Biogeosciences Discuss., 11, C5166–C5175, 2014
www.biogeosciences-discuss.net/11/C5166/2014/

Biogeosciences
Discussions
Open Access

Interactive comment on "Nitrous oxide emission hotspots from organic soils in Europe" *by* T. Leppelt et al.

T. Leppelt et al.

thomas.leppelt@ti.bund.de

Received and published: 16 September 2014

The following revisions will be made in response to referee #1 comments:

Thank you for the critical comments and useful suggestions. Like suggested we added a basic description of fuzzy logic principles in section 2.2 to introduce these model technique to the reader in a more comprehensible way. Following text were added to make the modeling method more transparent for the reader, P. 9140, L. 26:

"These techniques are based on the concept of fuzzy logic, a set theory that extends the binary logic of true (1) and false (0). It allows to have fuzzy sets with truth values in the range between 0 and 1 (degree of fulfilment) and therefore it is able to handle partial truth, uncertainties or so called fuzziness. The fuzzy sets can be used to clas-

sify factor domains not only by constant crisp sets but also by different function types (e.g. , triangular, quadratic) with variable membership grade over the factor domain. Furthermore it can be utilized to divide factor spaces into sub domains and calculate all possible combinations in fuzzy interference schemes (FIS) by fuzzy logic algebra. These FIS can be merged in conditional rule systems to model multivariate problems."

Referee Comment: "I found the discussion of uncertainties too short, especially considering that it is an explicit topic of the study (research question 2)."

We extended the introduction to the general upscaling procedure in section 2.3, P. 9142, L. 19:

"The regionalization describes the application of our validated fuzzy model on EU-wide available input datasets to derive consistent N2O emissions for Europe."

and discuss the uncertainty estimation in section 2.4 in more detail to convey, that the uncertainty estimation is an important part of our study, P. 9144, L. 22:

"N2O emissions can vary largely in space and time and the capabilities to model these variation are restricted to the size of the sample dataset and the data quality. Therefore it is important to propagate the uncertainties during the modelling process to be able to estimate the overall accuracy of the model result. For several ecosystems the confidence interval limits of IPCC emission factors for N2O emissions from peat soils are greater than the mean values. The modelling approach aims to reduce this variability by using explanatory parameters to predict N2O fluxes."

and P. 9145, L. 11:

"The N2O emission budget is the sum of all raster cell values that are located within a defined area. The corresponding uncertainty of the inventory can be calculated by error propagation. Spatial explicit modelling introduces autocorrelation into the calculation of GHG emission inventories and their uncertainty estimation. Without consideration of the spatial covariance we would underestimate the real uncertainty. This is a methodical problem we solved by integrate the covariance into the error propagation equation to improve the uncertainty estimation:"

Followed by formular 4 (equation for the standard deviation of a sum that is calculated by the sum of the summands covariances.) and the appropriated description:

"where σ i,j is the standard deviation of a raster cell, indexed by i and cov ij the corresponding covariance between all raster cell values, indexed by i and j. We approximated the covariances between raster cells as a function of distance and calculated the corresponding covariance matrix to apply Eq. 4 to the raster map."

Referee Comment: "Also, I found parts of chapter 3.4 and 3.5 difficult to read because of a mix of methods and results/discussion."

Furthermore we moved methodical descriptions in section 3.4 and 3.5 into the Material and Methods chapter to improve the readability, P. 9154, L. 16-23 moved to P. 9144, L. 19:

"The general land use distribution on organic soils can be separated into the forestry dominated boreal zone, the agricultural temperate zone and the main natural peatland areas in the subarctic Northern parts of Europe. N2O emission hotspots were identified on the map together with related ranges of drivers separately for each land use specific model. In order to locate N2O emission hotspots in Europe we computed the flux distributions by land use category from the N2O emission map and defined the fluxes above the 90th quantile as hotspot emissions for the particular land use category."

and P. 9157, L. 15-20 moved to P. 9144, L. 15:

"The IPCC Tier 1 approach stratifies land use classes by drainage, peat type and climate zone. The delineation between the temperate and boreal zone can be derived from the IPCC definition applied to climate data. Drainage and peat type, however, are not available in a spatially explicit way. We therefore applied the default of nutrient-poor conditions in boreal forests, nutrient-rich conditions in temperate forests, and deep

drainage in temperate grasslands."

