

Response to the interactive comment on the manuscript

## **“Event and seasonal hydrologic connectivity patterns in an agricultural headwater catchment”**

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In the following document we reproduce all the comments of the Referees in *italic characters* followed by our answers.

**Anonymous referee #2:**

*This study analyses the connectivity between hillslopes and stream within an agricultural small catchment by looking at the spatial and temporal similarity between groundwater, soil moisture and streamflow dynamics. The study is quite complex and my overall opinion is that it is difficult to follow. I hope some of my suggestions below might help to make the reading a bit smoother. The data collected as well as the analysis carried out in the study are quite nice and show an interesting way to examine catchment hydrological connectivity. My recommendation is moderate revisions are needed before publication.*

We thank the Anonymous referee #2 for the time he/she spent on this manuscript. We have considered and addressed all his/her insightful comments in the following.

### **Here are my comments:**

*1. I miss an explanation about why is interesting to study connectivity in an agricultural catchment - in other words, why are you carrying out this study in an agricultural catchment? There is a very brief reference to it in the last sentence of the Conclusions but I think it is necessary to extend this much more, by including an explanation and references in the Introduction. I think you can say something about it in L67.*

The understanding of hydrologic connectivity in an agricultural setting can help us decipher how the nutrients and other chemicals move in the catchments, providing us with information for better agricultural practices and monitoring. We will expand the introduction with the explanation and motivation why we do this study in an agricultural catchment.

*2. As I said above, it is a complex study. A better correspondence between the key questions and the subsections of the Results and Discussion sections will improve the reading of the whole paper. Also, by better explaining how you are specifically going to answer these questions. Mainly: K1: “What are the spatial and temporal patterns in the relationship between the streamflow, groundwater and soil moisture responses to precipitation events in an agricultural headwater catchment?” - You have to explain somewhere how are you going to look at the temporal patterns (through wetness conditions). I think I have not seen it before the Results.*

We will change the Results and Discussion titles to link them more clearly to the science questions as suggested. We will also add references to the science questions in the appropriate subsections of the Methods section.

*- In the discussion, “4.1. Spatial patterns of groundwater and soil moisture responses” should be “Spatial and temporal patterns of groundwater and soil moisture responses to precipitation”..?*

We will change the title of subsection 4.1 as suggested.

K2: *“Is the relationship between the streamflow and groundwater or soil moisture dynamics more related to site- or event-characteristics?” You have to say somewhere that for this you use the type of response.*

We will add this information to the Methods section.

*Also, what variables do you use to characterise the event. I think nothing is said before the Results.*

The variables used to characterise the events are described in the Methods subsection 2.5 Event response definition and characterisation.

*3. The type of responses (L260-278) should be in the Results sections.*

We will move these lines to the Results, to section 3.2 Response type occurrence.

*4. Landscape units of Fig1 and landscape position (Table 1) are the same? Then use the same term (in all figs -eg fig 7-, tables and text) otherwise is confusing.*

Thank you for noticing that. The landscape units and landscape position are the same. We will make it consistent over the whole manuscript.

*5. In L215 you say “similar patterns exist among the stations in the same unit” but later on, in 3.2.1, “the other two landscape units show only low co-occurrence rates of groundwater response types between stations in the same unit” (L365). So this is a bit confusing, at least the way it is explained. Looking at how similar the hydrological response is within the landscape units is quite interesting and an important result. I think it should be further and more clearly discussed in the text.*

“Similar patterns exist among the stations in the same landscape units” in line 285 means that the correlation of stations in a specific landscape unit to streamflow is similar in magnitude to the correlation of these stations among themselves. E.g. correlation of lower slope stations to streamflow is low as the correlation among these stations is also low. We will rephrase the first statement for clarity.

*6. The temporal pattern of similarity is only discussed with two references (Blösch et al 2016 and Penna et al. 2015). I think this should be expanded.*

We will provide additional references to broaden the argument.

### **7. Minor comments:**

*L40-42. Can you include studies carried out in other landscapes than grasslands and forest? For instance you can take a look at Latron & Gallart 2008 (old abandoned terraces).*

Thank you for the suggestion. We will add additional references of studies in other landscapes.

