July 6, 2022

Memorandum

To: Pro. Lixin Wang, Editor of *Hydrology and Earth System Sciences*

Subject: Revision of hess-2022-4

Response to Editor:

Dear authors,

Thank you for the thorough revision of the manuscript. All three reviewers are generally satisfied with the revision and supported the publication of this manuscript. At the same time, one reviewer pointed out several important issues that require further justification or discussion. I look forward to reading a revised version of this manuscript with the reviewer's additional comments in mind. Thank you!

Yours sincerely,

Lixin

Reply: *Thank you for nice comments on our revision work. Pro. David Dunkerley provided some further comments, and the other two reviewers agreed to accept the paper. We have carefully addressed all the comments and revised the manuscript. The comments have helped us further improve the overall quality of the manuscript. The page and line numbers in the following response refer to the revised manuscript with changes marked.*

In addition, Pro. Juan Pinos helped us polish the manuscript, and we added him in the author list.

Response to Referee #1 (Pro. David Dunkerley):

General comments:

This paper analyses some field data on interception, throughfall, and stemflow in two shrub taxa from the Chinese drylands. The data were collected in 2014-2015. The authors explore some of the behaviour of the interception parameters both among separate rainfalls and at the intra-event scale.

On the whole, the paper is very systematically set out, and generally clear. The work reflects a considerable and commendable effort in instrumenting dryland shrubs to record interception, stemflow, and throughfall. It is good to see such work carried out under natural rainfall, and not rainfall simulation, which generally fails to reproduce key characteristics of natural rainfall events, notably including their durations. Nevertheless, there are some more serious issues with the data and the interpretation of the results, which I explore further below.

Reply: *Thank you for nice comments on our revision work and providing further suggestions. We have addressed all the comments and incorporated them to revise the manuscript.*

1. Comment:

A fundamental issue that the authors do not dicuss is whether it is actually important to investigate water partitioning for individual shrubs (as they do in this paper) or whether area-wide water balance is more significant, given that shrub root systems can extend widely, well beyond the limits of the canopy. In other words, for a given shrub, is it not possible that an important component of the water accessed via the roots is actually from open-field rainfall, and not from stemflow or throughfall? A critical issue here is whether, and to what extent, shrubs can generate metabolically useful stemflow, say, focussed on the root system. Otherwise, shrub canopies do nothing but reduce the depth of rainfall arriving at the root system (owing to interception losses on the above-ground plant parts). This is why extensive root networks become so important. It is also generally considered that small showers of rain are not of great use to shrubs, many of which have deep root systems that access water accumulated in the deeper soil over months or years. Small rainfall events can nevertheless benefit microphytic plants and microbial communities.

The authors need not resolve the issue of individual shrub versus landscape-level analysis, but in their paper, they certainly need to discuss this, and show that they have considered what their results really tell us that is of ecological use, in helping to understand the true water balance of shrublands. For example, what is the actual ground cover fraction covered by shrub canopies, in their study area, and how much soil is exposed directly to rainfall with no interception?

Reply: *This is an insight comment. The study area is in the south fringe of Mu Us sandy land in North China, and the shrub is distributed sparsely with distinct interspaces. The actual ground cover fraction covered by shrub canopies was less than 20%, with the rest of soil being exposed directly to rainfall with no interception (see P.7, Lines 176-178). Therefore, this study focused on the rainfall partitioning (interception, throughfall, and stemflow) of individual shrub. We agree with the reviewer that the small rainfall events are very important for the xerophytic shrubs in drylands. We have measured the soil moisture, water isotopes and root systems. In our next research, we will analyze the soil moisture responses to rainfall partitioning and examine how the shrubs actually make use of small amounts of throughfall or stemflow (see P.26, Lines 615-619). It is also an important further scope to extend the work on individual shrub to the landscape-level analysis (see P.26, Lines 619-622).*

There are also technical issues that I think require further classification and justification.