Referee Comment: "9141, l. 8 – l. 20 : After introducing the NSE, later in the manuscript an NSE_cali and NSE_cv are mentioned that should be explained here."

Additionally we added a description for the NSE for calibration and validation in this chapter, P. 9141, L. 20:

"The NSEcali and NSEcv refer to the NSE coefficient for the model calibration and the cross validation, respectively."

Referee Comment: "9154, l. 15: With reference to Fig. 8 – I understand that the models are upscaled with two different land cover classifications. Which one is represented in fig. 8?"

Figure 8 shows the model which has been upscaled on the basis of CORINE land cover. We will mention the land use classification in the figure caption, P. 9182:

"The land use classification is based on CORINE land cover."

Referee Comment: "9157, l. 15-21L Again, this seems to be a methodological description of parts of the extrapolation and should be described in the methods section."

We moved the methodical description into the Material and Method section as described above.

Referee Comment: "9158, l. 21- 9159 l.3: This chapter can be added to chapter 3.5."

The anthropogenic N2O emissions section 3.6 is different to the previous hotspot and budget sections 3.4 and 3.5. The definition of base and anthropogenic emissions is an special subject that is not related to IPCC calculation like the budget calculation and hotspot detection. Therefore we would leave this section to emphasize this special topic.

Referee Comment: "9160, l. 5-6: This conclusion has not at all been mentioned or discussed earlier."

The conclusion to raise the water table for lower emissions has been described in section 3.2.2 and 3.2.4 for the cropland (P. 9148, L. 16-24) and forest model (P. 9151, L. 24 – P. 9152, L. 3), respectively. We also described the water table effect in section 3.1 (P. 9145, L. 24- P. 9146, L. 5) with figure 2 and 3a that show the relation of N2O emissions and groundwater table for different land use categories as box- and scatter plot. Later in section 3.3 we mentioned the importance of a water table distribution map to reduce uncertainties and enhance the inventory accuracy (P. 9154, L. 12). We changed the conclusion into a more general statement for the relationship of water table and nitrous oxide emissions, P. 9160, L. 5:

"The sensitivity of N2O emissions on mean annual water table across land use classes indicates that water table management is one of the most effective ways to mitigate N2O emissions from land use of organic soils."

The following revisions will be made in response to referee #2 comments:

Dear referee 2, thank you for the fruitful comments. According to your suggestions we changed the title to "N2O emission budgets and landuse driven hotspots for organic soils in Europe" to focus not only on hotspot emissions. We conducted the first spatial explicit model upscaling attempt to characterize high N2O emission conditions and locations and to quantify N2O inventories for different land use categories on that scale. The localization of hotspots is one of our study aims and a major contribution to our new results. The new title should represent our study aims and results in a more balanced way.

Referee Comment: "I understand that "land-use specific frequency distribution functions of observed water table in database" (P 9143 L. 19-20) are the only way to go, but I doubt that it is the annual water table alone but rather its seasonal fluctuation which determines the magnitude of N2O emissions. Did you include seasonal WT fluctuation in your statistical analysis of the overall data set? If so, say something about it

in the paragraph page 9146, L. 24 ff."

The water table fluctuation could have been a better predictor for the magnitude of N2O emissions but the information were only available for a small fraction of the data set. The seasonal fluctuation would also be very hard to upscale. We included a statement about seasonal water table variations in section 3.1 to refer to these potential improvement, P. 9146, L. 5:

"The seasonal fluctuations of the water table could be better predictor for the magnitude of N2O emissions but these informations were only available for a small fraction of the data set. Therefore we were restricted to use only the mean annual water table in our analysis."

and also indicated that regional fluctuation maps could improve the GHG inventory determination in section 3.3, P. 9144, L. 15:

"Improvements in the spatial representation of water table annual mean values as those by Bechtold et al. (2014) and also seasonal fluctuations would strongly enhance inventory accuracy."

Referee Comment: "Table 2: give significance levels for the correlation coefficients."

