Responses to reviewers' comments point by point

Journal: HESS
Title: Revisiting the Hydrological Basis of the Budyko Framework with the Hydrologically Similar Groups Principle
MS No.: hess-2022-290
MS Type: Research article

Dear Prof. Roger Moussa and reviewers,

We are very grateful to you and the reviewers for the time and constructive comments on our manuscript "Revisiting the hydrological basis of the Budyko framework with the hydrologically similar groups principle" (MS No.: hess-2022-290). The comments have helped improve the paper quite tremendously.

We have carefully studied these comments by Reviewer#1 and revised our manuscript accordingly. The point-to-point responses are listed below. Please note that the comments from the reviewers are in **bold** followed by our responses in regular text. The changes in our manuscript are underlined with red.

We believe the quality of the manuscript can now meet the high standard of HESS and deeply appreciate your consideration of our manuscript.

Sincerely,
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Response to Reviewer#1：

General Comments:

Below are my main comments.

Response:

Thank you for your positive comments. Your suggestions are very useful for us to improve our research. We revised our manuscript according to your comments. The changes in our manuscript are underlined with red. We believe our manuscript improved a lot after the modification. Please see the response below.

Major Comments:

Comment 1:

The English needs work. I only commented on the grammar when I could not understand the text.

Response:

Thank you for regarding the grammar and readability of our paper. We have carefully reviewed the manuscript and made revisions to improve the English language and ensure that the text is easy to understand. We have also had the paper reviewed by a native and subject matter expert English-speaking editor to catch any remaining errors.

Comment 2:

You do not adhere to HESS rules about the notation of variables, so expect to be asked to make edits if the Editor accepts the paper.

Response:

Thank you for bringing this to our attention. We have revised our manuscript to ensure that all variables are appropriately notated in accordance with HESS guidelines.

Comment 3:

The graphs improved.

Response:

Thank you for taking the time to review our manuscript and for your feedback on the graphs. We are pleased to hear that the improvements we made were effective in enhancing the clarity and effectiveness of the graphs.

Comment 4:

The results section is tedious to read. Perhaps combine the Results and Discussion sections to make it livelier.

Response:

Thanks for the good suggestion. As you suggested, we have combined the results and discussion sections to enhance the readability. Further details can be found in the results and discussion section of the revised manuscript.

Comment 5:

The comparison between the results from the categorized catchments and from lumping all catchments in a single category are completely missing from the discussion.

Response:

Thanks for the good suggestion. We have added a discussion in the revised manuscript that presents a comparison between the results from the categorized catchments and from lumping all catchments in a single category, as follows,

"Grouping watersheds based on their hydrological similarities ensures that watersheds within the same category

exhibit similar behaviors in settings with comparable climate, soil and vegetation characteristics (Kanishka and Eldho, 2017a; Sinha et al., 2019). The model developed based on the principle of hydrologically similar groups considers the unique hydrological characteristics of different watersheds and can more accurately simulate the hydrological response in complex watershed systems (Santra et al., 2011; Kanishka and Eldho, 2017b; Jin et al., 2017; Kouwen et al., 1993). As a comparison, in the non_PwM, all watersheds were lumped into a single category and showed a similar hydrological response to changes in watershed characteristics. That non_PwM, as the similar model used in previous studies (Zhang et al., 2018; Liang et al., 2015; Xu et al., 2013), may overlook and oversimplify the intricate interplay between climate, watershed characteristics and hydrology, thereby potentially resulting in less precise predictions of Pw across diverse watersheds." (Lines 255-264 in the revised manuscript)

Comment 6:

I made some additional comments in the attached file.

Response:

Thank you for your thorough review and your detailed suggestion. We have carefully reviewed your comments and incorporate them into our revisions.

Comment 7:

Overall, I stand by my earlier assessment that the paper makes an interesting contribution. I am not familiar with the regression tree methodology, so I cannot judge if the comments by the other reviewer were adequately addressed.

Response:

Thank you for your positive assessment of our manuscript and for your feedback on the contributions made in the study. We are glad to hear that you find our work interesting and valuable. We believe that we have addressed the comments about the regression tree methodology from the other reviewer.

Comment 8:

The organization of individual paragraphs sometimes makes it hard to understand the line of the argument. It is difficult to make suggestions for improvement if I cannot understand the point you are trying to make.

