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Biogeosciences Discussions

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8, C4187–C4195, 2011

Interactive Comment

Interactive comment on "Spatialized N budgets in a large agricultural Mediterranean watershed: high loading and low transfer" *by* L. Lassaletta et al.

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Author's response to anonymous reviewer #1

We thank the insightful comments of Reviewer #1, they have been very useful to improve our manuscript and to clarify several aspects of the text which may help the understanding of the readers.

As required, we hereby respond to all the specific comments. We have also prepared a revised version of the paper thoroughly describing all the information required and including new contents both in the Materials and Methods section and in the Supplementary Material.

Specific comments:

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Interactive Discussion

Discussion Paper

Reviewer comment: P 8725, line 13: replace “augmented” with “grown”

Authors’ response: Ok, thank you.

Reviewer comment: P 8729, line 1: Schaefer et al 2009 and Schaefer and Alber 2007 could be added to the list of NANI studies. In particular, they report on effects of temperature in Southeastern and Western US watersheds which might be relevant to the discussion here and elsewhere in the text. Schaefer, S.C., Hollibaugh, J.T. and Alber, M. 2009. Watershed nitrogen input and riverine export on the west coast of the U.S. Biogeochemistry. 93(3):219-233. Schaefer, S.C. and Alber, M.A. 2007. Temperature controls a latitudinal gradient in the proportion of watershed nitrogen exported to coastal ecosystems. Biogeochemistry. 85:333-346.

Authors’ response: Thank you. We have included both references in the introduction section; they are indeed very interesting and we have also used them in the discussion section.

Reviewer comment: Page 8729, lines 5-10: The language describing N deposition is somewhat confusing. The authors seem to saying that they are including only net reduced N in the estimate of deposition, though it seems to be clear on p 8734 that they are including both reduced and oxidized N terms. Can the authors justify this detail given that the total (net) N deposition estimate is a relatively minor input in general (4-9% of N inputs)? (there seems to be little further discussion in the results and discussion, beyond indicating that oxidized forms represent a source and reduced forms a net loss of N. Why aren’t these terms included individually in table 2?)

Authors’ response: The way to take into account atmospheric deposition differs in the NANI Black-box approach and in the agricultural surface balance. In the NANI approach, we argue that only the net atmospheric deposition figure should be considered. This is why we established a complete balance of deposition and emission of reduced N. In the soil surface balance (Table 2), on the other hand, total (reduced and oxidized) N deposition on agricultural surface is considered for calculating the surplus N inputs with respect to harvested crop output. Moreover, a detailed discussion of the budget of Nr and Nox atmospheric deposition could not be carried out at the scale of territorial units due to the low resolution of EMEP data (50x50km).

Reviewer comment: Lines 19-21: Why include ICEP? While I understand that the N and P watershed fluxes are put in the context of nutrient limitation in coastal waters by examining the Redfield ratio with respect to Si, the discussion seems a bit distracting in a paper primarily about watershed N budgets (and which does not claim to estimate P or Si fluxes). It seems like a companion or follow up paper would be a better place to discuss the relative importance of N and P loads to coastal waters, and their relationship to Si fluxes.

Authors' response: ICEP (Billen & Garnier, 2007) is a useful index to evaluate the eutrophication potential in nearshore waters; it is based on the proportion of nutrients that are exported from continents to coastal areas. This index has been widely used in the scientific literature. One of the main conclusions of the paper is: "The hydrological and agricultural management characteristics of the catchment, along with common agricultural practices in Mediterranean areas, namely the high density of irrigation channels and reservoirs, produce high N retention within the territorial units and hamper N transfer among them. As a consequence, very little of the reactive N that enters the catchment flows out to the sea. This prevents severe eutrophication problems in the coastal area but leads instead to many problems in the catchment, such as pollution of aquifers and rivers, as well as high atmospheric emissions." Therefore, we consider that the inclusion of an estimation of the potential effects of N export to the sea makes this conclusion sound. The paragraph focused on ICEP has been shortened in the revised version and is now centered only on N.

Reviewer comment: P 8730, lines 21-28: The discussion of the estimate of N fixation refers to an equation "that relates crop yield, N fertilization, and crop residues" but is otherwise unspecified, ie there is no mathematical formulation of the N2 fixation relationship. It is impossible to evaluate the validity of this estimate without a more precise statement of the relationship used.

