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Reply on RC1

Shengping Wang et al.

Author comment on "Agricultural intensification vs. climate change: what drives long-term changes in sediment load?" by Shengping Wang et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-567-AC1, 2022

Authors response

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The following documents the authors' response to reviewer' comments. Whilst the reviewers' comments are displayed in blue, the authors' comments/responses are displayed in black.

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Reviewer#1

I found the preprint titled "Agricultural intensification vs climate change: What drives long-term changes of sediment load?" an interesting and worthwhile contribution to the exploration and identification of potential drivers of long-term changes in suspended sediment. I applaud the authors on their well written abstract and introduction, use of data analysis techniques, and helpful interpretation of their results. I found much of the writing clear and concise. I have a few major comments, and some minor ones, that I hope the authors will consider.

RESPONSE: We thank the Reviewer for this positive evaluation. We revised the manuscript addressing the major and minor comments raised by the Reviewer as follows:

Major comments:

R1_1:Only 1 metric of "climate change" was evaluated in this paper and this metric, monthly mean precipitation, does not capture the change in climate most likely to effect sediment transport. Metrics such as change in the magnitude, frequency, or duration of the highest precipitation events (> 75th or 90th percentile? Max event?) would be more appropriate for assessing the effect of changes in climate on sediment transport. Furthermore, I don't see any discussion related to the type of precipitation (i.e., changes in the proportion of precipitation as snow versus rain). The catchment is located in Austria, so surely snow fall is a consideration. Is it possible there has been a shift from snow to rain which could be driving some of these changes in sediment?

RESPONSE: We agree that the metric of mean precipitation may not characterize erosion severity entirely. Therefore, we investigated both mean precipitation and erosivity density (Please see Figure 3 in the original submission) which is calculated from peak event rainfall intensity (I_{30}) and kinetic energy of rainfall (E). This is a metric that has been developed within the frame of the most widely used USLE/RUSLE set of erosion models. Kinetic energy of rainfall and maximum intensity of rainfall commonly are both considered to be the main driving forces of rain on erosion. Because we focus on the change in sediment loads, we think that such an index is a good indicator representing storm characteristics for erosion susceptibility.

Although the study area is in Austria, the HOAL is considered as a lowland catchment, it is located in a region with quite small amounts of snowfall. Snowfall in the catchment plays a minor role in sediment production, considering that melted snow may drive sediment transport for only a few events. So, in our analysis we also reported precipitation for the winter season, and this precipitation includes both rainfall and snow fall, but as mentioned above this s not very important. We will include a comment to this effect in the revised paper.

R1_2: The differences in sampling methods between the two time periods needs more attention. As presented, I am not convinced we aren't just seeing changes in sediment due to changes in sampling methods (collection frequency and also techniques). Sediment is particularly sensitive to changes in sampling (see couple of references at bottom). Lines 228-230 suggest an approach for dealing with differences in sampling but it is not clear to me how this technique takes care of the potential issue. Even if the difference in sampling methods/techniques cannot be resolved, I think this analysis would still be worthwhile, as long as this issue was thoroughly discussed in the context of the results.

RESPONSE:

We fully agree that differences in sampling methods (in terms of sampling frequency and sampling technique) may affect estimated changes in sediment load in our analysis. As mentioned by the reviewer, addressing this issue is difficult with the available data. To address different sampling frequencies, we made use of the relationship of *a* against *b* which, to a certain degree, ensures that the values of the pairs of *a* against *b* lie nearly on the same straight line, as long as the sediment regimes represented by the pairs of *a* and *b* do not change significantly. In the revised manuscript, we will add more detailed explanations on the sampling methods used. Additionally, we will discuss the possibility that different sampling techniques may have affected our observation in the discussion, and point out that less difference among various sampling techniques usually is found when the monitoring focuses on fine sediment textures such as in our study. Finally, looking at the total annual sediment loads that may be calculated only from sediment concentrations times water flow, it is clear that the total annual loads differ substantially between the two periods. Also, the comparison of measured data to some results of a quick erosion model application (see lines 551 ff) provides confidence in the results obtained. Thus, although some uncertainty exists due to the different sampling strategies, we are confident that the different sediment loads are not only artefacts of the sampling.

R1_3□Statistical techniques can and should be used to help identify and quantify differences between periods. The text indicates a t test was used for assessing differences in monthly erosivity density (line 189) but how differences between the SRCs and the sediment loads were determined isn't described. I appreciate the development of the theoretical SRCs but even the differences between these are discussed qualitatively. For example, on lines 433-435, how is the distinction between "considerably higher" and "not different" being made? There is considerable overlap in the 5 and 95th percentiles in both panels of Figure 7. Specifically, on panel (a), the line for the 50th percentile for Period II falls outside the gray area for Period I. Using a statistical test like ANCOVA or a regression equation with categorical variables for season and time would help to determine which slopes and intercepts are (statistically) significantly different.