2. Comment:

The authors derive an estimate of I10max. But as far as I can see, their rainfall data are locked to the time-step of the logger. To find short-term maximum intensities correctly, much higher temporal resolution of the rainfall data is needed. For instance, suppose the logger records the rainfall in the periods 10:00-10:10, 10:10-10:20, etc. Then, if the most intense 10 minutes actually occurred from 10:05-10:15, it will be missed by the logger data, and the maximum intensity recorded will only be about half of the true value.

Reply: *In this study, to better reflect fluctuations in rainfall partitioning components at the intra-event scale, gross rainfall, TF and SF data measured by tipping-bucket rain gauge (with a 0.2 mm resolution) were all aggregated every 10 minutes. The I_{10}* means *rainfall intensity at 10-min interval (i.e., 0-10 min, 10-20 min,….) since the start of rainfall. I_{10_max} means the maximum I_{10} of one rainfall event, not maximum rainfall intensity in 10 minutes (see P.8, Lines 199-202).*

3. Comment:

The authors express canopy water holding capacity (C) by weight gain of branch specimens dipped in water. They then proceed to estimate the canopy storage capacity of entire shrubs by multiplying by the total biomass of the shrub, estimated from an allometric growth model. Why they did not actually weigh some entire shrubs is unclear. In any case, the problem with this procedure is that it is far more likely to be the surface area of the plant parts that governs C, and not weight. The authors need to discuss this, and to defend or justify the procedure that they adopted, based on mass not surface area.

Reply: *First, it is difficult to weigh the entire shrubs due to the high canopy volume. The average height and canopy area of S. psammophila is 3.5 m and 23.8 m^2, respectively, and the corresponding value of C. korshinskii is 2.3 m and 5.27 m^2 (see Table 1). The allometric growth model obtained in our previous work had very high accuracy with R^2 more than 0.92, which can be used to estimate the total biomass of the shrub (see P.9, Line 238 to P.10, Line 241).*

Second, the surface area of the plant parts is an important factor affecting canopy water holding capacity, and the mass of the plant also plays an important role. However, how to accurately obtain the surface area of the plant parts (including branch, stem and leaf) is a great challenge. In comparison, the weight of shrub can be easily and accurately obtained. Therefore, the water immersion method (i.e., based on mass) was widely used in previous studies to measure canopy water holding capacity (see P.9, Lines 231-236).

4. Comment:

Likewise, the authors estimate total shrub stemflow by measurements on a few branches, then multiply the result by the total number of branches on the shrub. This again seems unlikely to be reliable, given that some branches form the outer perimeter of a shrub, and some are more sheltered, internal branches. There are also upper, more exposed branches, and lower, more sheltered branches within the canopy. The presumption that all of these generate the same stemflow flux warrants justification.

Reply: *Three representative shrub plants were selected in each shrub species to measure rainfall partitioning at inter-event scale. The total number of branches was 143 and 218 for selected C. korshinskii and S. psammophila plants, respectively. A total of 53 branches of C. korshinskii and 98 branches of S. psammophila were used to measure stemflow (37.06% and 44.95% of total number, not just a few branches), which covered different types of branches (see P.10, Lines 256-259). The SF volumes measured on the selected branches were averaged to obtain the average volume of SF on the branch scale. We multiplied the average branch SF with the number of branches to obtain the total SF volume from the plant, but did not make presumption that all of these generate the same stemflow flux.*

5. Comment:

The maximum throughfall fractions reported by the authors - around 80% - seem very low in light of the depth of some of the rainfall events (more than 40 mm). I would expect that in such an event, the throughfall fraction would approach 100%.

Consider some rough calculations:

For both shrubs, the value of Cm is about 5 litre.

For C Korshinskii, the canopy area averages ~ 5 m2, so the depth of rain over the canopy required to fill Cm is about 1 mm.

For S psammophila, the canopy area averages ~ 24 m2, so the depth of rain over the canopy required to fill Cm is about 0.2 mm.

