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Biogeosciences Discussions

Interactive comment on "Nitrate removal in a restored riparian groundwater system: functioning and importance of individual riparian zones" *by* S. Peter et al.

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Author's response to Referees comments

First, we would like to thank the two anonymous Referees for their positive and constructive reviews.

Anonymous Referee #1

Referee 1: This was an easy paper to review. The study design was good and the authors provide multiple corroborating lines of data to support their conclusions. The paper is well written. I have only a few suggested changes to the text. The only

substantive issue with the paper is the low sample sizes. For example why is only data from 1 piezometer used to average discharge conditions (page 6724, L24)? However, the authors provide chemical, hydrology, isotope, and genetic data to make their case all of which seem to point in the same direction. It's very interesting to note that while the willow zone is most efficient, the forest zone contributes greatest to N removal. The results beg the question of "what is so great about willow zones that makes them so good at removing N". The authors suggest that willow contributes organic carbon to the substrates that fuel denitrification. That may be true, but willows grow where hydrologic conditions are conducive because they require flooding and generally wetter conditions. So, the authors should not exclude the possibility that the willow zones are unique hydrologic features of the river ecosystem. Furthermore, suggesting to grow willow to increase N removal in restored riparian zones will be dependent upon creating the proper hydrologic conditions. In other words, willows will not grow just anywhere.

Authors: We were pleased to read that the quality of our study design, the multiple lines of evidence and the clarity of the paper were acknowledged. We are aware of the problem of small sample sizes. As this was a complex interdisciplinary project with different sub-projects we had to compromise on the number of piezometers to be drilled. As a consequence the replication of sampling sites differed among different functional process zones. In response to the remark on the interaction between hydrologic conditions and vegetation zones we added the following statement in section 4.3 to refer the reader to a recent study on the relation between the willow root system and the hydrology at the same site: "The vertical root distribution and density of Salix sp. in alluvial environments has a tendency for increased growth towards the groundwater table with more distance to the river (Pasquale et al., 2012)." Furthermore, in the conclusions we address the issue of the habitat conditions for willows as followed: "Willows are among the main colonist of alluvial environments with open and wet habitats (Kuzovkina and Volk, 2009) and can be considered as unique hydrological features of riparian systems. When established they can endure extreme water fluctuations."

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Specific comments

R1: P6719, L14: comma after “consequence”

A: Done

R1: P6719, L24: use past tenses of verbs

A: Done

R1: P6721, L2: this sentence could use a citation

A: The reference to (Diem et al., in preparation) was added.

R1: P6724, L24: why only one piezometer

A: We chose only one piezometer per FPZ for the model to (i) keep it as simple as possible, (ii) that way we could choose the piezometer of a FPZ where we had most data available, and (iii) for some FPZ we had only a complete data set for one piezometer. Based on our data, we are confident, that the piezometers chosen represent well the conditions in the individual FPZ.

R1: P6727, L15: can you apply stats to this comparison of NO3 removal between restored and channelized section?

A: A t-test revealed a significant difference between removal rate of the restored and channelized section. This is now added to the text in section 3.3.

R1: P6728, L22: why were no samples analyzed for gravel or pasture?

A: On 23 June 2009 we did not sample the gravel FPZ because it was flooded. The pasture zone was not included in every sampling campaign because we were very restricted in sample numbers that we could process.

R1: P6729, L20: change “individual riparian zones” to the term FPZ A: Done

R1: P6731, L5-8: this long sentence is vague and difficult to understand

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A: We reformulated this sentence paragraph as follows: “In a parallel study at the same field site, however, Peter et al. (2012) found that the suspended microbial community is actively growing in the groundwater. Therefore, the gene abundances in this riparian groundwater seem to reflect local, and to a lesser extent upstream, environmental conditions. They may be used as an indicator for local microbial processes in the groundwater.”

R1: P6732, L23: do you mean by transfer times, flow velocity?

A: We changed to water residence times.

R1: P6733, L3: here, you could cite Mayer etal 2010 JEQ 39:810–823

A: Done

R1: P6733, L18: here, you could cite again Gift etal 2010

A: Done

R1: P6735, L7: change “warrant” to another word. I don’t understand the meaning in this context.

A: Changed to ensure

R1: P6735, L12: what is meant by “ventilate”?

A: Changed to ‘provide O2 to’

Anonymous Referee #2

GENERAL CRITERIA

Referee 2: The manuscript represent a good contribution to scientific progress on buffer zones efficiency after river and its corridor restoration project (Good). The interdisciplinary of the authors group and the level of interaction between the different scientific disciplines are excellent (Excellent). In my opinion there are too many references to other manuscripts that hide information for easy comprehension of the text.

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Inter-disciplinarity is definitely a good step but the results and discussion should be as clear as possible and well-structured (Fair)

A: In the revised version, we tried minimized the use of multiple references on the same topic or to better document the main information in earlier publications. However, in such a interdisciplinary study, it is difficult to repeat all the information contained in other references and still adhere to a concise writing style (see also the answers to the individual questions).

INDIVIDUAL SCIENTIFIC QUESTIONS

R2: Results 3.1 Hydrodynamics It is not clear to me why the upper soil, usually the most active part, is excluded from the budget.

A: The upper soil contribution (water flux) is included in the model by (Huber et al., 2012) whose results we used to calculate the budget. However, we only used the nitrate concentrations of the deeper soil parts, because these concentrations are more relevant for the question what is leached into the groundwater. The study by Huber et al. (2012) addresses in detail the processes in the unsaturated soil column.

R2:The river feed groundwater but what going on in the first two meters?

