Biogeosciences
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Discussions

Interactive comment on "Effects of experimental nitrogen deposition on peatland carbon pools and fluxes: a modeling analysis" *by* Y. Wu et al.

Y. Wu et al.

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Major comments

1. "The methodology is fairly hard to follow. The manuscript would greatly profit from a concise description of the PEATBOG model (possibly including a conceptual figure) in terms of what it does and what it does not simulate. In the current version of the manuscript, some of this material is not present (e.g. how do the vegetation dynamics work, how is production and nutrient uptake modelled?), or it is spread in the introduction (p102754 l 26) and the results section (p10284 l1ff), which makes it hard to appreciate what the model does. Of course, the model has been published elsewhere, but a reader should be able to understand what a model does without having to refer to the model description paper frequently."

A paragraph in the introduction (P. 2, L. 26 –L. 38) and a session in method (2.2 P.4, L. 11) were added to explain how plant competition for light and nutrients is modeled in PEATBOG.

2. The authors state that their model "consistently emphasises mass-balance principles" (which I think is trivial), but then they modify the modelled GEP and RE estimates by some empirical scalar to compare this to chamber measurements. It is unclear to me whether this correction occurs after the modelling, or whether the model has been rerun with the correction applied. They then state that (p 10282 l 2ff) these corrections accounted for the model's LAI biases, but it is unclear, how this estimate was derived, and whether this means that the LAI biases of the model were corrected. In particular p 10279 l 20ff left me puzzled as to what as actually done. A particular concern is that the authors have applied a specific GEP factor for each fertilisation experiment, effectively compensating for a tendency of the model to overestimate the growth response to fertilisers. Applying a fertilisation specific calibration for the dominant process somewhat reduces the utility of using a process-based model to simulate the effect of fertilisation on foliar N and production. If the response had to be calibrated specifically for each treatment, this inspires little confidence into the predictive capacity of the model. Step four in the model development only really become clear when one hits Figure 8. I strongly recommend to move this section to the model description and also outline the reasoning and main effects there. Importantly, it also remains unclear whether the results in Figures 1-7 are based on version 1 or version 3.

The methodology was rewritten in section 2.3 (P.5 L.37 to P.6 L.15) following the reviewer's suggestions. In the new version the procedures used should be better comprehensible. We have conducted the study in four steps with the first two steps on the short-term effects simulations and the last two steps on the long-term simulations. The first step we simulated short-term effects of N on the C pools and fluxes. As a second step, we examined discrepancies of the simulations for the "short-term" simulations and identified key controlling factors of the results. In the third step we simulated long-term

effects of N on the C cycle and the fourth step experimenting on the key controlling parameter and the variability of long-term results. The simulation results in figure 1-7 were based on the original model parameterization without any modifications. Only figure 8 and 9 were produced from modified model.

3. "The authors state that they inferred GEP from NEP and RE, but how is it then possible that there are more points of GEP than of NEP and RE in Figure 1 and 9?"

The observed NEP was measured at full, half, and quarter of the incoming radiation and in the dark and ER was measured once at mid-day with PPFD larger than 1000 umol m-2 s-1. The data were collected approximately bi-weekly during the summer. Then the sum of NEP and ER was related to PAR level and obtained a correlation of GEP and PAR for each plot for each year. GEP that was used for comparisons with the model output was calculated from obtained relations between GEP and PAR and using measured PAR from the flux tower as a driver in the transfer function. We did it this way to have a continuous record of observed GEP data over time. NEE that was used for comparison with model output was calculated by subtracting ER from the GEP that was calculated as described above.

4. "The authors state that the 2001 GEP is overestimated by the model. To me it seems that rather there is an jump in GEP between 2001 and the remainder of the time series. Why blame the model?"

We suspected that the "jump" was mainly a result of the discrepancies between the starting status of the model and the observations. Another contributing factor was that 2001 was an exceptionally dry year and the observed CO_2 uptake was much lower than the other years (Lafleur et al., 2003).

