Response to the comments about the submitted paper *"LPJmL-Med – Modelling the dynamics of the land-sea nutrient transfer over the Mediterranean region–version 1: Model description and evaluation"*

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We would like to thank Reviewer 1 for taking the time and effort necessary to review the manuscript. We sincerely appreciate all valuable comments and suggestions, which helped us to improve the quality of the manuscript (ms hereafter).

Please note that reviewers' comments are in blue while our answers are in black.

Reviewer R2

The paper modeled the dynamics of water discharge, nitrate and phosphorus export to the Mediterranean Sea with the LPJmL model. The authors integrated a number of formulas in quantifying processes of N and P losses into rivers, in-river retention, and export. These processes include remineralization, adsorption, nitrification, denitrification and phytoplankton dynamics, etc. Indeed, these formulas in quantify the processes are not new, but the model runs on daily time scale. The key question is modeling N and P input into rivers from terrestrial sources with effective validation, which would make the model robust. That is particularly difficult and challenging. Up to now, less study or modeling can be validated in this area.

We would like to thank the reviewer for this comment. We agree withe the referee that the modeling of N and P input into rivers from terrestrial sources is particularly difficult and challenging for agro-ecosystem model. This paper is the fruit of a considerable effort on the implementation of the biogeochemical land-sea nutrient transfer processes and the preparation of the inputs/boundary conditions of the model.

From technical point of view, I have following questions regarding N and P input into rivers, in-river and in-reservoir retentions. Figure 1, regarding the conceptual diagram of nitrate and phosphate losses to rivers, diffuse sources include soil source, urban land source, rural land source. In addition, aquacultures feed also should be considered.This paper only modeled the soil diffuse source, without quantifying other diffuse sources such as urban land source, rural land source and aquacultures feed.

We are not sure what does the reviewer mean by "diffuse urban and rural land source". This paper considers both point sources and diffuse sources. Point sources deliver nutrients through wastewater release, this occurs at any location with population, whatever urban or rural. Could such "point sources" be what does the reviewer mean by "urban and rural point sources", and being considered as "diffuse" because population is distributed in every cell? Usually what we state as "diffuse sources" are the agriculture sources, which deliver nutrients to the soil. Through leaching, they percolate with water towards rivers. We agree with the reviewer that onshore aquaculture should be considered, as this sector contributes to nutrient load in the Mediterranean [Gorjanc et al., 2020] despite many programs for treating or recycling this load. Several studies on fresh water quality and modelling exercises which account for the impact of fish farming can be found in the literature but they are mostly local [Kontogianni et al., 2007, Kagalou et al., 2012] and focus often on the coastal zone. The integration of such nutrient load source within the whole Mediterranean catchment would need a huge data collection (spatio-temporal dynamics of aquaculture ponds, their typology for estimating regional mean load and cleaning processings, policy regulation time-series, etc. Such a work could not be done within the present study, it should be the objective of another paper. We have explained this point within the ms, both in the introduction and in the discussion.

However, we are aware that our approach still suffers from a lot of limitations, and the implementation of the aquacultures feed input in the model could be among the future improvement of the model.

For soil diffuse source, I concern the impact of cropping system change on N and P budgets, this is particularly important from long-term agricultural activities. I am particularly interested in in-river and in-reservoir retention of N and P. For in-reservoir retention, the temporal pattern in construction of artificial dam-reservoirs can significantly influence reservoir's retention/removal of N and P. A group of newly-built reservoirs in upriver can influence downriver "aged" reservoir's retention of N and P, particularly for P, because the inputs of N and P to these "aged" reservoirs have been changed due to the newly-built reservoirs in the same river networks.

The cropping system is a very important driver of N and P budgets, so any change in the system will impact those budgets. The land use input data for LPJmL have been compiled from the combination of different sources, among other the decadal cropland and grassland data from the HYDE3.1 dataset [Goldewijk et al., 2011], which allow us to account for the land use change dynamics. We have constructed an input data set with yearly crop and managed grassland distribution data since the year 1700. This is explained in section 4.1.1 of the ms, that we have slightly modified in order to make clearer the dynamic properties of the land use input data. (cf. 1st paragraph of section 4.1.1 in the revised manuscript)

The land use data for the crops in LPJmL-Med had been compiled from different sources, as explained in [Fader et al., 2015, Fader et al., 2010]. Decadal cropland and managed grassland data from HYDE3.1 [Goldewijk et al., 2011] were interpolated to derive annual values and then used for extrapolating the detailed crop distribution patterns of 2000 ([Portmann et al., 2010, Monfreda et al., 2008]) to the past, until 1700. Historical irrigation fractions were determined as explained in Fader et al. (2010). Further information is given by [Fader et al., 2015, Fader et al., 2010]. Following, this input dataset accounts for both land use change since 1700 and one important indicator of agriculture intensification, i.e. irrigation.

For in-river retention, N and P retention by different river orders should be considered at the river network scale, because rivers with different orders have different hydraulic loads which can control N and P retention.

Denitrification of NO_3 and adsorption of PO_4 are the main processes leading to N and P retention in rivers (see e.g. [Billen and Garnier, 2007]).

We compute the PO_4 adsorption in rivers following [Billen and Garnier, 2007], where PO_4 adsorption depends on the water volume and on the concentration of suspended solids, which we compute as a function of the land use, as explained in section 2.4.3. In such formulation, possible hydraulic load effect on P retention is not accounted for.

On the other hand, we consider the impact of hydraulic load on N retention (see equation 44), process reported in the literature since several decades when statistical analyses have shown that higher annual hydraulic loads are correlated with lower nutrient retention (see e.g. [Behrendt and Opitz, 1999]). However, we acknowledge that we had to improve the computation of the hydraulic load, which was a simple constant value in our equation. We now redo the computation of the hydraulic load by considering the seasonal dynamic of the water discharge and the river dimensions (this shows differences implicitly related to the river orders). We also take into account the seasonal temperature variations in the computation of the uptake velocity for denitrification.

Finally, the model runs on daily time scale, authors should showed the dailytemporal changes in nitrate and phosphate concentrations for those rivers flowing into the Mediterranean Sea.

In deed the model runs on daily time scale, but it is forced by monthly climate inputs data that are daily interpolated (considering the distribution of the monthly precipitation on the number of rainy days randomly distributed). See section 4.1 describing the model inputs. Following the simulated daily nitrate and phosphate concentrations cannot be considered to be realistic, when the monthly values are. Furthermore, the marine model that will use these simulated nitrate and phosphate concentrations (in another exercise) runs with monthly nutrient forcing inputs. The LPJmL simulations at a monthly time scale are therefore well adapted to such a modem cascade, as this is indicated in the discussion.

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