Identification of erosion hotspots and scale-dependent runoff controls on sediment transport in an agricultural catchment

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We sincerely thank Prof. John Quinton for the time he took to provide his detailed, thoughtful and constructive feedback, which significantly helped us to improve the quality of the manuscript. We have addressed all the comments and propose revisions accordingly, as detailed below. Prof. Quinton's comments are shown in black, author replies are in blue. We hope these updates have resolved all the issues and look forward to further feedback.

Kind regards,

Christopher Thoma and co-authors.

1.) This is an interesting paper that provides a lot of detail on the transfer of sediment through the HOAL catchment. However, because of the volume of information the paper struggles to move from a detailed study of the HOAL catchment to a paper which highlights findings that have wider interest to the hydrological community beyond those working on HOAL. This is a major weakness and will require a major revision. Currently the paper reads like a report or chapter on the HOAL catchment rather than a paper suitable for publication in HESS.

We thank the reviewer for this insightful comment and agree. We have therefore restructured the narrative to highlight transferable processes, mechanisms, and event-scale sediment-transport dynamics relevant to agricultural catchments beyond the HOAL. We have reduced the descriptive content and worked on the cross-station synthesis so that the focus lies on hydrological processes rather than site-specific characteristics. We clarified the broader relevance of the HOAL: Its diverse hydrological and sediment transport pathways (tile drainages, overland flow, wetlands, springs) provide a natural laboratory in which different sediment flow pathways and transport processes can be studied. This diversity makes HOAL representative of a wider range of agricultural catchments, as also emphasized by Blöschl *et al.* (2016). We hope, that the revised manuscript now more clearly articulates how the findings relate to agricultural catchments in the alpine foreland, central Europe, and other regions with comparable soil types, precipitation regimes, land-uses, and cultivation practices.

2.) The analysis is largely based around means and deviations around the means for different characteristics of the hydro/sedigraphs. Not surprisingly there is a lot of variability which makes it hard to see if there are any differences. I wonder if there are better ways of analysing these time series which pair the data in some way. For example paired ratios or erosive to non-erosive land use for individual events. This requires a significant effort.

Thank you for this helpful and constructive comment. We have now added information on the event-based differences between erosive and non-erosive cultivation by analysing the ratio of erosive to non-erosive conditions in relation to event size (=EI_{30}).

For Areas A, B, and GW9, event sizes are evenly distributed between erosive and non-erosive cultivation. This indicates that the observed differences are not an artefact of event-size.

For Area C, however, event sizes are unevenly distributed: larger events predominantly occurred during erosive cultivation, whereas smaller events occurred during non-erosive cultivation. To assess whether the previously identified significant differences are biased by this uneven distribution, we re-analysed discharge, suspended sediment concentration, and sediment load for Area C while explicitly accounting for event-size.

At the hillslope-scale (E2), the results remain unchanged, and the significant effect of cultivation in Area C persists even when controlling for event size. In contrast, at the catchment-scale (MW), the results change: when accounting for event-size, cultivation in Area C no longer shows a significant effect on suspended sediment concentration or sediment load.

To improve visual interpretability, we revised the existing boxplots by adding individual event points, with point size representing EI_{30}.

I have made a large number of comments below.

Below, we outline how we address all the comments raised by Prof. John Quinton.

3.) L142 Figure 2.

3.1) It is hard to see these points on the map. Perhaps include an inset map with the stream

We agree. We have increased the dot size of Figure 2, enhanced the contrast, and brought the monitoring stations to the foreground to improve readability.

3.2) Is the non erosve cultivation always in the same place?

Non-erosive cultivation occurs throughout the catchment, and its location and extent varies from year to year. In addition to Table 1 and Figure 2, which shows the spatial distribution of erosive and non-erosive cultivation for the year 2015 as an example, we have prepared maps showing the annual distribution of erosive and non-erosive cultivation for each year of the study period. These are provided in the Supplementary Material.

3.3) Needs to separate out the pathways from the monitoring points. For example: 'this pathway is important for these reasons and is monitored at this point using this kit'

Thank you for this comment. We fully agree and have revised the manuscript to clearly separate the description of the hydrological and sediment transport pathway from the description of the monitoring points.