Authors' response: We have rephrased the description of the calculation and made the equation explicit. Biological N2 fixation by legumes is a difficult term to be accurately assessed. It is of current practice to use general figures by crop, which can however overestimate N fixation in low productive crops and underestimate it in high-yield crops. We developed a formula that relates total N fixation by a legume crop to crop yield, includes non-harvested residues and underground biomass, and takes into account the fact that, in the period prior to nodulation, N is obtained by legumes from mineral nitrogen present in the soil, while only after nodulation is achieved, N is progressively assimilated from N2 fixation. The relationship is the following: N fix (kgN/ha/yr) = ïĄą* Nyield – A where Nyield is the harvested biomass expressed in N content (kgN/ha/yr); ïĄą is a coefficient expressing the ratio total biomass produced with respect to harvested biomass (a typical value of ïĄą is 1.4 (Carlsson and Huss-Daniel, 2003) and A is the amount of N taken up by the legume crop from the soil mineral N pool prior to nodulation. We approximated the latter term as the amount of mineral fertilizers applied to the legume crop (between 12 and 100 kgN/ha depending on the crop). All these explanations have been also included in the Supplementary Materials section.

Reviewer comment: P 8731: The authors state that they have compiled data on livestock numbers, human inhabitant-equivalents, and WWTPs in order to estimate the manure N and N inputs to streams from human sources, but they do not specify the details of these calculations. It is impossible to evaluate the assumptions used in the calculations unless details are provided. Actual parameters, etc could be provided in supplemental materials.

Authors' response: Following the reviewer's suggestion, we have extended the Supplementary materials section including a new map and giving further explanations. For manure, we only need to clarify that we have used 85 kg N per Livestock Unit. The way manure has been spread onto agricultural areas was already explained in the original manuscript (Page 8732, Lines 24-25). Regarding point sources, more detailed explanations have been included in the Supplementary Materials section. A map showing all the point sources has also been incorporated.

Reviewer comment: P8733, lines 13-14: The authors state that the effect of fraction of watershed dammed and irrigation channel density on N retention was "statistically analyzed", but no details are given. More information is needed to evaluate this.

Authors' response: First of all, we correlated the surface area of the catchment that drained into a dam with the percentage of retention by means of a Spearman Rank Order correlation. Secondly, we split the data into two groups: samples with a proportion of surface higher or lower than 0.058 km/km2; this value corresponds to the irrigation density of the whole Ebro basin. We compared the mean retention of these two groups performing a Kruskall-Wallis test. Finally, we constructed a non-linear regression model to assess the response of each sub-catchment in terms of % retention with regard to the proportion of surface area that drained into a dam. We used the GraphPad Prism software to estimate the parameters of the model and also the % of variance absorbed. This paragraph has been included in the manuscript for better understanding.

Reviewer comment: P 8735: annual N input to TU1 is characterized as "moderate (4361–6368 kgNkm−2 yr−1)", but the abstract characterizes the overall average new N input to the Ebro basin as "relatively high (5118 kgNkm−2 yr−1)". Isn't this inconsistent? What do "high" and "moderate" mean?

Authors' response: We agree with the reviewer that this could be confusing. We used high and moderate in relative terms in comparison to European and Ebro values respectively. To set all in the same scale we have replaced "moderate" by "relatively high".

Reviewer comment: P 8736: Discussion immediately following section 4.3 – I assume that the sample of 21 catchments is the same as the 21 catchments discussed in section 3.4, and that they were chosen on the basis of available data at monitoring stations.

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Authors' response: Yes, we have clarified this point in the revised version.

Reviewer comment: The relationship between retention and fraction of area dammed was evaluated using a Spearman rank order test, though the explicit mathematical form selected (eq 1) was not evaluated – how well does the model in eq 1 fit the observations? Why are these data not presented in a table or supplemental materials? Were other relationships for retention evaluated (eg watershed area?) Is the proportion of area dammed a particularly strong predictor of retention compared to others? What is the basis of the criterion of 0.05 km/km2 irrigation drainage density for separating catchments into irrigated or non-irrigated categories? Was there some analysis involved, or can a reference be cited? P 8736, eq 1: ïĄůïĂăappears to be a superscript font, and should instead be regular size

Authors' response: We have used the software GraphPad Prism to estimate the curve parameters and also the R2 of the model. Please see previous responses. This predictor explains almost 60% of the variance, so we can conclude that it is a strong predictor. The relationship between watershed area and retention was statistically analyzed and no significant relations were found (Spearman R = 0.37; p = 0.1). We split the dataset into samples higher and lower than 0.058 km/km2; this 0.058 value corresponds to the irrigation density of the whole Ebro basin.