Minor comments

1. "Abstract line 11ff. At this stage, the reader does not yet know that you mean leaf N concentrations and its effect on GEP -please make this clear."

Information was added in the abstract (P.1, L.31 in the word version).

2. "Introduction: P 10274 L 3-5: these estimates are based on assuming no air-pollution control, whereas the newer scenarios assuming air-pollution control suggest declining N deposition over Canada. Locally this may be different of course, but here and in the discussion there should be a reflection as to how realistic the simulations and experiment in assuming a quadrupling of N deposition are. See Lamarque et al. 2011"

Information was added in P.10, L. 18 (word version)

3. "P 10274 L 10 -15. This text confuses time-scales. Peatlands have arguably been a large C sink during the holocene, but their contribution to the current net terrestrial C uptake is likely rather small, given the small NEE and limited geographic extend."

Information was added in P.2, L. 17 (word version)

4. "P 10274 L 24ff. Yes, but see Janssens et al. 2010"

The sentence was rewritten in P.2, L. 40 (the word version)

5. "P 10275 L 26ff: This is unclear, partly because one does not know what the PEAT-BOG model is actually doing. I would recommend to create a new Section 2.1, in which the model is briefly described (see comment above), and this explanation is integrated"

A new section in method was added in the PEATBOG model description (P.4, L. 11).

6. "P10279 L 7ff. To remove all doubts, this paragraph should end with, "the results presented in Fig 1-9 are based on version X, unless stated otherwise.""

Information was added (P. 5, L.10 in the word version)

7. "P10280 L 1: This paragraph would follow more logically the first paragraph of this section. Maybe move the model strategy paragraph to a separate section, in which the PEATBOG model is also briefly explained?"

This paragraph has been moved to 2.3 following the model description section 2.2.

8. "P 10280: L 17: I'm left puzzled as to why the ER data were corrected linearly and by year. Why would one not assume that the bias between day-time and daily average RE was constant with time?"

The mistake was corrected. The correcting factor was not distinguished by year but by treatment. The observations of ER occurred in the mid-day about every two weeks during the summer. Therefore it represents the values at the highest daily temperature. The model on the other hand, was driven by daily average temperature and generated daily average ER. In order to have more comparable observations and simulations, we scaled up the modeled daily average ER by a factor that in principle represents the difference between daily average and maximum temperature. This factor is chosen to be the slope of ER and the air temperature, i.e. the correlation between ER and temperature. We differentiated the ER-T slope of each fertilization treatment to exclude the effect of other factors on the ER-T relation, such as leaf area index and biomass. Information was added in P.5 L.45 - 47.

9. "P 10283 L 7: As this refer to the fertiliser response, it should read "with increasing N inputs/fertilisation"."

Corrected (P.7, L.18)

10. "P 10284 L 1: This mentioning of model details would be more suitable within the Methods section -comes a bit out of the blue here"

This part is moved to the method. (P.6, L.2 – L.7)

11. "P 10285 L 11 I cannot see this in Figure 5, possibly due to the large variability there?"

We've added data points for 11-year averages over the length of the repeated input data in Figure 5.

12. "P 10293 L 24: This is one of the places where an introduction to the PEATBOG model would really help to understand what is going on."

An introduction of the PEATBOG model has been added section 2.2 P.4 L.13 – L.46.

13. "P1ß296 L 3-5: Would one not rather assume that the model converges to a new equilibrium without a phase of C losses? Please explain why you think that in the long term N fertilisation would cause C losses."