A: We did not investigate the processes in the first two meters of infiltration because this was outside of the scope of the study. We agree that in the first meters of infiltration intense biogeochemical processes can occur, however, the focus of this study was to investigate processes relevant on the scale of the whole riparian aquifer. The small scale processes along the soil-groundwater interface were documented in great detail by Vogt et al. (2012). We clarified this point in the text in the last paragraph of section 1 where we addressed the objectives of the study and at the end of section 2.1 (description of the study site).

R2: Is it any temporary sub-superficial flow come from field during heavy rain? Did you checked if there was any hydraulic connectivity between field and FPZ?

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A: Infiltration through the unsaturated zone can occur during heavy rain. However, simulation results with a three-dimensional groundwater flow model (Diem et al., in preparation) have shown that the influence on groundwater flow field is small compared to the river infiltration. Along the same line of evidence, Vogt et al. (2010) calculated that the main contribution to the riparian groundwater at this field site was the infiltrating river water. In addition, Vogt et al. (2012) observed no relevant contribution of the unsaturated zone to the groundwater flow in the first meters of the River Thur aquifer. We added a sentence to the description of the study site (sect. 2.1) addressing this issue: "The riparian groundwater is primarily fed by the infiltrating river water and the contribution of vertical water flow from the unsaturated zone is negligible (Vogt et al., 2012;Diem et al., in preparation)."

R2: 3.3 Nitrogen budgets for individual FPZ The groundwater is really isolated form the top layer in the willow bush or forest? The root-system can break the impermeable layer making vertical flow-path, Was it checked?

A: The NO3- contribution of the soil (top layer) to the groundwater was inferred from the coup model (daily water fluxes) and NO3- concentrations in the soil (Huber et al., 2012). This model is based on coupled heat and mass transfer. Meteorological data (air temperature, precipitation, relative humidity, global radiation, wind speed) and continuously recorded groundwater levels were received from the meteo-station and pressure head sensors installed in 20 observation wells, respectively. The effect of vertical-flow paths was not explicitly checked, but should have become obvious from modeling the daily water fluxes (Huber et al., 2012). Also, the model by (Diem et al., in preparation) confirmed a minimal influence of vertical flow from the unsaturated zone compared to the river infiltration. During flood events, the root systems may facilitate some vertical flow. However, the budget calculations were performed for average flow conditions, when vertical transport can be neglected.

R2: 3.5 Is it possible to explain more about how you calculated the abundance? Which is your unit volume?

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A: The abundance of the functional genes is usually given in copies per ng DNA. The methods used for these calculations are given in detail in the manuscript. The normalization to DNA is common in the field of microbial ecology, as it provides an unbiased view on the composition of the microbial community. In contrast, reporting copies per volume of extracted water will introduce sampling bias for two reasons. First, the amount of microbes in a water sample depend on water sampling strategy. Second, the efficiency of DNA extraction from filter membranes is highly variable. Both parameters are difficult to account for on a quantitative basis. For this reason, we report copy numbers per ng extracted DNA.

R2: 3.6 Cloud be very useful to have C content of the soil profile too.

A: We added the results by Huber et al (2012) on DOC in the soil water in the section 3.6: "The OC of the soil water, measured by Huber et al. (2012) in the different FPZ was lowest in the willow bush zone (533 $\pm$ 70 – 605 $\pm$ 45 μmol L 1) and highest in the forest zone (743 $\pm$ 40 – 983 $\pm$ 299 μmol L 1)."

R2: Discussion In general, the discussion could be improved by an analysis with more purpose application instead of a re-analysis of the results. For the same reason I would like to suggest to add also the mg/l unit for a faster understanding and comparison with other systems.

A: We feel that our sections on N sources and sinks, nitrate removal processes and vegetation- soil-groundwater coupling go well beyond a "re-analysis" of the results. We do not share the view on concentration units. The units mol/l instead of mg/l facilitates the comparison of microbial processes and stoichiometric calculations. It is very easy for a reader to convert the different values.

R2: The sentence between line 5 and 10 (pag 6730) seems quite discounted and I do not understand the added value of its.

A: See comment of Referee 1: "It's very interesting to note that while the willow zone

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is most efficient, the forest zone contributes greatest to N removal."

R2: Lines between 5 and 10 (pag 6731) I am not sure that could be enough one references (what does it means companion study? same study site? To support your comments please be more scientifically persuasive or cogent.

A: This was a parallel study at the same field site. This is now clarified in the text. Also, we reworked this part for better understanding (see also the answer to Referee 1).

R2: Lines 19 to 25 (pag 6733) May be the willow bush is a hot spot because the higher water table than the willows vegetation itself, but this is not clear explained in your manuscript.

A: Inundation of the vegetation occurs only > 300 m3 s 1 discharge which is a rather rare event (1-2 per year) and might therefore not have a relevant effect on the observations in this study. This is now added to the text.

R2: Conclusions Could be very useful to indicate or suggest which are the most effective parameters to monitor the nitrogen removal efficiency of a riparian zone within restoration measures.

A: We agree and added a statement on N-monitoring for the assessment of successful river restoration: "For a successful N monitoring in the groundwater of a restored site, the spatial and temporal investigation of NO3 concentration and its isotopic composition proofed to be very powerful." In addition we argue that the multi-dimensional linkages should be considered.

R2: Moreover to facilitate a good comparison with other systems and restoration projects I suggest to add the efficiency of NO3 removal in kg/ha . The number is now added in the conclusion section.

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Interactive comment on Biogeosciences Discuss., 9, 6715, 2012.