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Biogeosciences Discussions

Interactive comment on "Effects of long-term flooding on biogeochemistry and vegetation development in floodplains – a mesocosm experiment to study interacting effects of land use and water quality" *by* A. M. Banach et al.

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Responses to the general comments of the Referee #2 Shallow soils from two fields differing in prior land-use history (intensity of fertilization, mowing vs pasture) were collected and subjected to 9 months of continuous inundation with flood waters that differed in sulfate and nitrate concentrations. The paper is well organized and written, but in parts missing some key information. The results especially for vegetation development are clear for the two fields measured. The results would be more generally applicable if sods had been taken from more than one field of each type. The discus-

sion could be strengthened by more thoroughly incorporating details of other studies of floodplain biogeochemical and vegetation response to flooding but with varying experimental conditions such as timing and duration of inundation, quality of water or soil characteristics. It could further be strengthened by providing more details of local hydrology: pristine/natural, changed by flood control, and proposed changes.

We are pleased to read that the referee stated that the paper is well organized and written, and have now adopted all comments. We have included more information from literature on other types of wetlands, the relation to field conditions in more pristine areas and to other experimental conditions (long-term versus short-term, winter versus summer); see below. In addition, details about current and possible future hydrology have been incorporated, and the results were compared with those of Antheunisse and Verhoeven (2008), Beumer et al. (2008) and Loeb et al. (2008b).

Responses to the specific comments of the Referee #2 Abstract should be improved for clarity and content. Information needed to understand results is sketchy. First sentence is too long and diffuse, with many important concepts, suggest breaking it down. A clearer description of the study design here would help, including the length of flooding and the time (ie 9 months starting in January, under natural conditions of temp and light).

We agree and changed this part of the abstract to: 'Raising safety levees and reinforcing dykes is not a sufficient and sustainable solution to the intense winter and summer floods occurring with increasing frequency in Eastern Europe. An alternative, creating permanently flooded floodplain wetlands, requires improved understanding of ecological consequences. A 9 month mesocosm study (starting in January), under natural light and temperature conditions, was initiated to understand the role of previous land use (fertility intensity) and flooding water quality on soil biogeochemistry and vegetation development.'

Introduction Page 3266, line 4: does dyke replacement signify dyke elimination? Is

dyke equivalent to a levee for flood control?

We changed 'replacement' into 'displacement'. Dykes and levees are equivalent in lowland rivers, so we changed this to 'dyke/levee'.

Page 3268, line 10: What is meant by permanently flooded? Is it permanent cover of water in fields, or is it a floodplain open to flooding by river when flood stage is reached? That is, a reconnected floodplain subject to periodic naturally occurring floods.

In this study we tested the effects of permanent cover of water in the floodplains (marshland) as a result of reconnection to the river. We added the next sentence to clarify this option: 'This measure is one of proposed strategies to counteract flooding risks; next to the creation of temporarily flooded areas for water storage during flood peaks which was investigated in our previous work (Banach et al., 2009b) and that of others (Antheunisse & Verhoeven, 2008).'

Materials and methods The two meadows chosen for samples, do they have different land use histories by accident, or because they differ in some properties making them useful for only pasture or haymaking respectively?

We added the following sentence to answer that question: 'Along this river there are several meadows which show different cultivation histories depending on the preferences of their owners.'

Do they have the same hydrology/degree of connectedness to the adjacent river? Is the depth of water table, and frequency and duration of inundation similar?

Yes. We added (L24): 'showing exactly the same hydrology'.

Is the organic matter similar for both types of fields in terms of origin, quality and state of decomposition? What was the nature of the fertilizer used?

We added: 'Both meadows have the same geological origin and... (P3269, L2) and 'The HAY soils have been more strongly decomposed as a result of fertilization.'

(P3269, L9), to clarify this issue.

The fertilizer was a commercial product. We added: '(with commercial fertilizer)'(P3268, L25).

