

Dear anonymous referee #2,

first of all, thank you very much for reading our revised manuscript and going into so much detail again:

The manuscript entitled “Combining traditional nutrient load analysis and storm hydrograph separation unveils unexpected patterns in event-driven nutrient export dynamics in a rural headwater catchment”, by Ditzel et. al. present normalized cumulative load functions as a promising tool to characterise solute export patterns in total discharge and event water. This combined approach presents an interesting perspective and it is certainly valuable to the readers of HESS. However, the discussion lacks thorough integration into the literature. So far, the results and discussion section reads more like a results section with additional explanations by the authors. Single processes like infiltration-excess overland flow are cited, but these citations are not specifically explained, nor the context in which these studies came to their conclusions. One example is the sentence in Lines 377-378: “A difference in the pattern of nutrient mobilisation was expected and follows the literature (Frazar et al., 2019; Ebeling et al., 2021; Spill et al., 2024).” This does not clarify which differences were expected, why it was expected, what the cited papers have shown, and in which context. This is also true for the statements of something being unexpected. I am not arguing against some of these results being unexpected, but this needs to be carefully explained and backed up by literature. I am further not convinced results are per se “unexpected”, just because they have been shown with a novel approach, this needs further backing up by literature.

Speaking of details, please keep in mind that the whole manuscript is based on a somewhat exploratory method. Therefore, we believe the discussion section of the manuscript reads more like a detailed result section to you. This is not due to a disagreement about good scientific practice, but a matter of presentation and style. For example, we do not believe that we have to explain every process like infiltration-excess to readers from a hydrological background, which is the overwhelming audience of HESS. Furthermore, it is in our opinion not necessary to elaborate every reference in great detail as long as the stated argument can be reconstructed by the cited literature.

Since we agree that “unexpected” is somewhat debatable and strongly depends on the viewpoint of the reader, we changed the title once more:

“Combining traditional nutrient load analysis with storm hydrograph separation reveals concealed patterns in event-driven nutrient export in a rural headwater catchment”

Overall, thank you very much for the vivid discussion! This was really helpful for increasing the accuracy of our manuscript and we acknowledge every comment you made in both iterations of the reviewing process.

Line-by-line comments:

Lines 32-33: I suggest adding Bieroza et al. (2023)

Thank you for providing this additional information, we added the article of Bieroza et al..

Line 63: Point behind “2018)”

Added the Point.

Line 89: Comma behind “monitoring period”

Added the coma.

Fig. 1: Elevation in the legend should be shown as a gradient or include all colours. Currently, 13 colours are shown in the map, but only 6 colours are shown in the legend.

We added all elevations in the legend entry (we used a discrete scaling to visualize the elevation).

Line 100: I'm confused. From when to when was the setup removed? Until 07/2021 does not indicate a starting date. Or do you mean 07/2022?

This is a typo, we changed it. Thanks for mentioning!

Line 127: Remove redundant point

Redundant point removed

Line 211: value or shows, not values and show (grammar)

Sentence was corrected

Lines 233-241: Nice, but not part of the Methods. I suggest shifting that to the discussion

We shifted this paragraph to the discussion.

Line 246: I see an event with 18.9 mm (#13) and 30 hours (#7). Please check your numbers. Same for the mean given below.

We think that there is a misunderstanding, we were referring to most of the events while being aware of events #13 and #7. We added a sentence for a more detailed description of table 1: "However, events number 7 and 13 stand out with a duration of 30 hours and respectively a total precipitation of 18.9 mm."

Line 267: What are the < 70% referring to?

We mixed up a number, the correct range of event water portions was added : "(25-30 %)"

Line 279: If you say it was not expected, this needs to be explained. Not only why this might have occurred, but also why it was not expected.

We added some explanations why we did not expect the results of the cluster algorithm:

The behavior of the green and blue cluster and especially of event 5 and 12 was not expected, since high precipitation usually leads to higher event water portions and vice versa.

Line 292: (blue, green) – red is missing

Thank you very much, we added "red" to the description.

Line 303: delete "also"

Done

Line 305: Is there a reference for that?

We appreciate the reviewer's suggestion to provide a reference. However, we are not aware of a publication that explicitly states this relationship. The interpretation follows directly from the mathematical definition of the metrics used in this study. High volatility describes situations in which the discharge peak is concentrated within a short fraction of the overall event duration. This distinction therefore follows directly from the mathematical behavior of

the discharge function rather than from a previously published conceptual definition. We changed the sentence to add some information:

“A high rate of change can be attributed to the abruptness of changes in the discharge function, while high volatility, as defined in this study, describes situations in which discharge peaks are concentrated within a short fraction of the overall event duration”

Line 394: Just to be sure: is this the old #10 or the former event #12 that is now numbered 10 in the updated version of table 1?

Thanks for mentioning! You’re right, this refers to the old # 10. We deleted the sentence since it is not useful anymore.

Lines 395-396: I doubt this is a significant difference. Median values look very similar, and I would be very careful not to overinterpret this, especially given that the value on 0.27 is marked as an outlier.