4.) L149 Figs 3a and b are flumes not gullies. E1 and E2 are presumably flumes. Separate the monitoring from the features

We fully agree and have revised the manuscript so that E1 and E2 are now described as flumes used to monitor overland flow pathways.

5.) L154 Same point. these are flumes not tile drainage systems.

We fully agree and have revised the manuscript so that Sys1-Sys4 and Frau1-Frau2 are now described as flumes used to monitor tile-drainage pathways.

6.) L156 Is this from the surface or subsurface?

Thank you for highlighting this ambiguity. The exact origin of the sediment transported by tile drainage systems cannot be uniquely attributed to either surface or subsurface sources. Sediment delivery via tile drains likely represents a combination of surface-derived material entering the drainage network through preferential flow pathways (e.g. small burrows created by voles that form macropores) and subsurface-derived fine sediment originating from the soil matrix or the drainage infrastructure itself. We have revised the manuscript to explicitly state this mixed and uncertain sediment origin and to clarify the associated transport mechanisms.

6.1) Why aren't Frau 1 and Frau 2 monitored?

Frau 1 and Frau 2 were not monitored due to financial constraints. Available project resources were prioritised towards a limited number of stations to ensure continuous long-term data collection.

7.) L180 Again separate monitoring from the form/pathway. e.g. a) Flume used to monitor an overland flow pathway

Thank you for this comment. We fully agree and have revised the manuscript to clearly separate the description of the hydrological and sediment transport pathway from the description of the monitoring points.

8.) L188 Is this a combination/rotation of crops or is only one crop grown per year ? Not clear

The arable land is managed as a rotation of different crop types; each field is planted with only one crop per year. Occasionally, additional cover crops are used after the harvest of the main crop, but never in combination with maize, only grain crops. Across the catchment, multiple crop types are present at any given time. A map with a typical cultivation for the arable land in the year 2015 is presented in Figure 2 of the manuscript. We have clarified this in the revised manuscript and additionally provide a file in the Supplementary Material showing the planting and harvesting schedule for each field.

9.) L189 Is it permanent grassland?

Yes, the grassland is permanent. We have clarified this in the revised manuscript.

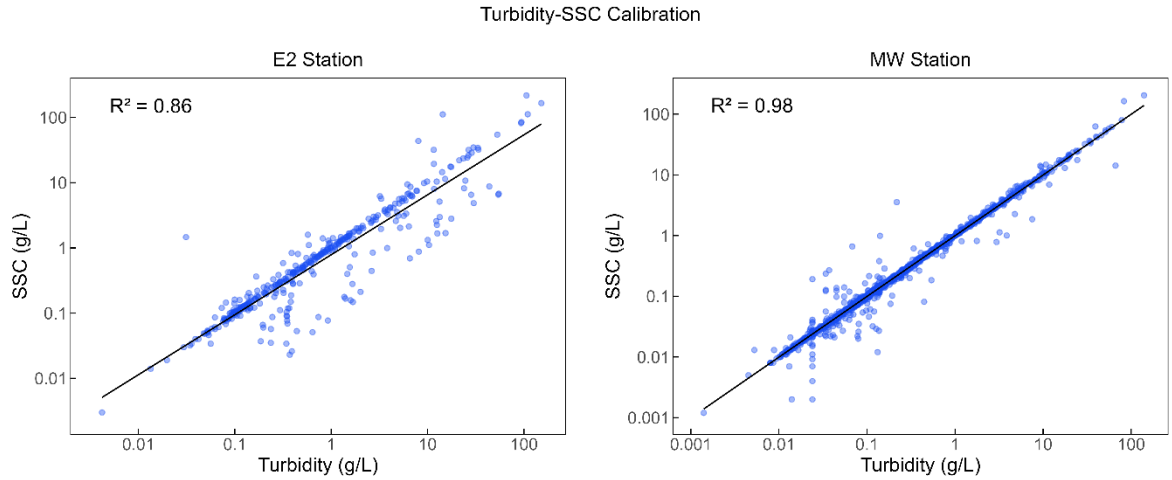
10.) L195 Precipitation was measured

Formulation was changed.

11.) L207 How good was this relationship? Was it affected by particle size? You need to tell us.

