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Hydrology and Earth System Sciences
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.

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We thank anonymous reviewer for their constructive comments. The manuscript has been significantly improved by addressing the comments.

Reply: The purpose of this research is to use a newly designed Lysimeter to directly measure the deep soil recharge (DSR) of the ASK plot at the depth of 2m without damaging the in-situ soil layers. Based on the obtained information of DSR at 2 m depth, the change in soil moisture content from the beginning of the experiment to the end of the experiment and precipitation amount, then evapotranspiration can be calculated by using a water balance equation. This is a new method to obtain the soil water flux

information at a targeted depth of soil layer based on direct field observation in arid and semi-arid sandy land when the regional water table is sufficiently deep so will not affect the measurement of DSR. The advantage of this newly designed instrument is that it can be directly installed at a depth of 2 m depth, and there is no need to wrap a soil column like a conventional Lysimeter to block the horizontal flow of soil. There are no outflow rivers and artificial recharge in this area, and precipitation is the only source of water recharge in this area. Considering that 99% of the water consumed by vegetation is evapotranspiration (ET), the residual water remained in plant structure could be ignored. According to the principle of water balance, precipitation = ET+ the change of soil water storage within 2m + the amount of DSR. Precipitation is measured by a rain gauge, DSR is directly measured by this new type of Lysimeter, and the soil moisture storage within 2 m is obtained by the soil moisture probes to obtain the soil volumetric water content, which is multiplied by the thickness of the soil layer to yield the soil water storage. Therefore, ET can be computed using above water balance equation. The experimental plot is flat, and the soil is relatively uniform in the horizontal direction, the coverage of the plot reached 80%, the plot is relatively homogeneous, so we can use one point experimental observation result to represent the entire homogeneous area. However, upscaling of the point ET value to the large-scale ET value should be cautious and not overlooked in the future investigations. The new instrument avoids disturbing the soil layer and directly measured the DSR at the soil interface at a depth of 2 m. In this experiment, five adjacent ASK samples are selected for excavation when collecting the root samples of ASK, and the mean value of the roots of each layer is used for analysis. The purpose of collecting this parameter is to explore the depth of the roots of the ASK and to determine the buried depth of the new Lysimeter. This study provides a new method for measuring the water flux of any depth soil layer(DSR) in arid and semi-arid regions, and based on this information, evapotranspiration could be calculated.

The following are our point-to-point responses to their comments.

1 L16-all other lines: Why do not use the Eddy Covariance System to measure the near surface evapotranspiration? At least the calculated values should be validated by this observation.

Response: This is a very valuable suggestion that can be incorporated in further investigations. Eddy covariance system is a method of measuring evapotranspiration, and this method is mostly used in large ecological observation stations and is usually quite expensive. Up to present, it has not been implemented in most semi-arid areas of China. In the future, we will conduct a similar experiment near an Eddy covariance system station and compare the data with the Eddy covariance system data. L72-other lines: The full text should use the passive voice, because characteristics of Artamisia sphaerocephala Krasch are not developed by itself, but formed by environmental forcing.

Response: Implemented. The text has been revised accordingly.

L133: Since the Artamisia sphaerocephala Krasch developed horizontal root, is it too small to excavate a length and width both of 0.3m soil column or design such size of a lysmeter?

Response: Thank you for the comment. 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 in the root zones(see supply figure A, the conventional Lysimeter; figure B, the new 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. Below the active root zones, horizontal movement of water moisture will be substantially reduced and vertical movement of water moisture starts to prevail. Meanwhile, if a conventional Lysimeter is used, the vegetation needs to be

transplanted into the container, so the soil structure and the vegetation root system will be disturbed. The new Lysimeter of this study is designed to be a small-sized instrument installed at any targeted depth of soil layer below the active root zones in arid and semi-arid regions, without blocking possible horizontal water moisture movement in the active root zones. The plot selected for the experiment is the artificially restored ASK sand-fixing land. The terrain is widely distributed in the Mu Us sandy land and is relatively flat. ASK is the main vegetation species and the soil types is sandy soil. Under these rather “homogeneous” conditions, the experimental result of selected plot may be representative of the ASK sand-fixing land region. However, we do want to point out that one should be cautious for conducting any upscaling of local value of evapotranspiration to large-scale evapotranspiration value. The groundwater is deeply buried in the selected plot (around 7 m deep) so the roots of ASK (which is usually less than 1.2 m deep) cannot tap groundwater for water supply. Therefore, precipitation becomes the only water source supply for ASK to grow. In order to maximize the water taking capability, the ASK root system develops horizontally, making the root layer of the plot relatively evenly distributed in a planar view. The other difference from the traditional Lysimeter is that the measuring face of the new Lysimeter is not only limited to the ground surface. In fact, this newly designed Lysimeter can be embedded in any depths below the active root zones.

L163: How the DSR is measured or estimated should be specified here

Response: The amount of DSR can be obtained directly through the newly designed Lysimeter, please see (Cheng et al., 2017).

L206: It makes sense to analyze the changes of soil organic matter.

Response: Thank you for the comment. Artificially planted ASK has significantly changed the composition of the soil in the studied area and the distribution of soil organic matter in the top soil. We have tested the organic matter and obtained relevant data for soil layer with the upper 200 cm soil profile, and we will add this new informa-

tion and analysis in the revised version of this paper. The soil organic matter of the ASK plot is higher than that of the bare sandy land plot at any specific depths within the active root zone. As the depth increases, the soil organic matter of the ASK plot decreases significantly. The soil organic matter content in the 0-20cm depth soil layer is the highest, reaching 1.92g/kg, and the soil organic matter at the depth of 200cm depth soil layer is only 1.5g/kg. The soil organic matter is certainly an important factor, more soil organic matter distribution information will be studied in details when investigating the ecohydrological aspect of the plants in semi-arid regions. The purpose of this research is to use a newly designed Lysimeter to measure the amount of DSR in order to explore the water balance in arid and semi-arid regions. The soil particle size is measured in this paper for the sole purpose of estimating the height of capillary rise, which will subsequently determine the height of the balance part of the new Lysimeter.

