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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Nitrate sinks and sources as controls of spatio-temporal water quality dynamics in an agricultural headwater catchment" *by* T. Schuetz et al.

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Dear Dr. Reeves,

please find below our point by point response to each of the comments and suggestions made by Referee #2

General comments:

1. The authors present a detailed assessment of synoptic sampling results from a small headwater catchment and develop a mixing/removal model to analyze in-stream retention and fluxes. The paper is well written and the results are presented in an

interesting way. However, I was struck by how much in-depth analysis and theoretical underpinning was devoted to a small 100 to 600-m reach in a small 1.7 km2 catchment. The authors wish to investigate nitrate sinks and sources in a "stream net-work", but can a such a small catchment with intermittent streams and tiles really represent a stream network? The authors go to great details attempting to resolve the mixing and removal model but how appropriate is this approach at such a small scale? How does a 100-600m reach in a 1.7 km2 headwater catchment represent a stream network? For me, the stream "network" would consist of many order 1, 2 , 3 and more streams – in my opinion, the present study is only focused on a single 1st order catchment and nothing more. I'm not sure how the authors can extrapolate beyond this small basin to say much about "stream network" behavior.

Answer

We agree that our study presents processes relevant for /observable in smaller, first-order stream networks to which we refer as an agricultural headwater catchment in the title of our manuscript. We will implement the expression "first order stream network" throughout the manuscript to avoid misunderstanding. However, we disagree that this limits the relevance of our study to these first order stream networks, considering the dominance of small, first-order streams in the regional stream network. For example, Poff et al. (2006) stated that nearly 48 % of the total stream length in the U.S. are first order streams (based on a 1:24,000 map). We also did a GIS based calculation (1:10,000 map) for the state of Baden-Württemberg in Germany: 63 % of the stream network with a total flow length of 43,170 km consists of first-order streams. Thus, nitrate export and turnover processes in headwater catchments can have a large impact on total catchment nitrate export even on larger scales. In this context it has to be recognized that for larger rivers (with deeper water columns) in-stream removal processes become less important (e.g. Basu et al., 2011) as nitrogen is often partly incorporated in biotic matters. We will emphasize this facet of our findings more clearly in the discussion and conclusion sections of the revised manuscript to avoid the impression that

our results could be directly transferred to larger scales.

Basu, N. B., Rao, P. S. C., Thompson, S. E., Loukinova, N. V, Donner, S. D., Ye, S., and Si-vapalan, M.: Spatiotemporal averaging of in-stream solute removal dynamics, Water Re-sour.Res., 47, W00J06, doi:10.1029/2010wr010196, 2011.

Poff, N., B. Bledsoe, and C. Cuhaciyan (2006), Hydrologic variation with land use across the contiguous United States: geomorphic and ecological consequences for stream ecosystems, Geomorphology, 79(3-4), 264-285, doi:10.1016/j.geomorph.2006.06.032.

2. On lines 283-289, the authors acknowledge that they were not able to do an uncertainty analysis since they are uncertain about Q measurements and other estimated parameters. If there are not enough differences in the system to be able to accurately measure, I wonder if the scale of the site is not too fine for the methods. If the authors applied their methodology to a true stream network, perhaps there would be greater differences to quantify. As such, the reader is left to wonder how much of the in-stream mixing and removal model is real or an artifact of the measurements?

Answer

Even if we do not agree with the reviewer, we think as well that the description of our uncertainty calculations could be improved: The differences in our measurements are significant according to the applied measurement techniques. We stated that we did not carry out an uncertainty analysis for the complete mixing-and-removal-modelling approach due to the unquantified uncertainties in the assumptions made to define the boundary conditions of the nitrate sources (nitrate concentration interpolation, flux calculations). Instead we quantified a) the overall errors in the removal model (Fig. 4a) and identified contributing processes (Fig.7b). and b) we quantified the overall error of the proposed model by comparing the modelling results with the observed in-stream nitrate concentrations (Fig. 4b and 4c). In the interpretation of our results we show the effects of the spatial variability in the in-stream-removal processes on total export.

Even if there is an undetermined uncertainty within these export rates, the spatially variable impact of the in-stream-removal processes would relatively stay the same, due to the nature of first-order kinetics. According to the suggestions of Reviewer 1 we will improve the description of the uncertainty calculations and we will mention the issues discussed above in the revised manuscript.

3. Lastly, the synoptic sampling of the system was done during a short season of base-flow in one year. I question how much insight can be gained from this limited time period. Again, this goes back to the idea that the study is somehow addressing fundamental questions of stream networks when 1) the catchment and reach are very small; 2) there is unknown data quality and modeling differences are greater than measurement differences; and 3) the study was done for a limited time frame. I believe the paper presents an interesting study of a first order catchment but think the authors should back away from the idea that the study represents new insights on fundamental dynamics of nitrate in a stream network.

Answer

Point 1) and 2) are answered above. The synoptic sampling was carried out during the summer low flow period when changes within the catchment's hydrogeological storages occur slower (due to the decreasing slope of discharge recessions) compared with discharge dynamics during the wet season when surface runoff and near surface storages feed the stream. Nonetheless, there is a change in dominant sub-catchments during summer low flows, which control stream water composition and thus apparent in-stream nitrate concentrations. This period, during which lower nitrate concentrations than during the non-vegetated season might be observable in the stream, is a key period for the ecohydrological conditions (e.g. water quality thresholds) and eutrophication processes in the stream habitat.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 8577, 2015.