In our study, suspended sediment concentration (SSC) was derived by calibrating high-frequency turbidity measurements (FNU) against SSC values obtained from laboratory analyses of ISCO water samples collected during hydrological events. This calibration was performed separately for each station using paired turbidity–SSC data spanning a wide range of hydrological conditions. The turbidity–SSC relationship showed a strong and consistent fit across all events and sites (R^2 = 0.86 at site E2 and R^2 = 0.98 at MW). Particle size did not systematically affect the relationship, as the turbidity sensors responded consistently.

We have clarified this in the revised Methods section and included the turbidity–SSC calibration plots below for both stations in the Methodology or Appendix. We will also discuss the quality of the rating curves.



12.) L221 It would be good to have the planting and harvesting schedule as supplementary information. Could be a data base file

Yes, we agree and will provide a file in the Supplementary Material showing the planting and harvesting schedule for each field in the catchment.

13.) L249 Table 1. Can you give us a spatial feel for where the erosive cropping takes place? I realise that it might be impractical to have ten maps in the main paper, but perhaps in the suplementary information/

Erosive cultivation occurs throughout the catchment, and its location and extent vary from year to year. In addition to Table 1 and Figure 2, which shows the spatial distribution of erosive and non-erosive cultivation for the year 2015 as an example, we have prepared maps showing the annual distribution of erosive and non-erosive cultivation for each year of the study period, which are provided in the Supplementary Material.

14.) L254 define direct flow. Is it the same as overland flow? make sure you are consistent with your terms

Yes, “direct flow” refers to overland flow in this context. We have revised the manuscript to use the term overland flow consistently throughout.

15.) L317 Replace This with Thus, the ...

The text has been corrected.

16.) L320 can you provide a distance in m?Long and shorter could mean 1 cm or 1 km

Are these slope are so different? The range of slopes appears b to be quite narrow (9.7 to 11.5%) - I certainly wouldn't describe 11.5% as very steep. I suggest you just refer to the slope steepnesses in %

Thank you for this comment. We fully agree and have revised the entire manuscript to report slope steepness in percent and distances in meters, rather than using subjective terms.

17.) L351 Avoid these subjective steepness terms

We fully agree and have revised the entire manuscript to report slope steepness in percent instead of using subjective terms.

18.) L354 You have this information in the text. Either have it in a table or text, but not both

Thank you for this comment. We have retained the table and revised the text to refer to the table.

19.) L392. Avoid subjective descriptors of steepness and distance

Same reply as before: We fully agree and have revised the entire manuscript to report slope steepness in percent and distances in meters, rather than using subjective terms.

20.) L401 quote to $p<0.01$

The text has been corrected.

21.) L404 How did you get g/l as your turbidity unit. Did you calibrate and if so how good was the calibration and did you take account of that uncertainty when testing for differences. This needs to be described

In our study, suspended sediment concentration (SSC) was derived by calibrating high-frequency turbidity measurements (FNU) against SSC values obtained from laboratory analyses of ISCO water samples collected during hydrological events. This calibration was performed separately for each station using paired turbidity-SSC data spanning a wide range of hydrological conditions. The turbidity-SSC relationship showed a strong and consistent fit across all events and sites ($R^2 = 0.86$ at site E2 and $R^2 = 0.98$ at MW).

Following this calibration, turbidity values were converted into SSC values in g/L, and the complete turbidity time series was thus expressed in sediment concentration units.

We clarified this methodology in the revised Methods section and included the turbidity-SSC calibration plots for both stations. The quality of the calibration was very high, and the associated uncertainty is small relative to the observed variations in SSC; therefore, it does not materially affect the statistical analyses of differences between events.

22.) L407 Figure 6. I wonder if there is a better way of looking at this data since you clearly have a lot of variability caused by different event sizes which makes it hard to see differences. Could you for example look at the ratios of Erosive:Non Erosive and see how that relates to event size?

Otherwise you have lot of graphs which aren't very interesting and could probably be dropped from the manuscript

Thank you very much for this very helpful and constructive comment. We have now investigated the influence of event-size on the observed differences between erosive and non-

erosive cultivation by analysing the ratio of erosive to non-erosive conditions in relation to event size (=EI_{30}).

For Areas A, B, and GW9, event sizes are evenly distributed between erosive and non-erosive cultivation. This indicates that the observed differences are not an artefact of event-size. To improve visual interpretability, we have revised the boxplots by adding points for each individual event, with point size representing EI_{30}.