We removed “strong” from the sentence, but the increase in value ranges is visible. Of course, statistic significance cannot be robustly established with such a small sample size, we are aware of this.

Fig 8: The figure description needs to be informative on its own, even without reading the manuscript. “Area under the curve” needs to be further specified (which curve?)

We added further information to the figure description

Lines 407: Again, I am not arguing against the results being unexpected, but it is not sufficiently explained here. It should also be explained with literature.

We added some literature by shifting the mentioned paragraph from the method to this position. We also added some explanation and mitigated the “unexpected” part: “The changes in the distribution of NCL functions when using separated discharge instead of the total discharge, especially for NO₃⁻ loads, were not apparent, because the total discharge signal masked stronger dilution or flushing tendencies. This shows the potential of the proposed method for contributing to better understanding nutrient export processes in headwater catchments”

Lines 428-29: Please explain the criteria of Lee et al. (2002).

Added explanation: “Despite flushing tendencies, a NCL curve clearly showing a first-flush, could not be observed in this dataset. A first-flush would occur if a maximum distance of 0.2 between a function and the bisector could have been observed (Lee et al., 2002)”

Lines 431-432: I would not necessarily agree. There can be very different explanations for dilution patterns. Deeper groundwater, which dominates during low flow, might have higher concentrations as compared to water activated from shallower or proximate zones (for example, if fertilization rates have decreased over time and the older front of high nutrient levels has percolated down, e.g., Ehrhardt et al., 2019; Winter et al., 2021; Zhi and Li, 2020). Or you might have a point source that becomes diluted in an event (Ebeling et al., 2021).

Thank you for pointing this out, but since we are focusing on events, we didn’t look that much on low flow. Furthermore, our statement does not exclude any diluted point sources during events, at least not with any intention. But we smoothed up the sentence for a higher precision: “The same is true for dilution effects: during events, a steady supply of fresh

precipitation water, mostly free of nutrients, can dilute the nutrient background signal stemming from diffuse or even point sources (Ebeling et al.,2021)."

Lines 438-440: I acknowledge that the authors specified that this has never been shown by means of this method, because it has, so far, not been used for that purpose. However, it needs more for the results to be unexpected. The explanation given is not yet convincing, and I do not understand why and in which setting the cited papers support that statement.

Thank you very much for going into detail at this paragraph:

"This is of great interest, because it was not expected to see such dynamic changes in the NO₃⁻ load patterns between portions of discharge during precipitation events. by using a method originally developed to compare long termed solute export behavior"

But to be honest, we don't see which papers you are referring to. The Outram and Frazar papers support the following sentence, the three papers in the reference above support the sentence above. There is no reference intended for this sentence, since it stands on its own and concludes the applied changes to the NCL method.

You might find this not as interesting as we do, but we strongly believe that our results are not only unexpected but of interest to the scientific community. Why do we believe this is stated in the conclusions in greater detail. Please keep in mind that our method is still exploratory and we don't have the dataset to go beyond "unexpected". It would be a great stretch to delineate new hydrological processes detected by the method just showing the data from the Nesselbach. Therefore, we don't see what you are expecting us to deliver at this point, since the manuscript never claimed to either develop a new breakthrough method or to unveil a formerly hidden process. We enhanced an already established method and showed its potential; that's the core of our manuscript.

Lines 450: I assume "monitor", not "monitored"?

We changed the sentence to: "To evaluate the robustness of the proposed method, it was also applied to major ion concentrations sampled in the same catchment."

Lines 461-462: first-flush or flushing?

Thanks for mentioning. "Flushing" is correct. We changed the sentence.

Lines 490: This is a fair point, but it comes somewhat out of the blue here. This would need a separate paragraph and more explanation (what interval has been used, what interval might have been a better choice, ...)

Thank you very much for mentioning! We added a small paragraph:

"Since we used an hourly cleaning with compressed air in this setup, we recommend going down to 30 min, to minimize the influence of sediments covering the optical slit. For the manual cleaning we did a 1-week cleaning interval with brushes and hydrochloric acid (2%) to remove any biofilm. Recommendations for catchments with a higher biological turnover or water treatment plants influencing the discharge see Spill et al. (2024)."

Lines 496: "high accuracy" is a little bold. I recommend taking that out

Thank you for your recommendation, we took "high accuracy" out of the sentence.

Line 502: I do not understand the first question. How could NO_3^- export in event water be driven by point sources?

Thank you for pointing this out. NO_3^- exported within the event-water fraction may originate from localized inputs that become active during events, such as drainage outlets or wastewater-related discharges. The question therefore refers to the potential origin of the exported NO_3^- rather than to the hydrological origin of the water itself. It is intended as a more general conceptual question regarding the applicability of the method to headwater catchments with different land-use settings, rather than being specific to the Nesselbach catchment alone.

We changed the sentence slightly:

“Is the NO_3^- export in the event water primarily driven by point sources or by diffuse sources like drainage outlets or wastewater-related discharge?”