Soil is characterized for upper 20 cm, and the water table is normally below 30 cm. Does this matter? Soils with this high organic matter content and a water table that is lower than the peat should be somewhat oxidizing and losing elevation?

This is right, the soils are oxidizing as a result of this water table. We have described the upper 20 cm to characterize the soil layer that was used for the experiment, and added: 'leading to the partial oxidation of the top layer' (P3269, L4).

Experimental design When were the sods removed from the field? After the growing season? How long were they acclimated before being flooded? What is the size of each sod?

We have changed the part on the Experimental Design by adding the requested information: 'For studying the effects of long-term inundation with stagnating water, 40 sods (30x30x15 cm) were collected in total in autumn, with standing vegetation.'

What were the hydric conditions of the sods like prior to the beginning of flooding? Was the water table drawn down, or were the sods kept fully saturated?

The sods were kept fully saturated prior to the study.

Measurements and chemical analyses What was the frequency of sample collection for water analyses? I didn't see a description of how surface waters were sampled except for turbidity. Probably more detail is needed here. Also, are there estimates or a record of the volume of water needed during the nine months to keep water levels 20 cm above the surface for all of the plots? How would this affect the chemistry of porewater and surface water?

We added: 'The sods were kept inundated at 20 cm above soil level for 9 months

(January till November) and if necessary adequate volumes of floodwater were added to maintain the desired water column.' (P3269, L25)

We adapted part of the section to describe the sampling of surface water: 'Sediment pore water (50 ml) and surface water (500 ml) samples were collected monthly. Additional pore water samples were collected three times (Fig. 2) for determination levels of inorganic carbon (TIC, sum of CO2 and HCO3-). (P3270, L18).

Vegetation description I think above-ground harvesting of vegetation occur twice, once after 6 months, 3 months prior to end of experiment (page 3271, line 25-26) and then after 41 weeks. Did this affect the data from fig. 6, which are after 41 weeks, and represent growth from week 24 to week 41? Did this influence other experimental results, such as porewater chemistry, regrowth of species? Some discussion/clarification may be useful.

Although the harvesting may have had some effects on pore water chemistry and regrowth, we have chosen for this option to be able to measure biomass production rather than standing biomass. This was essential with respect to possible eutrophication, nutrient limitation and toxicity. In addition, vegetation in the field will be clipped by herbivores and may even be mown (as is done in many wet meadows in the Netherlands during short-term water table draw-down), comparable to the harvesting in our experiment.

Data analysis Page 3272 line 12 and 13. sentence not needed, better shown on relevant tables.

We have removed this sentence as suggested by the referee.

Results Consider leaving out the first sentence of second paragraph. Check to make sure each reference to table or figure is correctly identified. For example, Table 4b not found. For example, Page 3273, line 10. Is reference to table 4b correct? Table doesn't show changes in concentration of NO3 after 1 week.

We have removed the first sentence of second paragraph as suggested. We carefully checked all references to all tables and changed them accordingly.

Soil response to flooding Consider combining figures 2 and 3 to 2a and 2b, and figures 4 and 5 to 4a and 4b.

We combined figures as suggested, and added 'continued' to the captions of former figures 3 and 5.

Possibly consider putting surface water text references in a paragraph following the porewater discussion, rather than mixing both media in one paragraph, for clarity and ease of reading.

We have separated surface water data from porewater data by creating subsection 'Changes in water layer' after subsection 'Soil response to flooding'.

Vegetation response The results are clearly shown in Fig 6 for vegetation growth between 24 and 41 weeks. It may be helpful to graphically show the data from the period after 24 months.

In an earlier version of our manuscript, we indeed included the data about vegetation after 24 weeks (we suppose this is the time meant by the referee). However, because the trends were similar and this meant that, next to three additional figures, a complete extra statistics table had to be included, we chose to omit these data for reasons of space and clarity.

I find tables 6a and b confusing and not helpful in the format used. Perhaps these data could be shown a different way?

We agree that the table may be confusing and have changed it; 6a and 6b are the standard GLM tables as generally used in literature, and we have now clearly separated 6c (post hoc).

