Biogeosciences Discuss., 8, C4196–C4205, 2011
www.biogeosciences-discuss.net/8/C4196/2011/

Biogeosciences Discussions

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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Received and published: 7 November 2011

Author's response to anonymous reviewer #2

We are grateful to reviewer #2 for his several detailed comments. We believe that they will help us to make our manuscript more comprehensible. As we have also mentioned to Reviewer #1, new comments and further explanations have been included in many sections of the manuscript and in the Suppl. Materials.

Specific comments: Reviewer comment: "During the last few decades, Nr inputs in Spain have evolved differently than in other European countries". Please provide a reference.

Authors' response: We do not explicitly mention a reference here because we reel off

all related concepts and cite corresponding references some sentences later in the introduction.

Reviewer comment: "... Spain they have increased by 22% and 18%, respectively. "Please provide a reference.

Authors' response: Thank you. It was the same citation as for Europe. We have moved the citations to the end of the sentences to avoid misunderstandings.

Reviewer comment: "... despite a slight decline in the surface of land devoted to agriculture." Please provide a reference.

Authors' response: It was also the FAO citation, we have corrected it.

Reviewer comment: Catchment, fluvial catchment or basin. These terms are used all over without distinction. –

Authors' response: Thank you, we have revised the text. In this new version we use Basin only to define names of river basins e.g Ebro river basin or Po river basin. We use catchment in any other situation.

Reviewer comment: "have been polluted by nitrate and have been declared as Nitrate Vulnerable Zones according to the Nitrates Directive (http://www.chebro.es)". A more specific site should be given.

Authors' response: We have now given some examples of Nitrate Vulnerable Zones associated to irrigated agriculture (e.g. zones placed in the central part of the main axis of the Ebro river or those placed in the area of the confluence between the Cinca and the Segre rivers; http://www.chebro.es)

Reviewer comment: To say that "Mediterranean-type ecosystems are present in many parts of the world" is unprecise, and untrue.

Authors' response: Mediterranean climate is present in the following parts of the world: Mediterranean basin, California, central Chile, Cape region in South Africa, and areas in South and South-West Australia (e.g. see Ochoa-Hueso et al., 2011). We have included this statement in the paper.

Reviewer comment: “ecological processes in Mediterranean-type ecosystems differ greatly from those in other ecosystem types, such as temperate ecosystems”. On what do they differ? You should provide more details on your assertions.

Authors’ response: Mediterranean climate can typically be defined by a hot, dry summer and a mild, wet winter. There are many papers from different areas of knowledge where its particularities have been reviewed. For example, Zalidis et al. (2002) indicate “In countries around the Mediterranean basin, the degradation of soil and water resources is a serious threat for the human welfare and the natural environment as a result of the unique climate, topography, soil characteristics, and peculiarities of agriculture”. Breiner et al. (2007) found high disagreement between theoretical N critical loads and empirical ones due to the particularities of the Mediterranean climate, that they summarize in: “the prevalence of dry deposition over wet deposition that, during subsequent precipitation events, may result in large pulses of N inputs to the soil with the solubilization of accumulated N deposited to plant and soil surfaces during long dry periods; the frequent temporal asynchrony between these large N input pulses and plant and microbial demand”, among other issues. Álvarez-Cobelas et al. (2005) indicate “we are beginning to see that Mediterranean limnology does not meld well with many concepts of temperate limnology, as the many "exceptions to the rule" statements in discussions of scientific papers by Mediterranean limnologists highlight”. They review many of these discrepancies in their respective papers. In order not to lengthen the text too much we have selected the papers that we consider the most enlightening and we have also included two new references (Zalidis et al., 2002 and Ochoa-Hueso et al., 2011)

Reviewer comment: “many climatic models...” You provide here a superficial detail on the previsions being made for the area; expand on this.

Authors’ response: IPCC 2007 (Chapter 11) report indicates many temperature and precipitation changes in European regions. In some regions of Northern Europe precipitation will increase, however, in central Europe summer precipitation will decrease and risk of summer drought will increase. Trnka et al. (2011) show the evolution of temperatures and precipitation for different European regions and season running different Global Climatic Models (ECHAM5, HadCM and NCAR-PCM). In all the models it can be appreciated how the increase of temperature and decrease of precipitation are particularly clear for the summer period in many non-Mediterranean “European Environmental Regions” (see Metzger et al. 2005) such us Pannonian, Continental, Alpine South, Atlantic central and Atlantic North. Both citations have been included in the paper and the sentence has been extended.

Reviewer comment: “a high number of channels” You mean irrigation channels

Authors’ response: Yes, most of them.

Reviewer comment: “The selection of adequate measures is a crucial item, since their efficacy is frequently much lower than expected”. Please provide a reason for this, or delete the sentence.

Authors’ response: We have included 3 very interesting references illustrating this problem in different areas in Europe. In the Netherlands (Oenema et al. 2005), in Norway (Bechmann et al. 2008) and in France (Thieu et al. 2010).

Reviewer comment: “Therefore, a detailed study of N budgets, its dynamics, and its transfers within the catchment may be a useful basis to evaluate the potential effectiveness of corrective measures” Why this can be true? You need to be more convincing here.

Authors’ response: In this paper we have evaluated N inputs, surpluses and transfers in a large scale. We have detected the N hotspots and identified transfers, and we have used this information to discuss the most effective measures. In our opinion, this assertion is demonstrated throughout the paper.

Reviewer comment: In this context, the present study aims to expand the knowledge on the N cycle in the large European Mediterranean catchment of the Ebro River" This is a rather poor objective. Please provide a hypothesis that considers the relevance of Med rivers.