Response:

Thank you. We have carefully reviewed the manuscript to ensure that the organization of individual paragraphs is effective in conveying the line of the argument and that the point being made is clear and concise.

Additional minor comments:

Comment 9:

Line19 " . "

Typo.

Response:

Thank you for pointing out the punctuation error in our manuscript. We have changed the " . " to ". ", and carefully reviewed the manuscript to identify and correct any errors in punctuation.

Comment 10:

Line20 "convert to monotonically decrease with SM, in power functions"

Unclear, please correct grammar.

Response:

Thank you, according to your comments, we had reviewed the sentence and revised it to make it clearer and more concise. The revised sentence now reads, "The SM exhibits a power-law relationship with the Pw values, with increasing SM leading to higher Pw values in dry watersheds (SM ≤ 20 mm) and lower Pw values in humid watersheds (SM > 20 mm)." (Lines 18-20 in the revised manuscript)

Comment 11:
Line48 Table 1

"Zhang et al. (2001): $(\frac{PET}{P})^{-1}$"

Why not simply P/PET?
Response:

Thank you for your question. In regards to Zhang's formula, we agree that $(\frac{PET}{P})^{-1}$ can be simplified to $\frac{P}{PET}$. However, the $(\frac{PET}{P})^{-1}$ is frequently used in the published literature as a way to ensure consistency in the form of the aridity index (ratio between potential evapotranspiration and precipitation) (Zhang et al., 2001; Liu et al., 2022; Xu et al., 2013). Therefore, we have chosen to use the notation $(\frac{PET}{P})^{-1}$ in Table 1 as cited in Zhang et al. (2001).

Comment 12:
Line48 Table 1

"Tixeront (1964), Fu (1981), Zhou et al. (2015a): $(\frac{P}{PET})^{-1}$"

Why not simply PET/P?
Response:

Thank you for your question. In regards to Zhou's formula, we agree that $(\frac{P}{PET})^{-1}$ can be simplified to $\frac{PET}{P}$. However, the $(\frac{P}{PET})^{-1}$ is frequently used in the published literature as a way to ensure consistency in the form of the aridity index (ratio between potential evapotranspiration and precipitation) (Zhou et al., 2015; Moussa and Lhomme, 2016). Therefore, we have chosen to use the notation $(\frac{P}{PET})^{-1}$ in Table 1 as cited in Tixeront (1964), Fu (1981) and Zhou et al. (2015).

Comment 13:
Line87 "turned out to be a more generalized form"
Of what?
Response:

Thank you for your question. To explain this more clearly, in our revised manuscript, we have rewritten this section, as follows,

"Fu's equation is a commonly used parametric equation in Budyko-type formulas due to its versatility and adaptability (Zhou et al., 2015)." (Lines 86-87 in the revised manuscript)

Comment 14:

Line93 “equal the time for all precipitation conversion to evapotranspiration”
The grammar is off, but perhaps also the physics. I believe the residence time will be the average time between the moment a rain drop falls and the moment it returns to the atmosphere as vapor.
It seems to me that for Pw = inf, R = PET. In that case, the residence time would be equal to the watershed storage (expressed in mm water layer) divided by PET.
Response:

Thanks for your consideration. Here, we may have caused confusion by not expressing ourselves clearly. By considering the Pw=inf in Fu's formula, we can obtain R = P - PET. Additionally, because R = P - ET, we can obtain ET = PET (Pw=inf). This implies that as Pw tends to infinity, all precipitation remains within the watershed and all available water is lost through evapotranspiration. The period of water residence equals to the time taken for converting all precipitation to evapotranspiration. In the revised manuscript, we rewrote this section to describe that in detail.

“When Pw tends to infinity, the runoff approaches to the difference between precipitation and potential evapotranspiration. In this scenario, all precipitation remains in the watershed and all available water is lost through evapotranspiration. The duration of water residence equals to the time for converting all precipitation to evapotranspiration.” (Lines 92-95 in the revised manuscript)

Comment 15:
Line93-96 “So, the natural watersheds with a large Pw value may be “non-conservative” (i.e., precipitation is not the sum of streamflow and evapotranspiration), because part of the water remain in the watershed may come from groundwater flow and other hardly or not measurable flows.”
The statement is correct, but it does not follow from the previous text. The sentence therefrom should not start with 'So, '. Some rewriting is needed to develop a coherent argument.
Response:

Thank you. We have modified this statement as follows,

“However, in natural watersheds, it may be difficult to observe Pw approaching infinity since it is nearly impossible for all precipitation to be retained in the watershed. The natural watersheds with a high Pw value may be “non-conservative” (i.e., precipitation is not the sum of streamflow and evapotranspiration), as a portion of the water that remains in the watershed may not be solely from precipitation but may include groundwater flow and other difficult to measure flows. As a result, it may be challenging to accurately estimate the water balance, especially in regions with complex hydrological systems (De Lavenne and Andréassian, 2018; Goswami and O'connor, 2010). As a precautionary measure, this study sets an empirical upper limit of 10 for Pw to ensure that the watersheds in question remain conservative.” (Lines 95-101 in the revised manuscript)

Comment 16:
Line100 “runoff (R, mm yr^{-1}) and corresponding precipitation (P, mm yr^{-1})”
Both appeared earlier in the text. Declare them there. The same is true for PET in the next line.
Response:

Thanks for the good suggestion. In the revised manuscript, the words including runoff, precipitation, and potential evapotranspiration were no longer abbreviated. We modified it as,

“Hydrological data for modelling, including runoff and corresponding precipitation data, were collected from published literature (726 samples listed in Supplement 1, Fig. 1).” (Lines 104-105 in the revised manuscript)

Comment 17:

Line101 “globally published datasets”

If the data are on the web, they are globally published by definition, are they not?

Response:

Thank you for bringing this to our attention. We used the term "globally published datasets" to refer to the fact that the 726 samples data used for the study were collected from published literature (corresponding literature is listed in Supplement 1) and was available to the global scientific community. To avoid confusion, we have modified this statement as follows,

“Hydrological data for modelling, including runoff and corresponding precipitation data, were collected from published literature (726 samples listed in Supplement 1, Fig. 1).” (Lines 104-105 in the revised manuscript)

Comment 18:

Line106-107 “we derived the Pw values according to Equation 1.”

For each separate year, a moving multi-year window, consecutive, non-overlapping periods of x years each, or for the entire observation period? What did you do if the latter was not the same for different catchments?

Response:

Thank you for your question. The observation period corresponding to the data we collected has been listed in Supplement 1. We calculated the Pw values for each catchment using the annual average R, P and PET data for that observation period. The calculated Pw values from different watersheds are annual mean values and have consistent time step. To explain this more clearly, in our revised manuscript, we have rewritten this section, as follows,

“Using collected and extracted the annual average runoff, precipitation and potential evapotranspiration data for the observation period, we calculated the annual water yield coefficient (R/P) and aridity index (P/PET) for each sample. Then, we derive the annual average Pw value of each sample for the corresponding period according to Equation 1.” (Lines 110-113 in the revised manuscript)

Comment 19:

Line115 “(m>10) and unrealistic runoff rates (m<1)”

What is m?

Response:

Sorry for neglecting. The variable denoted by “m” in the original manuscript has been revised to “Pw” to accurately represent the intended variable, i.e., watershed characteristic parameter. (Lines 121 in the revised manuscript)

Comment 20:

Line129-130 “North America (west, southwest, midwest, northeast, southeast, except of the USA), South America, Africa, and Europe.”

Asia, Australia?

Response:

Thank you for your question. Our selection of geographic regions was based on the availability of data from GRDC observation data. Due to limited data availability in Asia and Australia, we were unable to include these regions in our study. In this regard, we have added the following contents in the revised manuscript,

“Due to the limited availability of GRDC observation data and simulation calculations in Asia and Australia, these regions were absent in the division of global geographic regions.” (Lines 135-136 in the revised manuscript)

Comment 21:

Line144 “the watershed characteristic variable”

Which one? Or should it be plural and is it referring to those variables in Table 2? Then, just say so.

Response:

Thank you for your question. The "watershed characteristic variable" in this sentence is not limited to the variables listed in Table 2, but rather encompasses any characteristic of the watershed that could potentially impact its hydrological response. To explain this more clearly, in our revised manuscript, we modified it as,

"Therefore, the relationship between Pw and any watershed characteristic variable does not change substantially in a hydrologically similar group." (Lines 149-150 in the revised manuscript)

Comment 22:

Line148-149 "Three watershed characteristic variables — surface soil moisture (SM), rainfall seasonality index (SI), and fractional vegetation cover (FVC)"

Repetitive. Simply refer to Table 2.

