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Dear Editor,

Enclosed, please find the manuscript entitled "**Landscape structures regulate the contrasting response of recession along rainfall amount**" by Lee et al. for the second review.

First of all, we would like to express our sincere appreciation for the editor and reviewers' patience and constructive feedback. In this revision, we have rewritten the discussion and summary sections to concisely express our thoughts. We carefully checked and clarified any unclear or confusing statements, and also had a native English editor polish the manuscript. We hope that these revisions will clearly convey our findings.

In this review, referee #1 asked us to address the decorrelation method's ability to separate the dependency between recession parameters completely, in addition to solving the unit effect between a and Q. We addressed this point in sections 2.2, 4.1, and the summary, and made revisions accordingly. We also want to thank referee #2 for his/her help in clarifying our findings and pointing out confusing statements. In due course, we comprehensively rewrote the discussion and summary sections, fixed any typos and grammatical errors, and rephrased unclear statements.

Please feel free to contact me if you have any questions. Thank you for your assistance.

Sincerely,

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Reply to Reviewer #1's Comments

GENERAL COMMENTS

This a much-revised version of the paper I previously reviewed entitled "Landscape structure and rainstorms swing the response of recession nonlinearity".

My main criticism of the original paper was of the interpretation of the causes of the variability in the recession parameter "a", which I said was flawed due to variability of "a" being unit-dependent as a consequence of the dependence of "a" on the power-law exponent "b". To address this issue, the authors applied the "decorrelation" method recommended by Dralle et al. (2017). I am skeptical that the decorrelation really solves the underlying problem such that causal mechanisms can confidently be attributed to variability in "a" when "b" varies. Biswal (2021) describes how the decorrelation does not completely dissociate "a" from "b" and concludes that the method of fixing "b" as a constant is preferable. I think the question that remains is, for the specific cases that the authors analyze, to what degree does the decorrelation method not solve the underlying issue but yet does improve the situation sufficiently that the interpretations that the authors make are generally valid, albeit with some uncertainty. This topic I believe is still an open research question, therefore I am open to having this paper be published. However, the authors should both acknowledge the arguments made by Biswal (2021) and acknowledge that there is methodological uncertainty in their analysis.

Overall, I am impressed with additional work that has been done. The introduction is much more thorough. The review summarized in Table 1 is, by itself, is a valuable contribution to the literature.

I think the English does not meet the standard of a HESS article. I sometimes guessed at the authors intended meaning. Improvement is needed throughout the entire paper, so I did not attempt to suggest edits. I am recommending major revisions primarily largely on the need to improve the English but also on some undeveloped arguments.

Reply: We appreciate that the Referee #1 recognizes our efforts on the revision, particularly for the application of the decorrelation method. We fully agree that this issue of dependence between a and b in power-law is quite open and needs more studies to solve. We added the following sentences in sections 2 and 4, and the summary to clarify the potential uncertainty and why the decorrelation method can't dissociate a and b completely.

In section 2.2 [L109-110], we added, the sentence, "<u>Notably, since nonlinearity is</u>

dimensionless, $\hat{a}$ is inherently strongly dependent on the unit of *Q* and *b* via fitting (see details in section 2.2.2)." to clarify the originality of the dependence.

In section 2.2.2 [L163-167]: We added the sentences, "Although the decorrelation method can reduce the unit effect and dependency on *b*, Biswal (2021) argued that the dependency of $\hat{a}$ and *b* can't be fully decoupled, and retrieving parameters from the power law and fixing *b* is preferable. Obviously, decoupling the dependency of $\hat{a}$ and *b* in recession is unsolved and challenging and necessitates further study. Nevertheless, after the decorrelation process, the number of catchments with a high correlation between *a* and *b* (R^2 > 0.1) decreased from 9 to 2, apparently mitigating the unit-effect and dependency of *b*."

In summary [L371-373]: We added, "Note that *a* and *b* are inherently dependent, so some uncertainty might be involved. Even so, both parameters, whether derived using the point-cloud or individual segments (Fig. 4), present similar fluctuations among catchments, which supports our arguments." We introduced Biswal's point to the readers and demonstrated the improvement in dependence through decorrelation in our study.