Discussion was added in P. 9, L. 23 to P.10, L. 5. As autotrophic respiration approaches a new steady state that corresponded to the new vegetation cover, heterotrophic respiration is critical to the overall C budget of the peatland. On the one hand, heterotrophic respiration was strongly linearly related to labile carbon content of the peat, which changes little after the ecosystem has reaches new stable states after about 20 years. On the other hand, heterotrophic respiration showed strong negative relation with C/N ratio of peat when mosses disappeared from the system. Also the model showed that most of the fertilized N was retained by peat without the "moss filter". Therefore the C/N of peat will decrease and subsequently the heterotrophic respiration will increase, as long as N fertilization sustained. Ultimately it is also possible that when the peat becomes N saturated, heterotrophic respiration will approach a maximum level. However, the trend of N saturation did not show this within the time period of the simulation. Therefore, based on the modeling results on a time scale of 80 years, we suspect a C loss from the peatland to occur.

14. "P 10296 L 19: How dod you extrapolate to 700 years. This is not clear."

Information was added in P. 10 L. 23 to L. 24.

15. "Table 3: I think that it's worth highlighting in the text that despite tuning the GEP, PEATBOG overestimates PEAT storage by a factor of three, even though the vegetation cover seems to be appropriately simulated. Why?"

Information was added in P.7 L.42 to L47. There are two factors contributing to this

overestimation. One is the hard-coded bulk density in the model that overestimated the bulk density and thus the C pools in the given 10cm depth. The other factor is that the model considers litter also as peat. The large increase of the modelled C pool in peat was in line with a large increase in the litter accumulation observed in the fertilized plots (Bubier et al., 2007).

16. "Figure 5 6: The long-term trends are difficult to spot because of the large interannual variability. I recommend smoothing these results using an 8 year running mean."

We've added trend lines of 11-year averages in Figure 5 and figure 6. The input data was repeated every 11 years.

The following references were added:

Aerts, R., J. T A. Verhoeven, and D. F. Whigham: plant-mediated controls on nutrient cycling in temperate fens and bogs, Ecology, 80, 2170–2181, doi:10.2307/176901, 1999.

Chong, M., Humphreys, E.R. and Moore, T.R.: Microclimatic response to increasing shrub cover and its effect on Sphagnum CO2 exchange in a bog. Ecoscience, 19: 89-97, 2012.

Evans, J. R: Photosynthesis and nitrogen relationships in leaves of C3 plants, Oecologia, 78, 9-19, doi: 10.1007/BF00377192, 1989.

Granath, G., Strengbom J., Breeuwer, A., Heijmans, M. M., Berendse, F. and Rydin H.: Photosynthetic performance in Sphagnum transplanted along a latitudinal nitrogen deposition gradient, Oecologia 159, no. 4, 705-715, DOI: 10.1007/s00442-008-1261-1, 2009a.

Granath, G., Wiedermann M. M., and Strengbom J.: Physiological responses to nitrogen and sulphur addition and raised temperature in Sphagnum balticum, Oecologia 161, 481-490, doi: 10.1007/s00442-009-1406-x, 2009b.

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Granath, G., Strengbom, J. and Rydin, H.: Direct physiological effects of nitrogen on Sphagnum: a greenhouse experiment. Functional Ecology, 26, 353–364, doi: 10.1111/j.1365-2435.2011.01948.x, 2012.

Hikosaka, K., and I. Terashima.: A model of the acclimation of photosynthesis in the leaves of C3 plants to sun and shade with respect to nitrogen use, Plant, Cell Environment 18, 605-618, doi: 10.1111/j.1365-3040.1995.tb00562.x, 1995.

Lamarque, J. R. , G. P. Kyle, M. Meinshausen, K. Riahi, S. J. Smith, D. P. Vuuren, A. J. Conley, and F. Vitt.: Global and regional evolution of short-lived radiatively-active gases and aerosols in the representative concentration pathways." Climatic Change 109 (1-2): 191–212. doi:10.1007/s10584011-0155-0, 2011.

Spahni, R., Joos, F., Stocker, B. D., Steinacher, M., and Yu, Z. C, Transient simulations of the carbon and nitrogen dynamics in northern peatlands: from the Last Glacial Maximum to the 21st century. Climate of the Past, 9, 1287-1308, doi:10.5194/cp-9-1287-2013, 2013.

