Response to anonymous referee # 1

Dear Anonymous Referee #1,

First of all, thank you very much for reviewing our paper entitled “Exploring river–aquifer interactions and hydrological system response using baseflow separation, impulse response modelling and time series analysis in three temperate lowland catchments (HESS-2021-422)”. We are very grateful for your time and comments that help to improve the manuscript.

We have responded point-by-point to your comments and suggestions. Please check the detailed replies in the following sections, with your original comments in *italic* and our answers in blue. A revised manuscript which specifies the adjustments based on your comments will be provided at a later stage, awaiting the review from a second referee and the editor’s decision.

We are looking forward to your further assessment.

On behalf of all authors,

With best regards,

Min Lu

Corresponding author

## 1. General comments

*The study looks in details at the hydrological interactions between lowland rivers and shallow aquifers in three different catchments in Belgium. In their analysis, the authors use a combined approach of baseflow separation, impulse response modeling and time series analysis over a 30-year period. Overall, the paper is well-written and the results are insightful and very useful to the hydrology community. I think the paper should be published after addressing the following minor/technical comments:*

- Thank you very much for your positive comments, support for the manuscript and addressing the manuscript's added values to the hydrology research.

## 2. Specific suggestions

*- Looking at Fig. 11(c), I can see a slight overestimation of the groundwater levels prior to 2000. Can the impulse response parameters be tuned to improve the fit to the data? Also the seasons, as described in the text, are not clear on the figure. Consider zooming in.*

- Thank you for the comment and suggestion. Indeed, there is a slight overestimation of the selected groundwater time series P021 in the Dijle catchment (Fig. 11c), especially between 1990 and 2000. If we split the 30-year study period into smaller sub-periods, for example, every 10-year period, and optimize one set of impulse response parameters for each sub-period, the fitting to the observed level time series can be improved.

- However, the option above mentioned deviates a bit from the scope of the study, which assumes that the hydrological system has not evolved drastically within the 30-year time frame (1990 - 2020) and analyzes the hydrological process of groundwater level responses directly to the system input of pure climatic drivers (precipitation and air temperature). Therefore, the model residuals may contain and reflect effects of human interferences, such as increased pumping during some periods or seasons (Fig. 11c). Further, we chose on purpose this not-so-perfect fitted groundwater time series (P021 does not have the highest NSE value among all groundwater level simulations in the Dijle catchment) to indicate that there is indeed some bias during simulation and estimation for some of the groundwater level time series.

- We agree with you that the indication of seasons, especially accompanying the text description of "…(L416) at the end of summer or begin of autumn… " , are not clearly visualized in Fig. 11(c). We improved Fig. 11 by adding minor gridlines on a yearly basis for helping visualizing the low points. We also adjusted the text from "…(L416) at the end of summer or begin of autumn… " to "…(L416) in the middle or second half of the year… ". The updated Fig. 11 is shown below and will be updated in the revised manuscript as well.

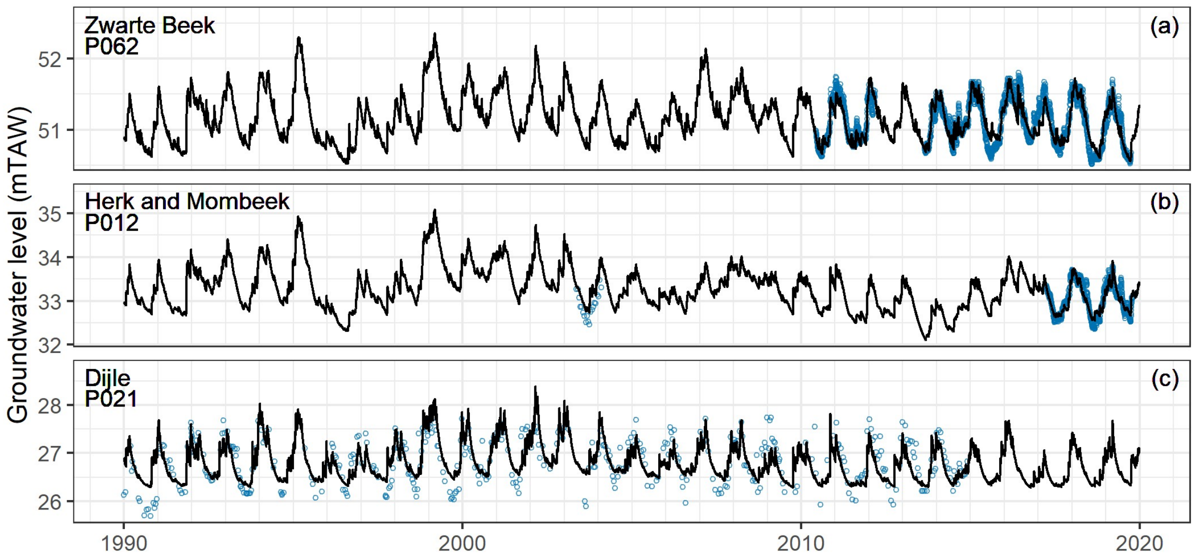


**Figure 11** Selected observed (in blue) and simulated (in black) groundwater level time series for impulse response modelling: (a) ZWAP062 in the Zwarte Beek (NSE = 0.838), (b) MOMP012 in the Herk and Mombeek (NSE = 0.857) and (c) DYLP021 in the Dijle (NSE = 0.583).