Both depths required to fill the canopy stores are negligible in relation to a rainfall of 40 mm, and should have resulted in an interception loss (even allowing for ongoing evaporation during rainfall) of at least 97%. Where did the rainwater go to yield throughfall fractions no larger than 80%? Here I begin to have serious doubts about the reliability of the field data. Perhaps the few throughfall gauges deployed underestimated that parameter? Perhaps intra-event evaporation is actually very significant for these shrubs? The authors need to comment on these possibilities and explain why the maximum throughfall fraction that they report is so low in events in which the loss to canopy storage should be no more than 1% or so of the incident rainfall.

Reply: *We think the reviewer ignores the stemflow, which is also an important component of rainfall partitioning. For the interception loss, besides the water storage capacity of the canopy, ongoing evaporation also accounts for a significant fraction.*

In this study, we conducted solid field measurement work, as indicated by all the three reviewers. The maximum throughfall fractions of C. korshinskii and S. psammophila reached 79.2% and 80.0%, respectively. The maximum SF% approximately tended to be at 12.2% and 5.5% for C. korshinskii and S. psammophila, respectively. The maximum IC% approximately tended to be at 9.0% and 14.5% for C. korshinskii and S. psammophila, respectively (see P.17, Lines 410-421). The obtained results are comparable to those in previous studies (see P.20. Lines 487-489; P.22, Lines 517-522). It is a further scope to measure every component of shrub canopy water balance (see P.26, Lines 614-615).

6. Comment:

These queries lead me once again to recommend that the authors provide more detail on the rainfall events that they recorded. How were separate events delineated? How were intensity and duration related, for these events? Further, given the air temperature and humidity data that the authors had available, did they estimate ongoing wet canopy evaporation losses during rainfall, as a component of the shrub canopy water balance?

Reply: *We have provided the detailed characteristics of the rainfall events, including rainfall amount, intensity and duration in the results (see P.15, Lines 362-376). Although we have measured air temperature and humidity data using meteorological station, it is still difficult to estimate wet canopy evaporation loss which needs microclimate data. It is a further scope to measure every component of shrub canopy water balance (see P.26, Lines 614-615).*

7. Comment:

Finally, of course, some further data on the shrublands themselves would be of use. What was the areal cover provide by shrubs (as distinct from shrub interspaces)? What were the shrub root systems actually like, and can the shrubs actually make use of small amounts of throughfall or stemflow? Though arguing that these aspects of shrub hydrology are important for us to understand, the authors have not really shown that they are significant at all, at least in the many small rainfall events that the authors describe (34% of rainfall events were smaller than 5 mm depth - see line 271).

Reply: *We found that the line number in this comment ("34% of rainfall events were smaller than 5 mm depth - see line 271") refer to version1 (original version) of this manuscript.*

The study area is in the south fringe of Mu Us sandy land in North China, and the shrub is distributed sparsely with distinct interspaces. The areal cover provided by shrubs was less than 20%, with the rest of soil being directly exposed to rainfall with no interception (see P.7, Lines 176-178).

This study focused on the rainfall partitioning (interception, throughfall, and stemflow). We agree with the reviewer that the small rainfall events are very important for the xerophytic shrubs. We have measured the soil moisture, water isotopes and root systems. In our next research, we will analyze the soil moisture responses to rainfall partitioning and examine how the shrubs actually make use of small amounts of throughfall or stemflow (see P.26, Lines 615-619).

6. Comment:

Minor errors:

line 49: interception loss is not comprised of transpiration
lines 328-329: English expression needs to be improved
line 338: 'slighter' should I think be 'slightly'

Reply: *We found that the line numbers in the comments refer to version1 (original version) of this manuscript. In version2 (first revised version) of this manuscript, we have changed "transpiration" to "evaporation" (see P.3, Line 56).*

The sentence indicated in the second comment is confusing, and we have deleted it (see P.18, Line 430). "slighter" has been changed to "slightly" (see P.18, Line 442).