*L50. Rosenbaum et al. (2012): what is the type of landscape here?*

The study site of Rosenbaum et al. (2012) is the Wüstebach test site, which is a hilly forested catchment. We will add this information to the text.

*L59-60. “Separation of temporal scales could also be linked to a separation of scales in space (Széles et al., 2018)”. This sentence deserves a bit more explanation,*

We will provide further explanation.

*Methods: you are using data of only two years, 2017 and 2018. You should indicate how representative they are (were they wet/dry/averaged years?)*

We will add this information in the Methods section.

*Fig 1. Please include the legend of the landscape units.*

We will add the legend for the landscape units to the figure.

*L137. 60 cm? In L130 you say 5,10,20 and 50 cm*

Thank you for pointing this out. The values in line 130 are the depths of the sensors, while the values in line 137 also include the boundary depths for the soil column (0 and 60 cm). We will rewrite Eq. (1) and the corresponding description in a different way to clarify this.

*L143. "interpolate". As soil moisture is collected every 15 min I guess you use 4 times the same value (for the hourly time step)..?*

The soil moisture data is linearly interpolated between hourly values. We will add this to the manuscript.

*L189. "2.5 Event response definition and characterisation" You should indicate "Groundwater and soil moisture response definition and characterisation at the event scale". In 2.4. you maybe need to add "Rainfall-runoff event definition and characterisation"*

We propose the following new section titles:

2.4 Rainfall-runoff event definition and characterisation

2.5 Groundwater and soil moisture event response definition and characterisation

*L264. You suddenly use GW and SM - define it before and use it from the beginning.*

We will define GW and SM at the beginning of the manuscript.

*Fig 6. The legends of HI may have an error. In the text (L219) it is said that "Clockwise loops, where x lags behind y, have negative HI values and counter-clockwise loops, where y lags behind x, positive HI values". Fig b), eg, is a counterclockwise and HI is negative. Is there a mistake?*

Thank you for this comment, there is indeed a mistake in the text. The clockwise loops have a positive hysteresis index and counter-clockwise loops have a negative hysteresis index. We will correct this in the text.

*L373. This sentence sounds a bit strange: "Only events when both events have a response are considered"*

We will rephrase the sentence as: The size of circles shows the number of events used in co-occurrence rate calculation.

*Fig. 13. I do not understand why you depict the day of the year while at season scale you use weekly time-step (L150)*

We will change the colorbar of the figure to depict the week of the year instead of the day of the year.

*L 412. This sentence is not clear: "Even upper slope groundwater stations, which do not correlate to other stations on the event scale, are well correlated to each other."*

The sentence will be rewritten as follows: "Even upper slope groundwater stations, which do not correlate to stations in other landscape units, are well correlated to each other."

*L551. This statement needs further explanation: "4). Negative seasonal time shift of some stations suggests that soil moisture – i.e. catchment wetness - controls the stream baseflow."*

Negative seasonal time shift of soil moisture to streamflow means that streamflow seasonal dynamics lags behind the soil moisture dynamics. This suggests, that on seasonal scale the amount of soil moisture, which is a measure of catchment wetness, should increase first before the streamflow increases. Hence the catchment wetness controls the seasonal streamflow, i.e. baseflow. We will provide further explanation in the manuscript.

*L565. What do you mean by “the dominant dynamics is seasonal”?*

The amplitude of seasonal dynamics for this group of stations is greater than the event dynamics. We will add this to the manuscript.

*L575. The explanation to the reference to the study by Exner-Kittridge et al. (2016) should be better connected to your results.*

We will rephrase that paragraph to better explain the connection of their results to our findings.

*L586. “but changes with catchment wetness conditions” -indicate in which sense*

The soil moisture pattern is spatially more homogeneous and the similarity to streamflow increases with increasing wetness conditions. This will be added to the manuscript.

*L593. This statement needs further explanation: “Differences in the similarity give us an insight into the interaction between the two subsurface systems.”*

We will rephrase this statement as: “Differences in the similarity patterns of groundwater on different time scales allowed us to divide the groundwater stations into groups which relate to their interaction with the two subsurface systems.”