RESPONSE: We will revise our manuscript by using ANCOVA for the comparison of SRCs, the relationship of coefficient a against b, and the derived tSRCS between seasons and/or periods. In the revised manuscript, we will explicitly point out, that the fitted SRCs (Figure 5) were significantly different between growing seasons or dormant seasons.

Whilst for the relationship of coefficient a against b (Figure 6), most parameters of these relations (in terms of the slopes and intercepts) were not significantly different at *p* level of 95%, except for the intercepts in the growing season. Thus, in the revised manuscript, we have rephrased the comparison of the relationships of coefficient a against b.

As for the tSRCs, we also found that the median tSRCs were significantly ($p<0.05$) different between the growing seasons or dormant seasons. However, to account for uncertainty of the tSRCS, we have rephrased the comparison of tSRCs.

As for sediment loads, we used t-tests to examine the difference, and we have added this statement in the revised manuscript.

R1_4: Given the structure of the dataset, how were the sediment loads presented in this report calculated? What technique was used? Relatedly, a table of these loads might be worth including since the term "load" is featured in the title. Also, Lines 459-460 used the word "load" to reference to Figure 8 but this figure is showing sediment concentration. In several places in the paper it feels like the terms "concentration" and "load" are being used interchangeably. Sometimes this can be ok since the SRCs are always positive and increases in concentration can be inferred to mean increases in load, but they are not the same thing and it would be prudent to be clear about which term is used when presenting the results of these analyses (i.e., these SRC are build using sediment concentrations not loads).

RESPONSE: We will add a short paragraph to explain how we estimated the statistic of sediment load. We will also present an additional table in the revised manuscript as well to show the statistical results. It is true that we have not sufficiently addressed fully defined the terms load and concentration and have occasionally mixed them. Thank you for pointing this out. Thus, we will revise the word "load" to "concentration" when referring to Figure 8. We also will check the whole text to make sure the word "load" and "concentration" are not misused consistently.

R1_5: I'm wondering about the choice to average concentration and streamflow data by month…. I wonder if some of the important variability (related to the magnitude of the events) is being muted? The report states that a majority of the sediment load is transported in just a few high flow events in each period, but these important events are being averaged with all the available data for each month.

RESPONSE: Yes, we also realized that the use of monthly average data may suppress some temporal variability of events. It is the discrepancy in sampling frequency that made us use monthly sediment concentrations, as we would like to understand the change in sediment regime due to land surface process without the potential interferences of sampling methods.

We agree that a monthly dataset may be not useful for understanding event processes, however, it is at least helpful for understanding seasonal or annual scale alterations of the transport regime between different periods. Because peak values of a sediment graph or hydrograph usually do not last for a long time in our catchment (size 66 ha), we think that it is less important to account for peak observations when calculating or estimating sediment load by month. It has to be noted though, that we have occasionally made improper use of the term "event" when talking about sediment loads because all our considerations refer to monthly loads. Thus, we will modify all text references to event loads to monthly loads.

Minor comments:

R1_6: Line 245: Is this saying the solid and dashed lines in 2b represent a shift in the sediment transport regime such that concentrations at a given discharge are relatively lower for periods A′, B′, and C′ compared to A, B, and C? Consider rewording.

RESPONSE: We will add an explanation for this. Specifically, we will explain this as "sediment concentrations at a given discharge are relatively lower for periods characterized by points A′, B′, and C′ compared to periods characterized by A, B, and C."

R1_7: Line 226: The text indicates SRCs were also fit by season-and-year however the results and discussion only present and discuss the SRCs by season. Suggest removing this since the by year and season results aren't discussed.

RESPONSE: Actually, we fitted the regression by each specific year's season (for example, growing season of 1950, 1951,...), instead of a pooled season (for example, growing season or dormant season). In the revised manuscript, we will rephrase this as "fitted by each specific year's season".

R1_8: Line 269: Figure 4 is used to support the statement that the coefficient of log a follows a normal distribution, but Figure 4 is a flow duration curve. Also "shown" would probably be a better word than "proven" in this context.

RESPONSE: Thank you for pointing this out. We will supplement Figure 4 in the revised manuscript and replace the word "proven" with "examined".

R1_9: Figure 3: Consider including labels that indicate which months are in the Growing vs. Dormant seasons. Are the months included in the growing and dormant seasons available somewhere in the text? I can't seem to locate it. My apologies if I just missed.

RESPONSE: Thanks for the suggestion. Growing season includes the months from April to October, while dormant season includes the months from November to March. In the revised manuscript, we will add a short explanation of this in the caption of Figure 3 "Figure 3 Distribution of a) monthly erosivity density and b) monthly precipitation for Periods I and II. The bars with dashed outline represent the growing season (April to October), while the bars with solid outline represent the dormant season (November to March)". We will also add this information to the methods section.