Wang, M., Murphy, M. T. and Moore, T. R.: Nutrient resorption of two evergreen shrubs in response to long-term fertilization in a bog, Oecologia, 174, 365-377, doi:10.1007/s00442-013-2784-7, 2014.

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Bond-Lamberty, Ben, and Stith T. Gower, Estimation of stand-level leaf area for boreal bryophytes, Oecologia 151, no. 4: 584-592, DOI 10.1007/s00442-006-0619-5, 2007. Bragazza, L., Limpens, J., Gerdol, R., Grosvernier, P., Hajek, M., Hájek, T., Hajkova P., Hansen. I., Iacumin, P., Kutnar, L., Rydin, H. and Tahvanainess, T.: Nitrogen concentration and δ15N signature of ombrotrophic Sphagnum mosses at different N deposition levels in Europe, Global Change Biology 11(1), 106-114, 2005. Fritz, C., G. Van Dijk, A. J. P. Smolders, V. A. Pancotto, T. J. T. M. Elzenga, J. G. M. Roelofs, and A. P. Grootjans.: Nutrient additions in pristine Patagonian Sphagnum

C6402

bog vegetation: can phosphorus addition alleviate (the effects of) increased nitrogen loads, Plant Biology 14, no. 3, 491-499. doi:10.1111/j.1438-8677.2011.00527.x, 2013. Granath, G., Strengbom J., Breeuwer, A., Heijmans, M. M., Berendse, F. and Rydin H.: Photosynthetic performance in Sphagnum transplanted along a latitudinal nitrogen deposition gradient, Oecologia 159, no. 4, 705-715, DOI: 10.1007/s00442-008-1261-1, 2009a. Granath, G., Wiedermann M. M., and Strengbom J.: Physiological responses to nitrogen and sulphur addition and raised temperature in Sphagnum balticum, Oecologia 161.3: 481-490, DOI: 10.1007/s00442-009-1406-x, 2009b. Granath, G., Strengbom, J. and Rydin, H.: Direct physiological effects of nitrogen on Sphagnum: a greenhouse experiment. Functional Ecology, 26: 353–364. doi: 10.1111/j.1365-2435.2011.01948.x, 2012. Lafleur, P.M., N. T. Roulet, J. L. Bubier, S. Frolking, T. R. Moore. 2003. Interannual variability in the peatland-atmosphere carbon dioxide exchange at an ombrotrophic bog. Global Biogeochemical Cycles, 17(2), 1036, doi: 10.1029/2002GB001983. Limpens J, Berendse F. 2003. Growth reduction of Sphagnum magellanicum subjected to high nitrogen deposition: 17 the role of amino acid nitrogen concentration. Oecologia 135: 339-345. Limpens, J., Granath, G., Gunnarsson, U., Aerts, R., Bayley, S., Bragazza, L., Bubier, J., Buttler, A., van den Berg, L. J. L., Francez, A.-J., Gerdol, R., Grosvernier, P., Heijmans, M. M. P. D., Hoosbeek, M. R., Hotes, S., Ilomets, M., Leith, I., Mitchell, E. A. D., Moore, T., Nilsson, M. B., Nordbakken, J.-F., Rochefort, L., Rydin, H., Sheppard, L. J., Thormann, M., Wiedermann, M. M., Williams, B. L. and Xu, B.: Climatic modifiers of the response to nitrogen deposition in peat-forming Sphagnum mosses: a meta-analysis. New Phytologist, 191: 496–507. doi: 10.1111/j.1469-8137.2011.03680.x, 2011. Manninen, S., Woods, C., Leith, I. D., Sheppard, L. J.: Physiological and morphological effects of long-term ammonium or nitrate deposition on the green and red (shade and open grown) Sphagnum capillifolium, Environmental and Experimental Botany, 72(2), 140-148, DOI:10.1016/j.envexpbot.2011.02.015, 2011. Nijp, J. J., Limpens, J., Metselaar, K., van der Zee, S. E. A. T. M., Berendse, F. and Robroek, B. J. M.: Can frequent precipitation moderate the impact of drought on peatmoss carbon uptake in northern

peatlands?. New Phytologist, 203: 70–80. doi: 10.1111/nph.12792, 2014. Sheppard L, Leith I, Leeson S, van Dijk N, Field C, Levy P: Fate of N in a peatland, Whim bog: immobilisation in the vegetation and peat, leakage into pore water and losses as N2O depend on the form of N, Biogeosciences, 10: 149-160. 2013.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/11/C6395/2014/bgd-11-C6395-2014-supplement.zip

