing the new Lysimeter (as the height of the balance part of the Lysimeter should be greater than the typical capillary rise height at the site).

4) There are no any numerical analysis/experiment to investigate/validate relevant hypothesis, which also jeopardized the credibility of this study.

Response: At present, there are many models to study the process of soil infiltration, but there are relatively few measured data for arid and semi-arid sandy lands. The purpose of this study is to use the newly designed Lysimeter to measure the water balance information of precipitation in this special type of land, and to evaluate the deep soil water information of the area through the measurement of DSR. The probes used here are commonly adopted by many other soil scientists and are reliable. It is our intention that such acquired datasets can be eventually utilized in sophisticated numerical modeling of unsaturated zone water dynamics in the future.

Response to other comments in the article 1 line 60, line 75, Citation error Response: Implemented.

2 line 95, The bottom right picture has glare effect, cannot give readers nice impression on the experimental site. Also, it would be nice to have a UAV image of the study site. Response: Implemented.

3 line 105-107, This is very confusing. Are you saying you have a groundwater table at 180cm? and 60cm capillary rise is from that 180cm GW table? But you said the region has GW table of 5.3 - 6.8m. This deserves careful consideration and clarification. Studies have shown that the vapor can be transferred to surface from more than 100m deep zone of the sand dune.

Response: The depth of the root layer of ASK in this area is 120 cm (meaning that water within the 120 cm depth may be transpired through root). Furthermore, the capillary water rise height of the sandy soil in this area is 60 cm (meaning that water may be moved upward a maximum height of 60 cm by the capillary force). Therefore, the maximum uplifting of water through the transpiration of root and capillary rise is the summation of 120 cm and 60 cm, which is 180 cm. In another word, for any water within the 180 cm depth, there is a possibility that it can return to atmosphere (through evapotranspiration); for any water below 180 cm depth, it is impossible for it to return to atmosphere (thorough evapotranspiration) and it can only keep going down to recharge the deep soil, assuming that vertical downward movement of soil moisture below the 180 cm depth is dominating and any horizontal soil moisture movement below the 180 cm depth is secondary and negligible. In this study, in order to increase the credibility of the data, we continued to extend the measured infiltration by 20cm and set the DSR measurement depth at 200cm. Above analysis will not be affected by the regional groundwater table which is sufficiently deep (with depths of 5.3-6.8 m).

4 line 140, what is the wet bulk density you are referring to? before and after backfill? Are they close to each other? If not , how will this affect your results?

Response: This paper does not concern the accurate determination of bulk density. The description here is that water is used to wet the soil before excavating the soil



profile and installing the Lysimeter to make sure that the sand is relatively compact and will not collapse during the excavation process. When installing the Lysimeter, excavation is conducted outside of the targeted area first to a designated depth and then conducted sideway horizontally, and the Lysimeter is installed under the undamaged soil layer above the Lysimeter. After the Lysimeter is installed, water is also used to wet the soil profile to make sure that the sand is relatively compact. The collected data can be used after the sand has settled naturally for one year to ensure data quality.

5 line150, The dimension/scale is not indicated in the figure. Please do.

Response: Implemented.

6 line 153, well, this deserves more consideration. In Land Surface Model, if you considered most of the physical processes (e.g,. intercepted water by leaf, interception-induced evaporation, through-fall, soil hydrothermal properties etc.) you should be able to estimate infiltration rate and runoff. This is very basic though.

Response: If all factors are taken into consideration, it is indeed possible to predict whether there will be runoff on the surface. However, the reality is that the environmental factors are complex, with large changes in vegetation coverage, precipitation, and soil moisture. This is indeed an important issue to address but further data collection works are needed to make it possible. The research here is based on direct field observations, and the terrain in this area is relatively flat and there is no surface runoff. The focus of this research is to explore the water balance process of precipitation water in unknown environments using a simple and straightforward water balance approach based on direct observation of DSR and other factors.

7 line 254, Do you have measurement of transpiration? I guess you mean root water uptake here? Do you mean all the soil moisture decrease can be attributed to RWUP here?

Response: From April 25th to June27th, there are 31 observed precipitation events in total. The maximum precipitation is 18.8 mm, and the minimum precipitation is 0.2 mm. These precipitation events did not change the decreasing trend of soil moisture. This study is incapable of tell whether soil water consumption during this period is transpiration or plant water consumption (root water uptake). However, the soil moisture drops sharply during the germination period. The transpiration intensity of this period is not the largest in an annual basis. The summer soil transpiration intensity is greater but we still observe that precipitation infiltrates to recharge deep soil. Based on this, we speculate that vegetation consumes a great deal of soil water during the germination period, and the specific amount of water consumed needs further and more detailed experimental observations.

8 line 280, Do you have long climatology to be compared with? In order to determine wet, dry and normal.

Response: As shown in line 90 in the text, the precipitation observation data from 1960 to 2010 in this area show that the average precipitation for many years is 358.2 mm. When the annual precipitation at a particular year is higher than 358.2 mm, it is considered a wet year; if the annual precipitation at a particular year is lower than 358.2 mm, it is considered a dry year.

9 line 287, This is not correct and not corresponding to the content of this section. Please rephrase. It is more "characteristics of DSR ... ..."

Response: Implemented.

10 line 355, It is more water balance analysis than water distribution.

Response: Implemented.

11 line 460, You mean even only 2mm DSR is enough to sustain the local water demand other than sustaining the local ecosystem itself. It is suggested to explain a bit more details in terms of 'sustainability'. Do you consider plant only here or also local water resources for other use?



Response: The DSR that can enter the 200 cm depth soil layer is the remaining water after the consumption by vegetation. If the DSR is greater than zero, it means that precipitation not only can meet the needs of vegetation growth, but also has excess water that can infiltrate into the deep soil layer. When this is the case, we regard the system as sustainable. Otherwise, if the DSR is reduced to zero, it means that the precipitation is not sufficient for satisfying the consumption of the vegetation, thus is unsustainable.

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**Fig. 1.**