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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.

yuanqiao.wu@ec.gc.ca

General: 1. One of the novelties of the paper I consider the test of the GEPmax dependence on leaf N content. In my view this deserves an additional exposition in the introduction and being mentioned in the abstract."

Information was added in the introduction in P. 1, L. 31, P. 2, L. 28 -36.

2. It is hard to judge how robust the response of the different PFTs to N fertilization actually is. Granath et al., 2009 suggest that some Sphagnum species behave differently and can actually adapt to higher leaf N content. Would a scenario with mosses having a higher max N tolerance in the N factor on GEPmax than in the original model also be possible? In this case mosses would simply be outcompeted by graminoids/shrubs

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through growth and light competition. Can you exclude this possibility?

Such a scenario is possible, however, we think that it is not likely. In our assumptions about the tolerance of Sphagnum to N we were conservative and considered the possible adaptation of Sphagnum by applying a rather high threshold value of leaf N content at 1.5 g N m-2 leaf area. The value is converted to N per grams of leaf dry mass with a specific leaf area of sphagnum that ranges from 135 to 473 cm2 g-1 (Bond-Lamberty Gower, 2007). With the specific leaf area of well-drained mosses of 135 cm g-1, the N content threshold in the model was in equivalent to 20 mg N g-1 dry biomass. This value is higher than the N content of Sphagnum found in natural peatlands (e.g. Bragazza et al., 2005, Granath et al., 2009a) and at the high end of the N content in Sphagnum in the N fertilization experiments (Limpens et al., 2011). Toxic effects of N on Sphagnum were suspected to occur at extremely high N content that impaired the photosynthesis and growth of Sphagnum (Limpens and Berendse, 2003; Fritz et al., 2012). With the implemented current knowledge about N toxicity threshold in the model, the modeling results suggested that toxicity of N plays an important role in the decline of mosses. Other factors, such as the shading from increased shrub biomass, may have also played a significant role in the declining of mosses in the fertilized plots as well (Chong et al. 2012).

Changes were made in P. 4 L. 27- 44 (in the word version).

3. Reading this model study I often found myself looking up the PEATBOG model paper (Wu and Blodau, 2013) in order to find the corresponding equation. I don't think this is a bad thing per se, regarding the complexity of the problem, but repeating the main model equations for a given sensitivity could greatly improve the visibility for the reader. My suggestions are e.g. the model eqs for (i) the dependence of GEPmax on leaf N content, (ii) the C/N effect on ER and (iii) the competition for N uptake.

Appendix A and B were added to specify the key equations and parameterizations.

Specific:

1. "p. 10274, l. 17: Please add global estimates/modelling studies for future peatland C storage changes under N fertilization and dynamic peatland vegetation change, e.g. results from Spahni et al., 2013."

Added the following information to P. 2, L. 22-24 (in the word version): For example, a dynamic global vegetation model has simulated a reduction of the maximum annual NPP from 800 g C m-2 yr-1 to 450 g C m-2 yr -1 when coupling a dynamic N cycle to the C cycle (Spahni et al., 2013).

2. "p. 10277, l. 14: missing "g N" units"

Information was added in P10288, L14 (in the word version P.4, L.5).

3. "p. 10277, l. 28: Please be careful with the wording. If you define GEP (gross ecosystem production) as photosynthesis, I assume you mean gross carbon assimilation during photosynthesis. Later on photosynthesis is shown being dependent on leaf N content. But there are two parts of N allocation as you explain 10 pages later: once to photosynthetically active processes and once to biomass growth. Please be more precise in general and early on, when you use the term "photosynthesis" as this is a major part of the paper."

The term "GEP" and "photosynthesis" was examined and changes were made in P. 3, L. 46 and P.11 L.30 (in the word version).

4. p. 10277, l. 28: To my understanding and according to Figure 1 this sentence is wrong, it should be GEP+ER = NEE and not ER+NEE = GEP.

This sentence has been rewritten in legend of Table 2

5. p. 10279, l. 5: Do 10000 years reflect the basal age of Mere Bleue Bog? Is the model in a steady state regarding net ecosystem carbon accumulation?

10000 years was similar to the basal age of the Mer Bleue Bog of about 8000 years. After 10000 years of spinning up, the model was at a steady state regarding the ecosys-

tem C and N accumulation and vegetation composition.

6. p. 10279, l. 20: typo "leaf area index"

Correction was made at P.10279, L.20 (P. 5, L. 35 in the word version)

7. p. 10283, l. 5: I can't follow the last statements. Do sphagnum and vascular plant biomass have different properties that directly affect the rate of respiration in the model? Please clarify.