For Area C, however, event-sizes are unevenly distributed: larger events predominantly occurred during erosive cultivation, whereas smaller events occurred during non-erosive cultivation. To assess whether the previously identified significant differences are biased by this uneven distribution, we re-analysed discharge, suspended sediment concentration, and sediment load for Area C while explicitly accounting for event-size.

At the hillslope-scale (E2), the results remain unchanged, and the significant effect of cultivation in Area C persists. In contrast, at the catchment-scale (MW), the results change: when accounting for event size, cultivation in Area C no longer shows a significant effect on suspended sediment concentration or sediment load.

23.) L416 But this is data from across all events where the variability will prevent you finding significant differences. The data needs to be paired in some way - see my previous comment.

Thank you very much for this clarification. As detailed in our response to Comment 22, we addressed this issue by explicitly accounting for event-size (=EI_{30}). All results for Areas A, B, and GW9 remain non-significant, while cultivation effects for Area C remain significant at the hillslope-scale (E2), even when accounting for event-size.

24.) L444. I am not convice by the graphs in Figure 7. They seem to repeat the information in Table 4.

We have revised Figure 7 and now retain only the plot for Area C, where statistically significant differences were identified, including the revised visualisation accounting for event-size as described above. All plots for non-significant results (Areas A, B, and GW9) have been removed, such that Figure 7 now provides visual support for the statistical results summarized in Table 4.

25.) L471 Figure 8 looks like a Table to me. Which location does the analysis relate to? Some of the correlations reported are non sensical. Why for example would you expect a correlation between EI30 and erosive area? Do not present correlations for things which you know are not correlated. Comment also applies to 'Figure 9'

The analysis in Figure 8 relates to the hillslope-scale station E2, as indicated by the sub-chapter heading "4.2.1 Overland Flow Characteristics," while Figure 9 relates to the catchment-scale station MW, as indicated by "4.2.2 In-stream Measurement Characteristics." We have renamed these headings to "Hillslope-scale (E2)" and "Catchment-scale (MW)" for consistency and clarity, and also specified this in the figure captions.

We fully agree that the correlation between EI_{30} and the percentage of erosive land cover involves two conceptually independent variables, as also noted in the community comment (CC1) by Prof. José Carlos de Araújo. In the revised manuscript, we have removed this correlation to avoid implying a causal relationship.

26.) L550 The areas you refer to are not flat! They have a slope of 7.2%!

Same reply as before: We fully agree and have revised the entire manuscript to report slope steepness in percent, rather than using subjective terms.

27.) L560 Here and in other places in the discussion (Figure 10, Figure 11) you introduce new results in the form of observations. These need to be in the results.

Thank you very much for this comment. We agree that new quantitative results or novel analytical findings regarding the spatial-scale effects should be presented exclusively in the results section. We have therefore revised the manuscript and moved the quantitative findings of the spatial-scale analysis from the discussion to the results section.

The descriptions associated with Figures 10 and 11, however, to us do not introduce new measured results, but rather provide qualitative, illustrative field observations intended to support the quantitative results presented earlier in the results section. Figures 10 and 11 are therefore used as visual example of erosion and deposition processes (e.g., erosive vs. non-erosive cultivation) that were already quantified and presented based on monitoring data in the results section. Thus, we suggest to keep these figures in the discussions section.

We have revised the discussion section accordingly to explicitly frame these descriptions as illustrative field evidence supporting the results, and to avoid wording that could be interpreted as introducing new results. We also clarified references to the corresponding quantitative findings.

28.) L580 This is an important finding. Put it at the front of the paragraph then discuss it.

Thank you for pointing this out. We agree that this is a key finding and have revised the paragraph so that it now appears at the beginning and is discussed immediately thereafter.

29.) L627 This seems like a an important finding which has more generic value than some of the very site specific findings that have been discussed above. I would recommend making it more prominent.

Thank you for this valuable comment. We agree that this finding has more general applicability beyond the HOAL-specific results. We have therefore made it more prominent in the discussion by clarifying its broader implications.

30.) L637-646 Reads like results rather than discussion

Thank you for pointing this out. We have moved this information to the results section.

31.) L671 A key point that is worthy of discussion. Place it at the top of the paragraph then discuss.

Thank you for this suggestion. We agree that this is a key point and have moved it to the beginning of the paragraph, followed by the corresponding discussion.