We added the significance levels for the correlation coefficients in table 2 (P. 9169).

Referee Comment: "P. 9145 L. 20. No outliers shown for N2O flux in box plots of figure 2. Why? "

The outliers in figure 2 were excluded to focus on the differences in the mean values for the land use categories. Due to few high peak emissions especially for cropland and grassland the limits on the y-axis would increase drastically so that the differences were not clearly observable any more. Therefore we decided to exclude outlier emissions which amount 3 to 9 percent at maximum of the data per land use category.

Referee Comment: "P 9146, L. 24 ff. ": a relationship between annual or seasonal climatic variables, e.g. soil/air temperature or precipitation and N2O emissions could not be observed". This statement holds for the entire data set? Since you did not continue with a "global model" (independent of land-use type) and later use autumn precipitation as a driving variable for annual N2O emission in grasslands, I wonder whether you need to say it at all."

The statement on P.9146, L. 24ff is only true for the analysis of the entire dataset and doesn't hold for single land use based models. Therefore we will remove it and rewrite the last sentence of the section:

"Several other studies found evidence for climate influence at particular peatland sites or regions (Dobbie et al., 1999; Sozanska et al., 2002; Lohila et al., 2010) which can be confirmed in the following landuse stratified models."

Referee Comment: "P. 9149 L. 1: what is "anthropogenic N fertilizer"? Skip "anthropogenic". Elsewise, I fully agree with the explanation given for the lack of a significant fertilization effect in the cropland model."

We skipped the inappropriate word "anthropogenic" on P. 9149, L.1.

Referee Comment: "P. 9151 L. 21-23: Soil pH as a driver for forest emissions: here, I feel you are cutting corners by suddenly switching from soil pH as a proxy for C/N to pH as a proxy for "nutrient availability". Add one sentence highlighting that pH < 5.5 still allows sufficiently low C/N ratios to legitimize your C/N threshold stated earlier."

The forest soil pH can be utilized as proxy for C/N ratios but can be also a driver for N2O emissions by itself. We observed in forests C/N ratios below 30 also under acid conditions. Despite of the range of C/N ratios for certain pH values, the pH could explain the major variability for N2O emissions. Therefore we added a comment in section 3.2.4 which will highlight this effect, P. 9151, L. 22:

"In forests we observed C/N ratios below 30 also under acid conditions and there- fore the relationship between pH and C/N, that has been stated before, exhibits too much

variation to get utilized. Nevertheless the soil pH can be selected directly as driver for N2O emissions because it explains a major part of the variability."

Additional changes:

Due to new information we will correct the land use category for one site from peat extraction to natural. The site was only in the past a peat extraction and has been rewetted before the measurements has been carried out. These will change the mean values slightly only by 0.0003 g * m-2 * a-1 for the natural peatlands and has no effect for the modelling part. Therefore we only will update figure 2.

We will also change the publication reference for Bechtold et al. (2014), Eickenscheidt et al. (2014) and Fuchs et al. (2013) because the cited discussion paper have already been published:

"Bechtold, M., Tiemeyer, B., Laggner, A., Leppelt, T., Frahm, E., and Belting, S.: Large-scale regionalization of water table depth in peatlands optimized for greenhouse gas emission upscaling, Hydrol. Earth Syst. Sci., 18, 3319–3339, doi:10.5194/hess-18-3319-2014, 2014."

"Eickenscheidt, T., Heinichen, J., Augustin, J., Freibauer, A., and Drösler, M.: Nitrogen mineralization and gaseous nitrogen losses from waterlogged and drained organic soils in a black alder (Alnus glutinosa (L.) Gaertn.) forest, Biogeosciences, 11, 2961–2976, doi:10.5194/bg-11-2961-2014, 2014b."

"Fuchs, R., Herold, M., Verburg, P. H., and Clevers, J.: A high-resolution and harmonized model approach for reconstructing and analysing historic land changes in Europe, Biogeosciences, 10, 1543–1559, doi:10.5194/bg-10-1543-2013, 2013."

Interactive comment on Biogeosciences Discuss., 11, 9135, 2014.

Table 2. Correlation matrix of N_2O fluxes and potential driving parameters for the available dataset from organic soils in Europe. The parameter names are described in Table 1.