There was a mistake in the sentence and a correction was made in P. 20183, L. 5 (in P. 6, L. 41-42). In the model, the ecosystem respiration (ER) was an aggregation of the autotrophic respiration (AR) of each PFT and the heterotrophic respiration (HR) of labile and recalcitrant soil C (Appendix A). The autotrophic respiration rates per area were similar in all PFTs, considering the respiration rate per biomass and the specific leaf area of each PFT. The large difference occurs in the heterotrophic respiration of the labile and recalcitrant soil carbon (Appendix A, Table 1). The ratio of labile to recalcitrant biomass was set to be higher in the vascular plants than in Sphagnum, as a representation of their lower decomposability (Bragazza et al., 2012). The model overestimated the Sphagnum biomass and underestimated the vascular PAI in 2008, both leading to an overestimation of the recalcitrant fraction of the fresh litter input to the soil. Therefore, the modeled decomposability of soil organic matter was also underestimated and consequently the HR and ER were underestimated as well.

8. p. 10287, l. 9: Is the C/N increase because of the shift in vegetation composition?

The increasing C/N ratio in the 5NPK, 10NPK and during the first 30 years of the 20NPK was a result of a faster net sequestration of C than N in the peat. The limited N sequestration in the peat subject to low N inputs was attributed to the moss layer that retained most of the N at the ground surface (Fig. 7b). When mosses were saturated and eliminated from the vegetation community, the N filtration failed and the N that had been retained by the mosses was transferred into the peat N pool. The C/N ratio in

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the peat thus started to decline after 30 years in the 20NPK treatment (Fig. 7i). Above explanations were added at P.9, L 39 – 42 (in the word version)

9. p. 10288, l. 26: Just to get it right, for the comparisons of the modifications 1,2,3 you do not correct GEP, ER, NEE anymore as you did in Fig. 1?

There were no corrections for modification 1, 2 or 3.

10. p. 10290, l. 3: Where can I find supplementary Figures?

The supplementary figures and tables are presented in a separate file named "supplementary information" that is downloadable from the manuscript webpage: http://www.biogeosciences-discuss.net/11/10271/2014/bgd-11-10271-2014.pdf.

11. p. 10290, l. 8: Use 'Mer Bleue' instead of 'MB' or define it at the first occurrence of the name in the text.

"MB" was changed to "Mer Bleue" (P.10, L. 18 in the word version).

12. p. 10291, l. 18: How does the model handle competition for N uptake exactly? Assuming a bog ecosystem with limited N availability: is there a priority rule for PFTs accessing nutrients? Would that change in the case for N fertilization and thus increased GEP?

We did not implement a priority rule for N uptake other than a moss filter. Instead the uptake is conceptualized as the result of differences in N uptake kinetics between PFTs. The N uptake of PFTs was modeled by considering the filtration of deposited N by mosses and the uptake of N by vascular roots. Mosses account for 95

The differences in GEP in the three modifications can be explained by a vegetation shift with regards to the amount of leaf biomass and the turnover rates. In the model, the maximum GEP was set to be equally high for graminoids and shrubs at about four times the level of mosses. Hence a shift from mosses to vascular plants changes the total GEP (Fig. 9d), but the relative abundance of shrubs and graminoids does not.

The modeled GEP differed greatly between modification 1 and 2 (Fig. 9f, 9g) despite a similar vascular foliar biomass (Fig. 8f, 8g). In modification 1, graminoids dominated resulting in more C assimilation over the same time period.

Information about the model algorithms used in plant competition was added in P.4 L. 27 – L. 44. Equations of N uptake in PEATBOG were added in Appendix A.4.

13. Table 3 caption is missing units: g C m-2 ?

The unit has been added (P.24, L.1 in the word version).

14. Fig. 1 caption has a typos: "The green dotted lines in? represent weekly averaged CO2 flux ...", and "Note that P was K not constrained in the model. " Please correct.

These expressions were corrected (P. 25, L. 5 in the word version).

15. Fig. 4: Figure shows "FPT" instead of "EPT"

"Biomass" has been changed to "C pools" in the caption of Fig. 4 (P.23, L. 15 in the word version)

16. Fig. 8: Please write out 'sh' and 'tr' in the line description. I guess 'sh' means shoot not shrub. Also correct 'shurb'.