Reviewer comment: Supplementary material: The supplementary material consists of a table consisting of columns specifying N output(%), and Yield $\pm$ SD for rainfed crops, irrigated crops and greenhouse crops (kg/ha) for each crop considered in the study. I believe that "N output (%)" is actually the percentage (by mass) of nitrogen in harvested biomass in each case, and should be stated as such, so that the actual N output (kg N/ha harvested area) associated with each crop and category is the product of yield and "N output (%)"/100. Is this correct?

Authors' response: Yes, it is exactly as you say; we have tried to state it more clearly in the table included in the Suppl mat in order to avoid misunderstandings. The revised text is: “N output (%) corresponds to the proportion of N that has been removed with the harvested biomass and can be thus considered as an output. It is expressed as a % of the crop yield. Therefore, the formula to calculate actual N outputs is: N output (kg N/ha) = crop yield (kg/ha) * (N output (%)/100)”

Reviewer comment: Given that the authors have chosen to provide this level of detail in the supplementary materials (for which I commend them), I think it would make sense to provide corresponding information for some other calculations, eg livestock & manure N calculations, etc

Authors’ response: As we indicated before, we have extended the Supplementary materials section including a new map (a new figure including information on point sources) and also further explanations.

Reviewer comment: Fig 2 The legend reads “Spatialized crop N outputs in the Ebro River Basin. Similar maps have been created for all N inputs.” This is good, but what is the point of announcing that these additional maps have been created if they are not presented? Will they be available in the supplemental materials, or in some published reference?

Authors’ response: We meant that we had obtained a GIS layer for each input. All maps have now been included in the Suppl. Materials section.

Fig 5a “pastures” is missing from the “rainfed and pastures” label in the figure

Authors’ response: Thank you, it has been corrected.

Reviewer comment: Fig 6 (and associated discussion) What explanation do the authors offer for the increased N retention in watersheds with higher irrigation density? One might argue that this would decrease retention time, and thus reduce retention rather than increase it. Is there a relationship between irrigation density and hydraulic residence time across these watersheds?

Authors’ response: We completely agree with the reviewer that further discussion on

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the effect of channels in N retention was needed. The final part of the 4.3 has been rewritten focusing on these aspects: “Oelsen et al. (2007) have studied how some irrigated agricultural systems in USA acted as N sinks instead of sources. This is not the case for the Ebro, where nitrate concentrations have historically increased in many streams, the increase being mainly related to agriculture (Lassaletta et al., 2009), and where nitrate concentrations in the irrigation return flows are also very high (Causapé et al 2006). In spite of this, our results show that the largest part of N inputs is being retained within the catchment. Bartoli et al. (2011) have recently underlined the severe effects of the morphological modifications of Mediterranean river networks, like the alterations made to a medium-sized agricultural and highly-channelized Mediterranean catchment in Italy. These authors have found a very high retention in the channels network due to denitrification, which is higher than river retention, and that can account for 12% of the N surpluses retained in the catchment. High retention rates in channelized agricultural systems, however, can be related not only to the channels themselves, but to the landscapes associated with these practices. Irrigation practices produce frequent water recirculation on the landscape before reaching the river outlet, therefore allowing this water to reach the aquifers earlier. These landscapes also comprise plenty of irrigation ponds (10000 in the Ebro Basin; http://www.chebro.es where N can be retained and processed. Extraction wells are placed in some irrigated areas and some barriers are commonly placed in the streams to divert the water to the channels that could also contribute to water recirculation and N retention, respectively. We have seen how N fluxes in irrigated systems can be also high in summer (Fig. 9). N retention in rivers is higher during the summer period because high temperatures stimulate N assimilation by the river biota (Merseburger et al., 2005), being also an optimum period for denitrification (Piña-Ochoa and Álvarez-Cobelas, 2006; Schaefer and Alber, 2007). N export from irrigated lands to the rivers and channels has therefore a greater opportunity to be retained in the summer period. Finally, the effect of climate on the proportion of N exported by temperate rivers (Schaefer et al., 2009; Howarth et al., 2011) could be exacerbated by the more arid conditions of Mediterranean catchments.”

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Interactive comment on Biogeosciences Discuss., 8, 8723, 2011.