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Figure 1 (a-d) Simulated and [**]observed weekly average of gross ecosystem production (GEP), (e-h) ecosystem respiration (ER) and (i-l) net ecosystem exchange (NEE) May to Aug in 2001, 2003, 2005, 2008. The green dotted lines represent weekly averaged CO_2 flux corrected for the biomass (a-d), for the air T- ER relationship (e-h), and NEE derived from the corrected GEP and ER. Positive NEE indicates that the simulated bog gains C. Note that P or K was not constrained in the model.
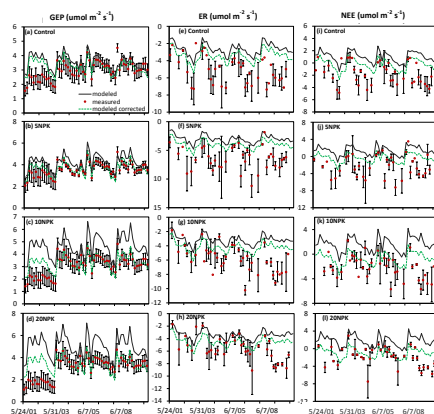
[**] The observed GEP was reconstructed from the observed PAR (half-hourly) and the derived GEP-PAR relations based on the recorded GEP at full, half, quarter light and dark conditions. The GEP-PAR relations were calculated for each year and each treatment, with exceptions in 2005 and 2008 when only the full light measurements were available. A GEP-PAR equation was derived from all the available data between 2001 and 2008 to calculate the GEP in 2005 and 2008. The observed NEE was obtained from NEE = GEP + ER.

Fig. 1.

C6405

Figure 2 Observed versus simulated weekly average gross ecosystem production (GEP) in 2003, 2005 and 2008. The black dots and lines represent original simulation and the red dots and lines represent simulation adjusted by a factor producing the "best-fit" (Table 2).
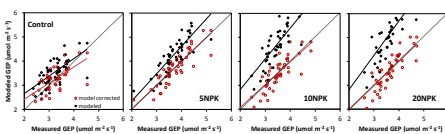

Fig. 2.

Figure 3   The simulated (bars) and observed (values) C pools in plants and peat in summer after 8 years of fertilization. Observed data from Xing et al. (2010) are shown in Table 1.
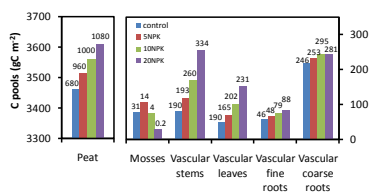

Fig. 3.

C6407

Figure 4   (a-i) Simulated annual average C pools in plants and peat, labile fraction of peat (mg C gC^{-1}) and C/N ratio in the upper 40cm of peat over 80 years of fertilization. Short term variation is due to variation in the climatic drivers.
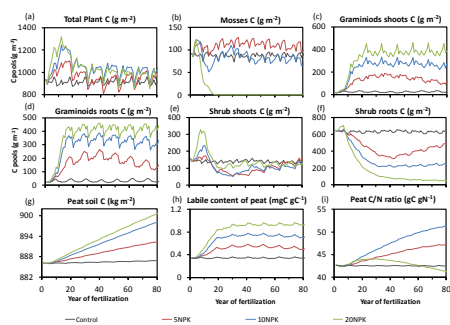

Fig. 4.