In this revision, the undeveloped or unclear arguments raised by the editor and referees were carefully reviewed and revised for accuracy of wording. Also, our manuscript and response were fine-tuned by a native speaker. We have also carefully checked all unclear arguments and grammatical errors in order to meet the standard of the high-ranking journal, HESS.

LINE-BY-LINE COMMENTS

45-47: The transition from 3 to 1.5 is not due to groundwater being "vertically sourced from different hydraulic properties". The transition is due to the influence of the upstream boundary condition becoming a factor as the aquifer drains.

Reply: Yes. We rephrased as "For parameter *b*, hydraulic theories indicate that *b* decreases from 3.0 to 1.5 during the transition from early to late recession as the influence of the upstream boundary condition becomes a factor when the aquifer drains in wet conditions (e.g., Rupp and Selker, 2006)." [L39-41]

211 and 229: Should this be Table 2?

Reply: Yes. We corrected it, please see [L200] and [L215].

255: See also Roque et al. (2022) who discuss the role of contrasting shallow and deep geologic layers on the recession parameters.

Reply: Thanks for providing the reference that can help deepen the discussion of the geological aspect. We rephrased the statement as follows, "Perhaps, other controlling factors, such as geological structure (i.e., connectivity between the deep aquifer and the stream, heterogeneous hydraulic properties, and/or the interface slope between the shallow and bedrock layers, see Roques et al., 2022) or land cover (Tague and Grant, 2004), might alter recession behavior as well." [L250-254]

301-302: I do not see why, necessarily, the "inverse relationship between H and 'a' confirms that the hydraulic parameters vary markedly with depth". H is the vertical distance between the highest and lowest points in the basin, correct? It is a measure of the surface topography, not of the underlying geology. This statement requires further explanation.

Reply: We have revised the section, and we would like to point out that the inverse relationship between H and a has been explained by the following sentences, "Flow-path height, *H*, is directly linked to the water table depth in the homogeneous hillslopes. A steeper hillslope corresponds to permeable soils with higher *H*, leading to a deeper and longer groundwater flow system and slower drainage (Karlsen et al., 2019)." [L281-283].

325-326: I do not follow the explanation of why "a" would decrease with large storms. Why would drainage be slower from a major typhoon? What is meant by "overwhelm the effect of flow velocity?" Could not expect the opposite? During a heavy storm, there is more drainage from the upper layers, which are likely to be more conductive. There will also be more surface storage being drained, which I would think would be associated with a high "a". Table 1 also show more studies found negative than positive relationships of "a" with measures of initial storage. How did those studies interpret the negative relationship? I think Section 4.3.1 requires additional explanation.

Reply: We apologize for the confusing statements in the section. We have revised it to clarify the explanation of why "a" may decrease with large storms. The revised sentences are, "Harman et al. (2009) demonstrated that the recession coefficient can be expressed as $a = V_0/R^{b-1}$ (where V_0 and R represent the mean of the velocity distribution of hillslope flow and rainfall rate, respectively). In the case of heavy rainfall, the increase of R is much larger than that of V_0. The effect of this disproportionate rainfall input increase on a could offset the increase in flow velocity, resulting in a negative correlation. Moreover, Biswal and Nagesh Kumar (2014) used a geomorphological recession flow model $a \propto c/q^{b-1}$ (where c and q represent the celerity and rate of channel flow, respectively, and which is similar to Harman's theory) to explain why "*a*" is negatively correlated with "*q*." To sum up, the negative correlation between coefficient a and rainfall amount (e.g. peak flow and prior soil moisture) is consistent with the literature and is prevalently in most regions (also see Table 1)." [L312-319]

Table 1: It would be helpful to the see the authors' study placed in this table, too.
Reply: We added our study in Table 1.