These unclear abbreviations were corrected in Fig. 8. âĂĊ

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/11/C6361/2014/bgd-11-C6361-2014-
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.
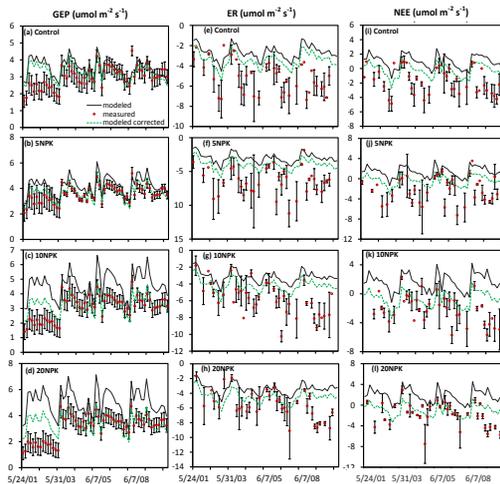
¨ The observed GEP was reconstructed from the observed PAR (half-hourly) and the derived GEP-PAR relations based on the recorded GEP at full, half, quarter light and dark conditions. The GEP-PAR relations were calculated for each year and each treatment, with exceptions in 2005 and 2008 when only the 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.

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).
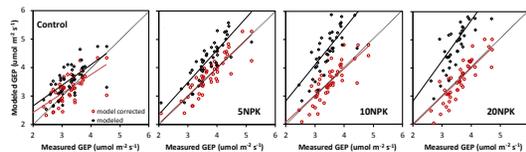
Fig. 2.

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.
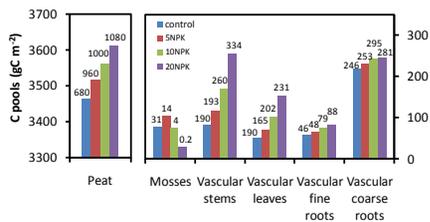
Fig. 3.

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.
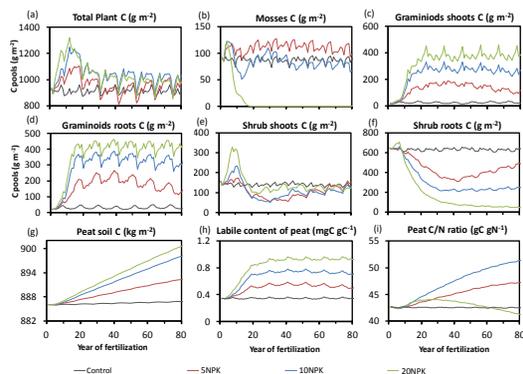
Fig. 4.

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.
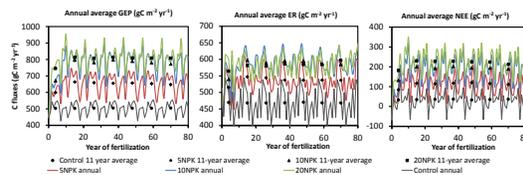
Fig. 5.

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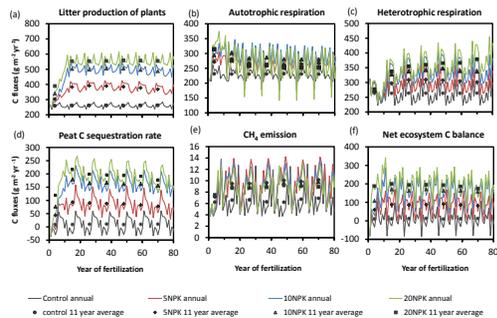
Fig. 6.

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.
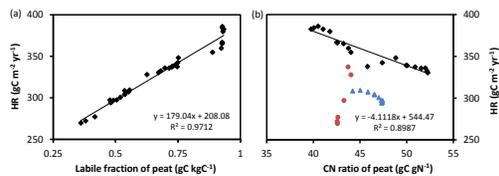

Fig. 7.

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.

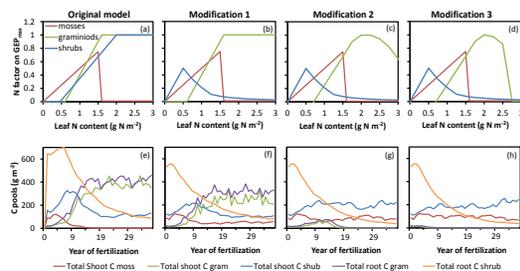**Fig. 8.**

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.
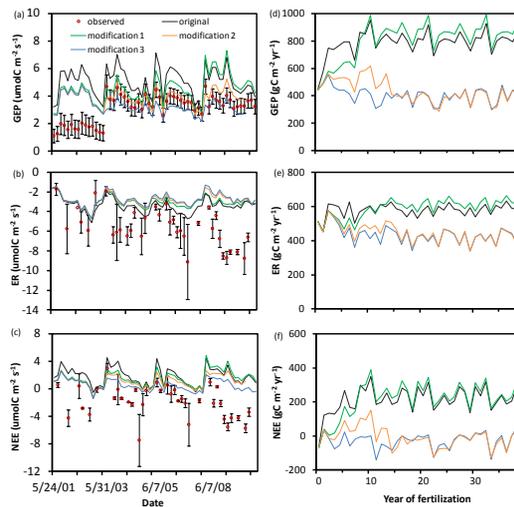

Fig. 9.