Authors' response: Formulated in this way, our objective seems indeed quite general. We can reformulate it more specifically: Due to climatologic constraints (droughts are rather frequent and river flows can be unevenly distributed throughout the year), reservoirs and irrigation channels are essential characteristics of most Mediterranean streams; however, their role in N retention and the effects of such structures for transfers between compartments is poorly understood. One objective of our study is thus to cast light on this issue. We hypothesize that reservoirs and channels may have an effect on N retention because they modify the natural flow regime, increase water retention (reservoirs) and imply a redistribution of water within the landscape. Following your suggestion, we have reformulated this objective in the form of a testable hypothesis. We think it states more clearly the importance of this issue.

Reviewer comment: The Ebro is a seventh-order river.

Authors' response: This has been corrected.

Reviewer comment: The way you describe the approach to different data sources is somehow confusing. Though is clear that you use several sources to complement the data, is no clear how do you transfer data between provinces (I guess administrative provinces) subcatchments and TUs. This needs to be addressed in a convincing manner, in particular how did the subcatchments combine with the TUs.

Authors' response: The following detailed explanation has been included in the Suppl. Materials section to improve the understanding of the readers: "First of all, we gathered all the information on crop yields and crop surfaces for the year 2000 provided by the

Spanish Ministry of Agriculture (http://www.mapa.es/). This information is given by province. Secondly, we assigned to each crop from the Spanish agricultural statistics its corresponding category in CLC, e.g. barley, triticale and wheat were assigned to CLC rainfed herbaceous category (code 21100). Third, knowing the proportion of each type of crop within each type of CLC category per province, and taking into account their related N inputs and outputs, we obtained the characteristic N fluxes of each CLC category in each different province. Based on this, we created the map (Fig. 2 and Suppl. Mat. 5) where each CLC polygon contains the precise information on N inputs and outputs that correspond to the real crop proportion of the province where it is located. Once we have such map with precise spatial information on N inputs and outputs, we overlay either the TUs layer or the Subcatchments layer and we calculate the N budgets within each different polygon (polygons may correspond to a specific TU or to a particular subcatchment). Finally, we use the relationship between retention and proportion of reservoirs and channels obtained with data from the 21 subcatchments to assess the retention in each TU (see Table 3)".

Reviewer comment: What is the equation to calculate N2 fixation? Please describe or provide a reference.

Authors' response: We have now 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: How did you obtain the TU classification? Which criteria and procedure did you use? How the boundaries between the classes were established? Provide beforehand labels for the TUs; this might help to follow your reasoning throughout.

Authors' response: To obtain the TU we took into account several criteria including the type of crops, soil uses and livestock information. In particular, as now specified in the text, "we overlaid the map of main uses (Irrigated and rainfed crops, pastures, natural and urban areas) with the map of livestock units. We defined each TU so as to delimit homogeneous units (in terms of both characteristics). The boundaries were then slightly modified to adapt the units to the hydrological features and to the limits of the studied sub-catchments".

Reviewer comment: The selection of the 21 stream monitoring stations is not explained. Which are these sites? You need to provide a table to show them, with indication of whether they were located in the main axis of the river, in a tributary or at the junction with the main axis.

Authors' response: The Ebro River Basin Authority has a dense river quality control network (www.chebro.es). In this work, we have included all the stations with enough nutrient concentration and water flow data to estimate the N flows. The required table showing the coordinates, showing if they are on the main axis or in any tributary, and the name of each sampling site has been included in the Supplementary materials section.

Reviewer comment: Please define CHEBRO.

Authors' response: It means Confederación Hidrográfica del Ebro ("Ebro Basin Confederation"). It has been replaced in the text.

Reviewer comment: Why is the relationship between P and Si relevant to your goal in the paper? This sentence is far too lengthy.

Authors' response: The flux of N to Si and the flux of P to Si is the principle for the calculation of the ICEP (Index of Coastal Eutrophication Potential), and it is related with the fact that surpluses of N and P with regard to silica may preferentially favor non-silicified phytoplankton groups, such as dinoflagellates or flagellates, that are often responsible for harmful algal blooms. That is the reason why we mentioned both elements when talking about eutrophication. Nonetheless, we have shortened the paragraph and focused it onto N to avoid misleading the readers.

Reviewer comment: Was the retention part of a consistent pattern? As a Mediterranean watershed, the Ebro is highly irregular in rainfall, water flow, and water abstraction. Please consider this point in the discussion.

Authors' response: We show that retention values are in general high and that they mostly respond to channelization and dams. However, there is a part of variance which is not explained by these variables and that may depend on particularities of the different areas. Howarth et al. (2011) show how climate specificities can exert an influence on retention. We agree with the referee that some other factors, such as climate variability and/or management characteristics, can have an effect on the retention variance. We have mentioned this in the discussion.

Reviewer comment: You describe TU2a as one of the most retentive and this related to the irrigation channels. Why the existence of the irrigation channels should contribute to the retention? The residence time of water in these channels is short (because of their use); we need a rationale here.

Authors' response: We completely agree with the reviewer that further discussion on 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."

Reviewer comment: Fig. 5a and b. Is not explained in the text how the curves were constructed, since they do not derive from the data. Please provide an explanation. Labels are misplaced.

Authors' response: We have redone this figure according to R#1 and R#2 advices. Using an approach developed elsewhere (Billen et al. subm., Biogeosciences discussions, same issue), we used the following formulation for relating Nyield to total Nfertilization: NYield = Ymax.(1-exp(Nfertil/Ymax)) This single parameter relationship is the simplest one having the two required characteristics of having an initial slope of 1 and tending asymptotically toward the value of Ymax at large fertilization rates.

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