Figure 9: It is not clear to me what the arrows are for in the lower three panels.
Reply: We have made the arrows more prominent and added a caption to explain their significance as follows, "Correspondingly, the bottom row shows how their recession parameters (or regressive line) in recession plots would move from light (dashed line) to heavy (solid line) rainstorms."

Reply to Reviewer #2's Comments

The revised version of the paper did take into account the methodological recommendations of the reviewers. However, the summary and discussion remain almost unchanged, i.e. the methodological changes are not reflected in these parts of the paper, which is surprising. In particular, the numbers in the discussion are not updated, which seems strange. The discussion and the summary of the paper do not convey, which of the findings are new, which ones are specific to the chosen case study and how the findings could be related namely to the climatic conditions. There are no clear conclusions, i.e. we do not know if the study found the same results as at other locations or if there are specific new insights. Some more comments are in the annotated pdf.

The language is critical, at instances hard to understand. In the annotated version, I highlighted some instances but those are by no means exhaustive.

Reply: We appreciate Referee #2's constructive comments and kind help in clarifying our unclear statements. Our response to this main concern is as follows:

In this revision, the discussion and summary were totally rewritten to express our work precisely, but the main story remains. Although we updated the parameter values using the decorrelation method, their response to various environmental variables has not changed significantly. Therefore, our original discussions and conclusions are not greatly affected. Nevertheless, we have updated the opinions raised by referee #2 in our discussions and summary. The main contribution of this study is to demonstrate that: "The results showed that *a* and *b* respectively increase and decrease with *L*/*G* (the ratio of flow-path length to gradient), particularly in small catchments. Additionally, corroborating previous studies, *a* decreased significantly with rainfall amount. However, nonlinearity increases with rainfall amount in larger catchments but decreased in small catchments."[L15-18] Additionally, we have compiled the literature on empirical recession behavior and identified the relationships between recession behavior and environmental factors, presented in Table 1, which should be important for further recession studies.

We would like to apologize for any confusion caused by our limited English proficiency, which may have made it difficult to understand our work. We are grateful to Referee #2 for drawing our attention to sentences with unclear meaning. We have not only rephrased those sentences but also thoroughly revised most of the text. Additionally, we have enlisted the help of native speakers to extensively edit the manuscript, and we hope that it now presents our arguments more clearly.

COMMENTS (***Line number in the previous annotated pdf**)

12-14: you do not mention the methodological changes between the first and the revised version.

Reply: We point out the decorrelation process in L15

65-67: not good writing practice

Reply: Rephrased.

67-68: unclear synthesis of the different theories, so what is actually the contradiction?

Reply: We have revised the paragraph in [L39-44] to better convey the contradiction. It now reads as follows: "For parameter *b*, hydraulic theories indicate that *b* decreases from 3.0 to 1.5 during the transition from early to late recession as the influence of the upstream boundary condition becomes a factor when the aquifer drains in wet conditions (e.g., Rupp and Selker, 2006). Spatial heterogeneity theory demonstrates that b only slightly increases with a wet antecedent condition (Harman et al., 2009). However, drainage network theory indicates that *b* increases with storage while the downstream receives more subsurface flow contribution but decreases with storage as the downstream receives less (Biswal and Nagesh Kumar, 2013)."

73: what is this?

Reply: We replaced "landscape regimes" with "regions" [L63].

86: you mean landscape characteristics?

Reply: Certainly. In fact, using the term "characteristics" is also an appropriate way to convey the broad sense in this context. However, given that we already mentioned L/G in the abstract and summary, we will retain the term "variables" here.

88: how? such a general hypothesis is not very useful.

Reply: After careful consideration, we realized that the general hypothesis may not be particularly useful in this context. As such, we have decided to eliminate it from our study. Thanks for bringing this to our attention.