	N_2O	bd	corg	ntot	ph	cn	pd	tair	tsoil	pp	wt	wfps	nmin	nfert
N_2O	1.00	0.17	−0.10*	0.07	−0.05	−0.19	−0.14*	0.06	0.07	0.11**	0.32	−0.30	0.10	0.43
bd		1.00	−0.80	−0.39	0.37	−0.48	−0.32	0.34	−0.08	−0.17	0.46	0.07	−0.04	0.25
corg			1.00	0.38	−0.50	0.59	0.27	−0.32	−0.08	0.15	−0.31	−0.12	−0.12	−0.13**
ntot				1.00	0.14*	−0.40	0.34	0.04	0.11	−0.04	−0.21	0.07	0.26*	0.16
ph					1.00	−0.64	−0.31	0.06	0.22*	−0.30	0.29	−0.03	0.29**	0.19
cn						1.00	0.02	−0.22	−0.18	0.15	−0.20	−0.19	−0.36	−0.18
pd							1.00	0.17**	0.29*	0.10	−0.39	−0.06	−0.20	−0.22
tair								1.00	0.77	0.02	−0.11*	−0.01	0.15	0.16
tsoil									1.00	0.44	0.15	−0.26	0.27	0.07
pp										1.00	−0.13**	−0.14	0.24*	0.01
wt											1.00	−0.39	0.08	0.17
wfps												1.00	0.10	−0.01
nmin													1.00	0.10
nfert														1.00

Level of Significance:

** Significant at $P \leq 0.01$

* Significant at $P \leq 0.05$

Fig. 1. Correlation matrix of N2O fluxes and potential driving parameters for the available dataset from organic soils in Europe. The parameter names are described in Table 1.

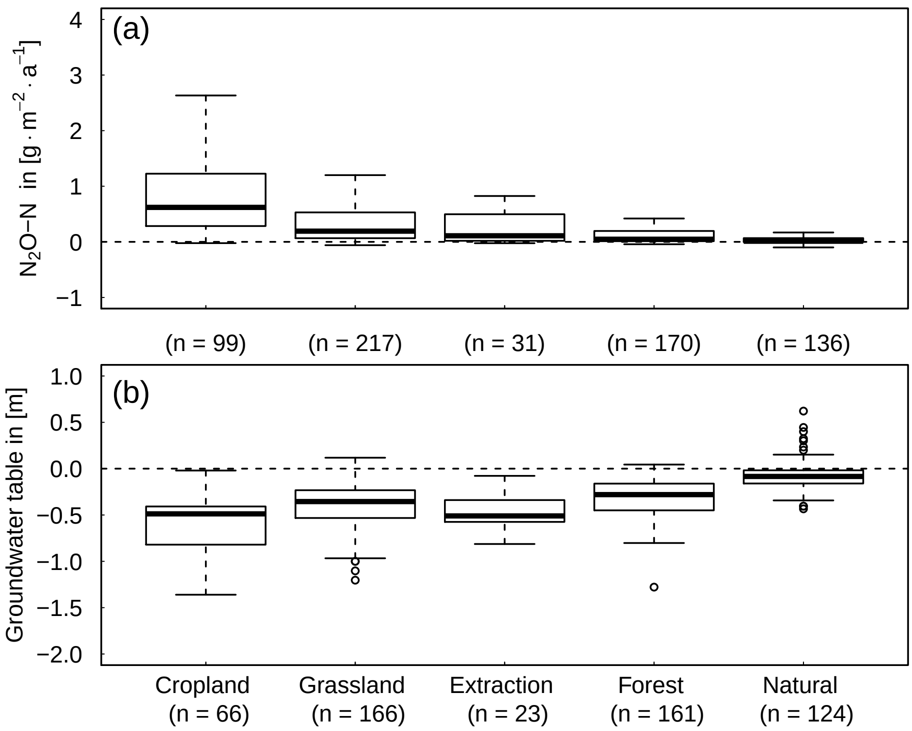

Fig. 2. Boxplots for N2O fluxes (a) and mean annual groundwater table (b) for five different land use categories (cropland, grassland, peat extraction, forest and natural sites)