*- Section 4.2.2: I am interested to look at the entire eigenvalue spectrums. I understand that the first mode at the 3 different sites dominate the rest of the modes. Does the spectrum die after the first leading modes? I expect the leading modes to change if there is some sort of an extreme rainfall event. It might be helpful to comment and discuss this further in the text.*

- Thank you for the comments on the eigenvalue spectrums. We improved Fig. 16 by adding the percentage of variances of the first five principal components (see Fig. 16 below). Figure 16 shows clearly the spectrum dies after the first/leading principle component (Fig. 16b, d, f). The figure will be updated in the revised manuscript as well.

- As this study mainly focuses on an overall catchment behavior for a broader time scale of 30 years in each catchment, we did not assess the impacts on the mode change due to extreme rainfall events, which usually take places at much finer temporal scales such as a few hours or days. The leading modes may change due to extreme rainfall events if checking at finer temporal scales. However, this assessment is out of the research scope and focuses.

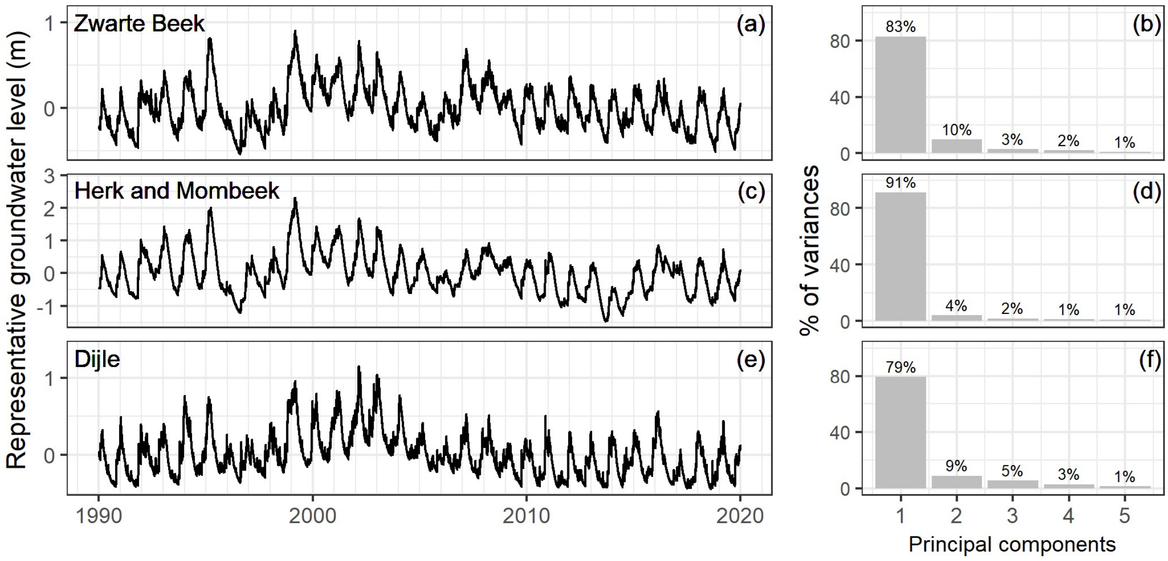


**Figure 16** The representative groundwater level (relative elevation) time series and the percentage of variances of the first five principle components in each catchment.

*- Do you expect the BFI estimates in these groundwater-dominated lowland catchments to change if the precipitation regimes change?*

- Thank you for raising the question. Yes, we expect the BFI will change if the precipitation regimes change. For instance, if summers are becoming drier with less precipitation (e.g. dry springs/summers observed between 2017 – 2020 in west Europe), the rivers are at risk of drying up. Expected groundwater discharge to rivers will also be limited due to lowered groundwater level.

- We think that the magnitude of impacts on the BFI due to the precipitation regime change also depend on the temporal scale of the regime change. If the precipitation regime changes over a longer period (e.g. 10 years, or even longer), the impacts on BFI will also demonstration a long-term trend. On the contrary, if the regime change just happens for a few years, its impacts on BFI will be short-term since the river-aquifer interactions in lowland environment are very robust.