135: why do you bring in the water balance equation here? this was not mentioned in the first round but in fact, it does not add anything here; it is rather confusing since E influences how streamflow reacts to a precip event and how much water will percolate and recharge groundwater, so it clearly has an influence on recessions; but: recession analysis is supposed to analyse how baseflow recedes in absence of input;

simply remove the comment on P and E

Reply: Thanks for the valuable feedback regarding our use of the water balance equation in this section. We have removed the water balance part and revised the beginning of section 2.2 to better reflect the storage-outflow relationship. It now reads: "The storage-outflow relationship is typically described by a power law if treating the catchment as a black box. The representative storage is, in fact, composed of many aquifers and thus exhibits a non-linear relationship". [L97-98]

138: all should have same units

Reply: Evapotranspiration has been removed accordingly.

139: Q=mSn, always or only during the recession?

Reply: Please see above.

141: well, P is small or zero by definition of a recession, but E is definitively not!

Reply: Comment on P and E has been removed.

177-178: this does not add anything and is wrong, recession (the true recession part) is only baseflow; but if you let the recession start at peakflow, part of the segment contains subsurface flow that is not baseflow (groundwater)

Reply: The treatment of recession segments depends on the purpose of the study. To ensure that groundwater dominates the recession signal, the recession segment is typically chosen to lag a few days after the peak flow (e.g., Biswal and Marani, 2014). However, other studies consider starting the recession segment from the peak flow, as fast-flow processes (such as subsurface flow) may also contribute to power law recession behavior (e.g., Dralle et al., 2017). Upon summarizing the empirical power law recession studies in Table 1, we carefully checked the initial time of the recession segment in Table S1. Table S1 indicates that out of the 24 studies, 15 of them had a lag time of less than 1 day for the recession segment.

195: English

Reply: Eliminated

205-207: reference?

Reply: We moved the reference, Roques et al. (2017), from [L155] to here [L156].

207-208: reference? how is k estimated, over all recessions or per recession? cannot simply refer to another paper, we need this information here; if it is estimated accross all recessions, how are they pooled together? if it is estimated per recession, then, of course, we have a new time-varying parameter.

Reply: The decorrelation method can be applied to either all recessions (point-cloud) or individual segments. In our study, we applied this method to both cases. For further details and a more comprehensive explanation of our methodology, please refer to Dralle et al. (2015), which is included in the reference list [L159].

216: English

Reply: Rephrased. Now it reads, "The streamflow recession plots of catchments W9, W5, and W8, as examples, are illustrated in Fig. 2." [L173]

232-233: small = asymetric; before you said skewed, what is the difference?

Reply: I apologize for the confusion. Now it reads, "The small difference between the median and mean suggests a relatively symmetric distribution." [L184-185]

240: English

Reply: Please see below.

248: deviation from what?

Reply: Please see below.

249: english!

Reply: It appears that Referee #2 had some concerns with the clarity of our original paragraph. We have since rephrased the paragraph to provide a clearer explanation. The revised paragraph now reads as follows: "Notably, when the drainage area is larger than 800 km^2 (W19 and larger), the point-cloud-derived coefficients become similar to the third quantile of the distribution of individual segments. For nonlinearity, the values derived from the point-cloud are consistently close to the lower limit of the distribution of the individual segment-derived values and the median and interquartile range of nonlinearity derived from individual segments are irrelative of drainage area. These distinct differences between coefficients and nonlinearities from the two fitting methods make comparison and interpretation difficult. The details of the recession characteristics for each catchment can be found in Table S4." [L192-197]

252-253: is this a common finding or not?

Reply: This finding is getting recognized recently (perhaps since 2017). We addressed this point in section 4.1. [L235-236]

254: referred

Reply: corrected.

256: english, the title does not mean anything

Reply: We rephrased it as "*Relationships between recession parameters and event/landscape variables*" [L198]

258: hydrometric forcing: what is this? hydrometry refers to the measurement of streamflow

Reply: You are correct that "hydrometry" refers to the measurement of streamflow. However, in the given sentence, it seems that "rainfall forcing" would be a more appropriate term to use [L199].

259-261: english: the correation is not significant, not the values themselves

Reply: We've rephrased it, now it reads, "As for initial event conditions, the 7-day antecedent precipitation, AP_{7day}, defined as the seven-day rainfall amount prior to a rainstorm, was not correlated to *a*, nor were other *AP* period lengths (3-, 5-, 14-, and 30-day)." [L203-205]

274: on what?