R1_10: Figure 1: Caption indicates a "black hatched area in b", but I don't see it. How different are the catchment sizes between the 2 time periods?

RESPONSE: The difference in size of catchment between the two periods is very small (around 200 m^2), which is barely visible on the map, a small area only around the catchment outlet. We will revise the figure caption, and we will replace this text with an explanation on the change of catchment sizes in the Methods section.

R1_11: Line 330: Can you support this statement more? I think the authors are saying that decreases in streamflow cannot account for the observed increase in sediment transport, because if that was the case, then we'd expected to see increased streamflow, correct? Consider rephrasing

RESPONSE: In the revised manuscript, we will rephrase this as "The decreased flow regime of Period II, probably partially due to increased evapotranspiration in the last decades (Duethmann and Blöschl, 2018), indicates that streamflow cannot account for the increased sediment regime over Period II, because if that was the case, we would expect increased streamflow in Period II." Please also note, that for a given catchment, there is usually a positive relationship between flow rate (be it annualy or monthly) and sediment load. Thus, if the flow has even decreased, this clearly points to a nonsignificant influence of flow rates on increasing sediment loads.

R1_12: Figure 6: Keep the colors used for Period I and II consistent between Figures 5 & 6. What are the arrows for? The text describes the right points being the "left-upper area" but this is not true for (a).

RESPONSE: We will change the colors of Figure 5 to be consistent with Figure 6. We will also explain the meaning of the arrow in the caption of Figure 6 "The arrows represent sediment regime shifted upward to a certain degree". As for the point distributions of Figure 6, we will rephrase the expression for clarity to "Interestingly, the values of both Periods I and II, in the growing season more concentrated in the right-lower area (Figure 6a), although different sampling practices were used in two periods, whilst a biased pattern of log (*a*) against *b* was found in the dormant season (Figure 6b), i.e. the values for Period I concentrated in the right-lower area (blue points), and were more concentrated in the left-upper area for Period II".

R1_13: Lines 436-440: The +/- ranges for the loads given in this paragraph would result in negative sediment loads. Also, +/- ranges are quite large suggesting perhaps there isn't a statistical significant difference between these loads?

RESPONSE: Unfortunately, annual sediment loads of small catchments usually have a large heterogeneity. Therefore, different periods of observation may exhibit large differences for annual loads such as in our case. To account for this statistically, in the revised manuscript, we rephrased the paragraph on loads. Specifically, we examined statistical difference between the loads by using a t-test. Also, we examined the statistical difference of the derived tSRCs by using an ANCOVA. We found, that sediment loads in the growing season were significantly different between Periods I and II, but they were not significantly different for the dormant season. As for the tSRCS, we found that $tSRC_{50\%}$ were significantly different between two growing seasons or dormant seasons. In the manuscript we would emphasize that, when accounting for uncertainties of tSRCs, their difference varies with flow rates: "ANCOVA suggests that the derived $tSRC_{50\%}$ were significantly different ($p<0.05$) between the growing seasons or dormant seasons. However, when accounting for uncertainties of the derived tSRCs, their difference varied with flow rate alteration. Specifically, at a given Q higher than approximately $Q_{70\%}$, sediment concentrations in Period II_G were generally higher than those in Period I_G, for the rest of the flow rates, concentrations were not different as the gray area of the two tSRCs overlapped obviously."

R1_14: Figure 8: What does the dashed vertical line at zero represent?

RESPONSE: In fact, when zooming into Figure 8 to check the variation of either parcel_effect or LUCC_effect at low flow conditions, we found that their values exhibited little plausible dynamics below a flow rate of 2 l/s. We mainly attributed this behavior to an artefact of calculation. In fact, sediment concentrations at low flows (no events) are almost zero in both periods, because sediment transport largely depends on events. Therefore, in our calculations, we focused on the sediment – flow relationships for flow rates above a base flow of 2 l/s. 'The dashed vertical line that is visible near the zero value (in fact it is the value of 2 l/s) is an artefact of this calculation procedure. In the revised manuscript we will change the minimum value of the x-axis to 2.5 l/s to avoid further misunderstanding of this figure.

R1_15: References on sediment sampling in rivers:

Awal, R., et al., 2019, A General Review on Methods of Sediment Sampling and Mineral Content Analysis, Journal of Physics: Conference Series, https://doi.org/10.1088/1742-6596/1266/1/012005

Groten, J.T., and Johnson, G.D., 2018, Comparability of river suspended-sediment sampling and laboratory analysis methods: U.S. Geological Survey Scientific Investigations Report 2018–5023, 23 p., https://doi.org/10.3133/sir20185023

Harmel, R.D., et al., 2010, Impact of Sampling Techniques on Measured Stormwater Quality Data for Small Streams, Journal of Environmental Quality 39:1734–1742, doi:10.2134/jeq2009.0498

RESPONSE: Thanks for the valuable reference information. We have added the relevant references to the revised manuscript.