*- The figures could be annotated better. For instance, in Fig. 13 does not label the black and the gray curves.*

- Thank you for this suggestion. The IRF curve from each of the retained groundwater level time series is plotted in black (with a transparency setting of 0.3), which makes it grey. Further, the overlaying of some curves darken some plot areas and they look like the black color. To clarify the color misunderstanding, we adjusted the individual curve to black without transparency setting (see Fig. 13 below). The figure will be updated in the revised manuscript as well.

- Following your suggestions, we also checked other figures to improve the annotation and clear visualization. For instances, we will adjust the annotation in Fig. 2 and add minor gridlines in Fig. 12, 17 -19, etc. Detailed figure adjustments and improvement can be found in the tracked and revised manuscript at a later stage.

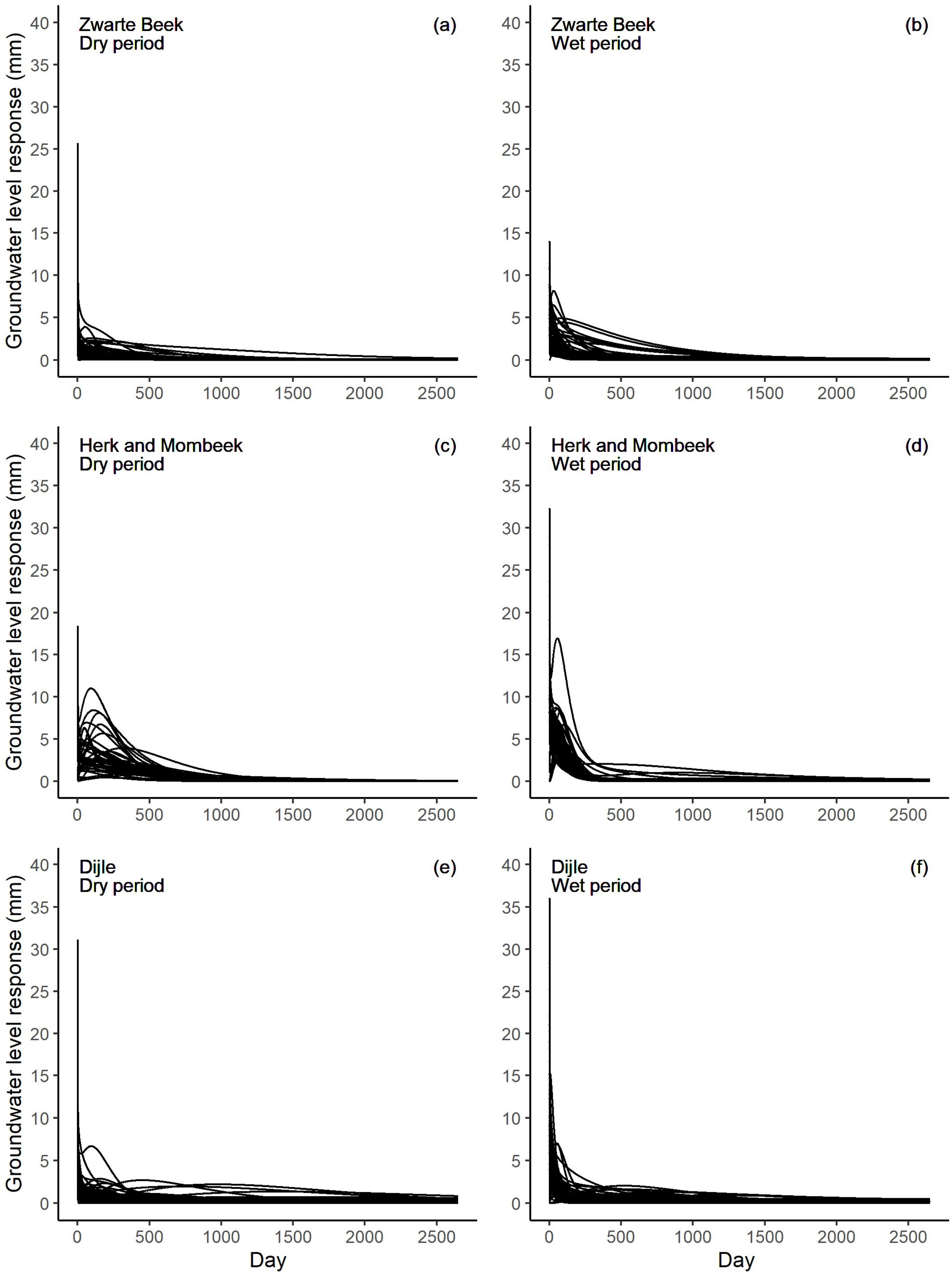


**Figure 13** IRFs derived from the groundwater level response modelling for dry (April–September) and wet (October–March) periods in the three catchments.