Reply: Typo and corrected [L209-210]

274-276: English

Reply: This is a redundant sentence. We've removed it.

294: this 4.1 does not discuss any link to "subtropical"

Reply: We apologize for any confusion. It seems that there have been a mistake. We've eliminated "subtropical".

295: coefficients

Reply: Thank you. The whole discussion has been rewritten.

299-301: what is new here? compared to literature?

Reply: While the concept that landscape characteristics could influence recession behavior is not a new idea, our study provides a novel approach for explicitly representing the aquifer and assessing the relationship between landscape structure and recession coefficients. Specifically, we introduced the L/G ratio as a useful index for analyzing recession behavior. We rephrased the sentence and it now reads "Taken together, these data demonstrate how landscape structure, particularly drainage density and flow-path-associated variables, can affect the recession coefficient. The findings presented in Table 2 corroborate this (discussed more in Sect. 4.2)." [L242-243]

311: this part is not specific to the the selected catchments but a general methdological consideration; and it is unclear how it relates to text above

Reply: This paragraph has been rewritten and the comment has been addressed in this revision.

348: English

Reply: Sorry for the any confusion. The statements were revised.

435: English

Reply: Please see below.

435-441: your perceptual model or a hypothesis developed previously ?

Reply: The perceptual model was developed by the authors of this study. We've rephrased the statement as follows, "The above two sections have demonstrated the influence of landscape and rainfall amount on streamflow recession behavior. Thus, a perceptual model which demonstrates the interactive regulation of landscape structure and rainfall amount on recession nonlinearity is introduced (Fig. 9)." [L339-341]

442: Type B to A: what is this?

Reply: We rephrased the sentence as follows, "Along the spatial heterogeneity dimension (from Type B to A, with increasing drainage area), additional perched storages respond increasingly with rainfall amount and thus enhance the recession nonlinearity." [L346-347]

452: new summary does not reflect new methods

Reply: Replied above. Also, the summary was thoroughly revised.

455: what is this "catchment events"? where, in what climate?

Reply: Please see below.

458 and 459: english!

Reply: We've rephrased the statement as follows, "This implies that it is not possible to infer recession characteristics by comparing the parameters found in the literature.

The coefficient and nonlinearity derived from point-cloud are considerably larger and smaller, respectively, than the median of individual segments." [L357-359]

460: inference is reserved to specific techniques, not correct use

Reply: Replaced "inference" with interpretation.

462: avoid abreviations of this case in the summary, make it more stand-alone

Reply: Thanks for the suggestion. In this revision, the only abbreviation is "L/G".

462-463: what is new here compared to previous work?

Reply: Please see below.

463: in the summary, should be made clear again what the recession coefficient is (the nonlinear recession has two parameters)

Reply: Suggestion accepted. Please see below.

470-471: at this stage, we would like to see answers, not hypotheses

Reply: Agreed and revised accordingly.

471: english! landscape cannot have preferences

Reply: Corrected.

473: response to what?

Reply: Please see below.

473-474: do not understand

Reply: The above 5 comments are related to the summary. The previous version of the summary was not clear and organized, which may have made it difficult for the referees to understand the arguments presented. We have revised the summary to address these concerns and provide a more detailed explanation of our findings.

1. The coefficient and nonlinearity derived from point-cloud are considerably larger and smaller, respectively, than the median of individual segments.
2. the coefficient increases with L/G and nonlinearity decreases with L/G significantly in small catchments. This likely reveals that both spatial heterogeneity and hydraulic properties regulate recession simultaneously.
3. Further, rainfall amount also plays a dominant role in estimating parameter a. It decreases with rainfall amount for all catchments.
4. The contrasting response directions of nonlinearity to rainfall amount could be

found along the dimension of spatial heterogeneity (drainage area)

5. landscape structure (spatial heterogeneity and hillslope hydraulics) may determine the recession behavior via various aquifer settings, and the rainfall amount tunes the magnitude of recession nonlinearity.