L240: How to physically define the thawing recharge period, germination consumption period, rain season recharge period and plant dormancy period and the frozen soil periodïij§

Response: Thank you for the comment. In this study area, the freeze-thaw period refers to the top soil (2 meters depth) from the beginning of freezing to the complete melting of the frozen soil (from October to April). The germination period begins from the end of freeze-thaw period to the period when branches of ASK are enlarged and one or two new leaves start to grow (from April to June). The rainy season refers to a period of relatively concentrated precipitation experienced after the germination period of ASK plot in this region (from June to October). The analysis of the soil water replenishment in the freeze-thaw period, the germination period and the rainy season in this area helps illustrate the replenishment characteristics and water sources of soil moisture and DSR at different times. We will add references to show soil temperature information based on other studies which have reported soil temperature monitoring experiments in similar plots like this study.

Figure 3 should show the soil temperature curve to identify whether it is soil thawing

period.

Response: We have designed a double-tube apparatus to measure the depth of the freeze-thaw layer depth. The double-tube apparatus consists of a hollow barrel with a vent hole and a rubber tube inside the barrel. First, the hollow barrel with the vent hole is buried vertically in the experimental plot. The upper level of the barrel is at the ground surface and the length of the barrel is 200 cm. The rubber tube filled with water is placed in the cylinder, and it will be extracted at 8PM daily to record the soil frozen state and the frozen depth, which can be used to interpret the thickness of the frozen soil at that moment.

L504: What is "sufficient precision" means? I'm sure that 2.33 will be changed with a different "sufficient precision".

Response: Thank you for the comment, the sufficient precision should be changed to wet year. The wet year means that the precipitation amount of this year is higher than the multi-year average precipitation amount. In 2016, the annual precipitation amount is greater than the multi-year average precipitation amount, so it is regarded as a wet year. Under the conditions of wet year precipitation, the infiltration rate of bare sandy land is 2.33 times of that of the ASK land.

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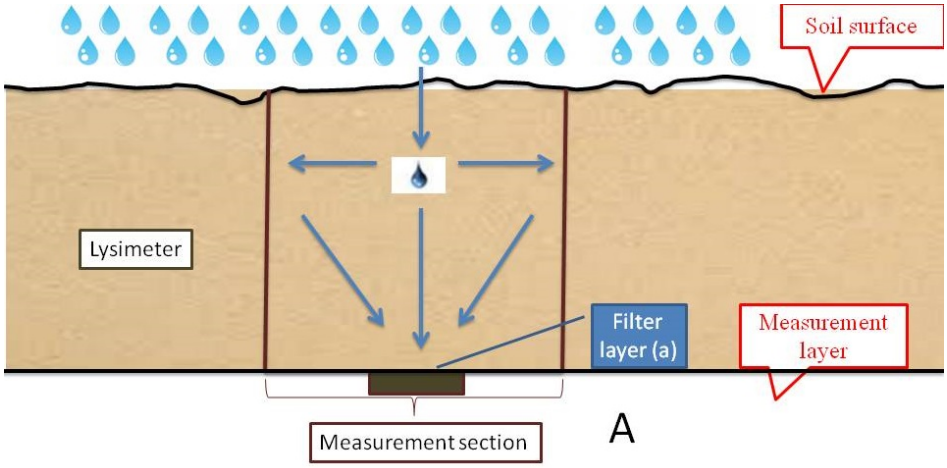
Soil surface
Lysimeter
Filter layer (a)
Measurement layer
Measurement section
A

Fig. 1.

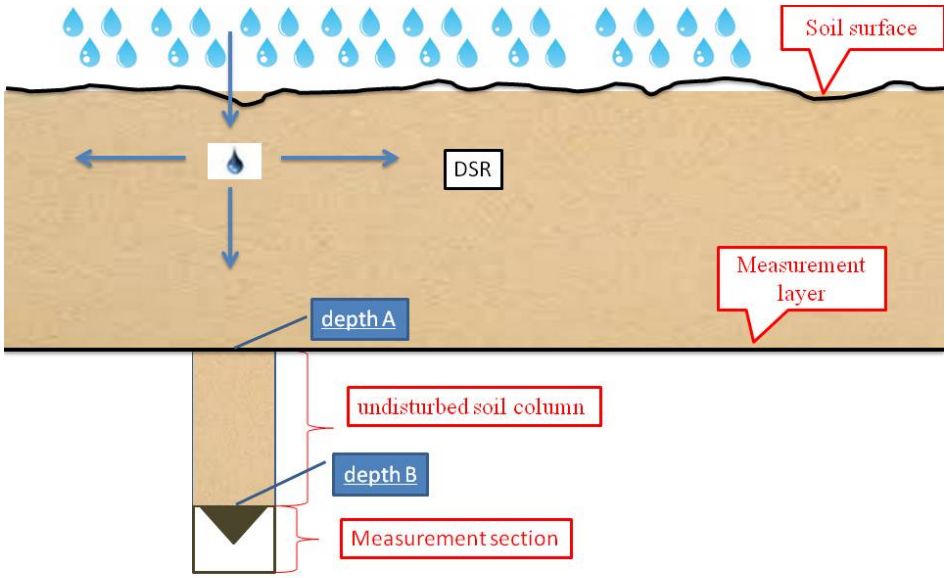
Soil surface
DSR
Measurement layer
depth A
undisturbed soil column
depth B
Measurement section
B

Fig. 2.