Response:

Thank you. In the revised manuscript, we modified it as,

"We used SM, SI and FVC for classification." (Lines 153 in the revised manuscript)

Comment 23:

Line162 "a polynomial"

Of what (maximum allowed) order?

Response:

Thank you for your question. We did not set maximum allowed order for the polynomial model.

Comment 24:

Line163 "the PwM is modeled as a function as,"

It does not appear in the equation!

Response:

Thank you. In the revised manuscript, we modified it as,

"For each hydrological group, the Pw value is modeled as the function:" (Lines 167 in the revised manuscript)

Comment 25:

Line171 "$non\_Pw = a_1 \times SM^2 + a_2 \times SM + b_1 \times FVC^2 + b_2 \times FVC$ (3)"

Why did you leave out the seasonality index?

Response:

Thank you for your question. In PwM, the variable SI is utilized for classification purposes, but it is not involved in the calculation of Pw. To ensure the consistency of variables between PwM and non_PwM, SI was not included in the non_PwM model.

Comment 26:

Line177 "term"

It is a constant or a variable, but not a term.

Response:

Thank you for your comment. To avoid any potential confusion, as you suggested, we have changed the "term" to "variable". (Lines 181 in the revised manuscript)

Comment 27:

Line306 "Discussion"

In the revision you repeated the procedure for the different categories of catchments for the entire population of catchments. You should compare the resutls to show the added value (or lack thereof) of stratifying the catchments into different categories. But you do not discuss this at all in this section.

Response:

Thanks for the good suggestion. We have added a discussion in the revised manuscript that presents a comparison between the results from the categorized catchments and from lumping all catchments in a single category, as follows,

"Grouping watersheds based on their hydrological similarities ensures that watersheds within the same category exhibit similar behaviors in settings with comparable climate, soil and vegetation characteristics (Kanishka and Eldho, 2017a; Sinha et al., 2019). The model developed based on the principle of hydrologically similar groups considers the unique hydrological characteristics of different watersheds and can more accurately simulate the hydrological response in complex watershed systems (Santra et al., 2011; Kanishka and Eldho, 2017b; Jin et al., 2017; Kouwen et al., 1993). As a comparison, in the non_PwM, all watersheds were lumped into a single category and showed a similar hydrological response to changes in watershed characteristics. That non_PwM, as the similar model used in previous studies (Zhang et al., 2018; Liang et al., 2015; Xu et al., 2013), may overlook and oversimplify the intricate interplay between climate, watershed characteristics and hydrology, thereby potentially resulting in less precise predictions of Pw across diverse watersheds." (Lines 255-264 in the revised manuscript)

Comment 28:

Line319 " . "

Typo.

Response:

Thank you for pointing out the punctuation error in our manuscript. We have changed the " . " to ". ", and carefully reviewed the manuscript to identify and correct any errors in punctuation.

Comment 29:

Line338-339 "the background value"

What do you mean?

Response:

Thank you for your question. To make it clear, we have modified this statement as follows,

"These results indicate that the relationship between Pw and FVC may be stronger than what was previously believed, and this relationship varies across different groups characterized by specific combinations of FVC and SI. This confirms that climate, soil moisture, and vegetation cover are not independent factors affecting the water balance (Gan et al., 2021; Yang et al., 2009). Coupling vegetation with other catchment properties resulted in greater Pw variations (Gan et al., 2021)." (Lines 234-238 in the revised manuscript)

Comment 30:

Line342 "the Pw values in the watersheds with middle-density (0.2<FVC≤0.5, Fig. 2f) and the high-density (FVC>0.5, Fig. 2g) vegetation coverage monotonically decrease with FVC."

Vegetation cover decreases with increasing vegetation cover?

Response:

Thank you. It could be that we are confused in our presentation. To explain this more clearly, in our revised

manuscript, we have rewritten this sentence, as follows,

"However, our study reveals a positive linear correlation between Pw and FVC in the IN_{WMS} (Fig. 2e) and IN_{WE} groups (Fig. 2h), whereas a negative linear correlation is observed in the IN_{WMM} (Fig. 2f) and IN_{WML} groups (Fig. 2g). Only in the IN_{WP} group, the relationship between Pw and FVC is not significant." (Lines 231-234 in the revised manuscript)

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