Discussion In the discussion it would be nice to know what the natural floodplain flood-

ing timing, durations, depths and frequencies are for similar systems. Perhaps there are references? This would enable judgment of appropriateness of mesocosm design to help inform management decisions.

We agree and added: 'This response is in contrast to our earlier findings on short-term flooding during summer, where flooding itself rather than water quality determined the biogeochemical response and the vegetation development (Banach et al., 2009b). The hydrological conditions tested in the present study relate to those in more or less pristine marshes dominated by sedges (Wassen et al., 2002; Kotowski et al., 2006).'

I would like to see some discussion on how continuous flooding of sods from January to October relates to proposed management changes in flooding regimes at the research sites. What is the expectation for vegetation development over many years with this kind of simulated hydrologic regime?

We agree that this is important, though beyond the scope of our experiment, and added: 'The long term vegetation development after years of hydrological changes may, however, diverge because of succession related to long-term competition between plants, dispersal of diaspores and herbivory, processes that could not be included in the present experiment.' (P3280, L11).

I would like to see a bit more detailed discussion and contrast of the different responses to short term summer growing season flooding compared with the long-term flooding. To some degree, this is included, but a more detailed discussion would be nice.

We agree and added (Conclusions): 'The actual effects on biogeochemistry and vegetation will, in addition, strongly depend on the actual flooding duration and frequency, the flooding season and the water level. We tested the creation of a permanently, shallowly flooded situation throughout the year, as this is one of the possible measures to combine the reduction of flooding risks for the population and the restoration of marshes along rivers. These results differ from those of short-term summer flooding (Banach et al., 2009b) where flooding itself had the most striking effects on plant

ecophysiology and soil biogeochemistry, regardless water quality. As the rate of the different biogeochemical processes and the growth of plants are both significantly influenced by temperature, winter flooding will have much less effects (e.g. Beumer et al., 2008; Loeb et al. 2008b).'

Can the strikingly different vegetation development from the two types of fields be fully explained by differences in water-quality response to flooding? What are other possible factors that were not explicitly addressed? For example, it seems to me heavy fertilization should affect soil organic matter properties beyond those chemical comparisons given in the table.

We agree that there is a strong interaction between water quality and soil quality (including factors not addressed in the table), but the differences still relate to differences in water quality, both by direct and by indirect effects. We added: ' , affecting a number of soil characteristics including those shown in Table 1)'. (P 3280, L12.)

Conclusions Page 3281 lines 23 to end expand just a bit.

We changed this text to: 'Our work emphasizes the important role of land use (level of fertilization). For heavily fertilized soils, desired vegetation development only seems possible if sulphate and nitrate levels in the surface water are low. This means that for intensively used agricultural areas, water quality seems to be even more important than for other areas, which is rather unexpected. Strikingly, development of sedge fens was possible for less fertilized soils even at higher sulphate and nitrate levels, although plant biodiversity was still relatively low (partly due the absence of plant dispersal in our experiment) and peat formation is less probable due to still high levels of nutrients, presumably leading to high decomposition rates.'

Vegetation development was hindered in sods taken from the field that had had lots of prior fertilizer applications except if flood water was stripped of nitrate or sulphate. Are concentrations at these low levels realistic for many river systems? A few? Some hint at how applicable these conditions are in general would be helpful. Perhaps it is easier

to find fields that have not had this history of fertilizer application, and concentrate floodplain rehabilitation on these types of fields, which apparently can handle higher river sulfate and nitrate concentrations, at least for a while.

We fully agree and changed the first part of the second paragraph to: 'Our work emphasizes the important role of land use (level of fertilization). For heavily fertilized soils, desired vegetation development only seems possible if sulphate and nitrate levels in the surface water are low as in less polluted rivers (Lamers et al., 2006).'

In addition, we added the following text at the end of the Conclusions: 'Especially if water quality of rivers is still unfavourable with respect to sulphate and nitrate, restoration measures should concentrate on those areas that do not show a history of heavy fertilization.'

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