C6408

Figure 5 Annual average gross ecosystem production (GEP), ecosystem respiration (ER) and net ecosystem exchange (NEE) over 80 years of fertilization. Positive NEE indicates C gain into the bog.
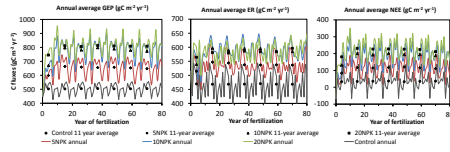
Fig. 5.

C6409

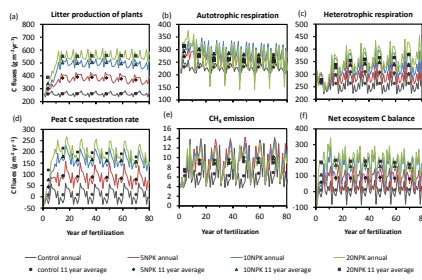Figure 6 Simulated annual average C cycling rates over 80 years of fertilization.

Fig. 6.

C6410

Figure 7 (a) The relationship between modeled annual heterotrophic respiration in the 20NPK treatment (HR) and labile fraction of peat C and (b) between HR and C:N ratio above 40 cm of peat (g C g N^{-1}) . The values were averaged for each 11-year interval with repeated environmental drivers, black diamonds are values from 2021 to 2130 in 10NPK and 20NPK, red circles are from 2021 to 2130 in 5NPK, and blue triangles are from 1999 to 2020 in 5NPK, 10NPK and 20NPK.
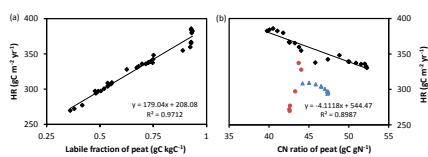

Fig. 7.

C6411

Figure 8 (a-d) The dependency of photosynthetic capacity (GEP_{max}) on leaf N content in simulations (original and modifications 1-3) and (e-h) resulting C pools in PFTs during 40 years of fertilization at 6.4 g N m^{-2} yr^{-1}. (a) Original model with positive relation between the photosynthetic capacity (GEP_{max}) and N content in vascular PFTs, (b) modification 1 with negative GEP_{max} to N relation in shrubs only, (c and d) modification 2 and 3 with negative GEP_{max} to N relations when leaf N content exceeds 1.5 g N m^{-2} (equivalent to 0.03 g N g C^{-1}) in shrubs and 2 g N m^{-2} (in equivalent to 0.024 g N g C^{-1}) in graminoids.
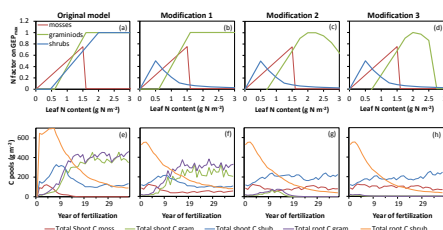

Fig. 8.

C6412

Figure 9 (a-e) weekly averages of simulated and observed gross ecosystem production (GEP), ecosystem respiration (ER) and ecosystem exchange (NEE) from May to August 2001, 2003, 2005, and 2008 fertilized with 6.4 g N m^{-2} yr^{-1}. (d-f) Annual GEP simulations (1-3) representing the same parameterizations as in Figure 8b-8d.
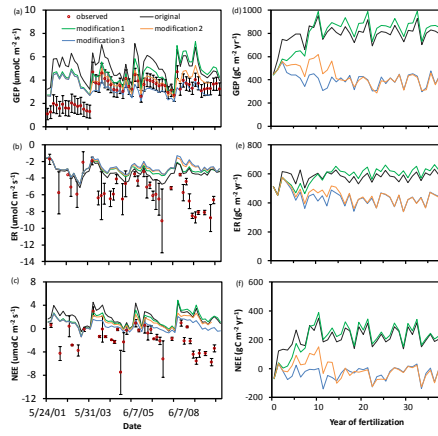
Fig. 9.

C6413