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DO THE VEGETATION FEEDBACKS OF NITROGEN DEPOSITION LEAD TO STRONGER OR WEAKER CARBON SINK IN A NUTRIENT LIMITED PEATLAND ECOSYSTEM?

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SUMMARY

We investigated vegetation and ecosystem CO_2 exchange at Mer Bleue Bog, Canada that has been fertilized with nitrogen, phosphorus and potassium or with nitrogen only for 7−12 years. Gross photosynthesis, ecosystem respiration and net CO_2 exchange were measured weekly during May−September 2011 using chambers and the seasonal CO_2 balance reconstructed using environmental time series. The highest nutrient additions were associated with 40% less net CO_2 uptake than in the control. A weaker C sink potential could be explained by changes in availability of nutrients limiting plant and microbial growth, a shift in biomass allocation to woody tissues, loss of *Sphagnum* moss and peat decomposability.

KEY WORDS: CO_2, C balance, nitrogen, photosynthesis, respiration

INTRODUCTION

Atmospheric deposition of biologically available forms of nitrogen (N) is increasing owing to fossil fuel burning and agriculture. In nutrient limited peatland ecosystems, increased nutrient availability has been found to increase vascular plant growth, but decrease *Sphagnum* growth (e.g., Heijmans *et al.* 2001, Bubier *et al.* 2007, Juutinen *et al.* 2010). Higher vascular plant abundance and higher nutrient content alter decomposability of plant litter (e.g., Bragazza *et al.* 2011). These changes in vegetation are likely to affect net imbalance of production and decomposition and thus carbon (C) accumulation in peat. Our aim was to study whether the vegetation feedbacks of N deposition lead to stronger or weaker C sink in a nutrient limited peatland ecosystem.

MATERIAL AND METHODS

We investigated vegetation and ecosystem carbon dioxide (CO_2) exchange at Mer Bleue Bog, Canada (45 °N, 75.5 °W) that has been fertilized for 7–12 years. Annual background inorganic wet N deposition in the region is 0.8 g N m^{-2}. Since the beginning of the experiment, we have applied 5, 10 and 20 times ambient summer time wet N deposition with or without phosphorus (P) and potassium (K). Nutrients have been applied in soluble form as NH_4NO_3 and KH_2PO_4 in distilled water on triplicate 3 x 3 m plots every three weeks from May to August. Distilled water served as a control. A subset of four fertilization (5N, 5NPK, 20N, 20NPK) and two control treatments were measured for CO_2 exchange in 2011. By September 2011, the cumulative N additions in these four fertilization treatments were 19, 19, 45 and 70 g N m^2, respectively.

Net CO_2 exchange (NEE) and ecosystem dark respiration (ER) were measured weekly during May−September 2011 using paired transparent and dark chambers (Alm *et al.* 1997). Instantaneous gross photosynthesis was calculated (P_g= NEE+ER). The seasonal CO_2 exchange was reconstructed using regression models and hourly time series of air temperature, photosynthetically active radiation (PAR), water table depth and photosynthesizing plant area.

Vegetation structure and species composition were measured every three weeks using point intercept method. Number of hits to vascular plant leaves and moss per m^{-2} was used as an estimate of photosynthesizing plant area in ER and P_g models. To examine changes in vegetation with increasing N influx, vegetation data collected in all treatments in mid July 2011 were compared with those from previous studies in 2001–2009 (Bubier *et al.* 2007, Juutinen *et al.* 2010, Juutinen *et al.* unpublished data).

RESULTS AND DISCUSSION

Increasing N influx for 7-12 years has changed the vegetation structure markedly (Fig. 1). Shrub biomass and canopy height have increased especially in the NPK plots. The increased biomass has mainly been allocated to woody shrub stems. *Sphagnum* cover has declined at NPK plots at a lower N load than at N plots presumably due to light competition from taller shrubs (Chong *et al.* in press). *Polytrichum* cover increased initially at low N rates, but has been outcompeted by vascular plants under the highest NPK load. The loss of moss has resulted in lower overall photosynthesizing plant area measured as green hits.

Differences in the ecosystem CO_2 fluxes among treatments were in line with changes in vegetation structure and composition. The highest nutrient additions were associated with 40% less daytime net CO_2 uptake than in the control (Fig. 2). Preliminary seasonal NEE reconstruction based on chamber measurements also showed a trend towards diminished C sink potential in the highest nutrient treatments: all fertilized plots were net CO_2 sources, whereas unfertilized controls had near zero cumulative net CO_2 uptake in May–September. In contrast, micrometeorological measurements of NEE in the unfertilized part of the bog adjacent to our experiment showed that the bog was a CO_2 sink for 8 mol m^{-2} from May 1 to September 1, 2011 (E. Humphreys *et al.*, unpublished data). Possible reasons for the lower C sink in our control plots include differences in the footprint and methods. Chamber measurements have been found to often underestimate CO_2 uptake (Burrows *et al.* 2005). Therefore the estimate for CO_2 balance is less reliable for our experiment than the relative difference among treatments.

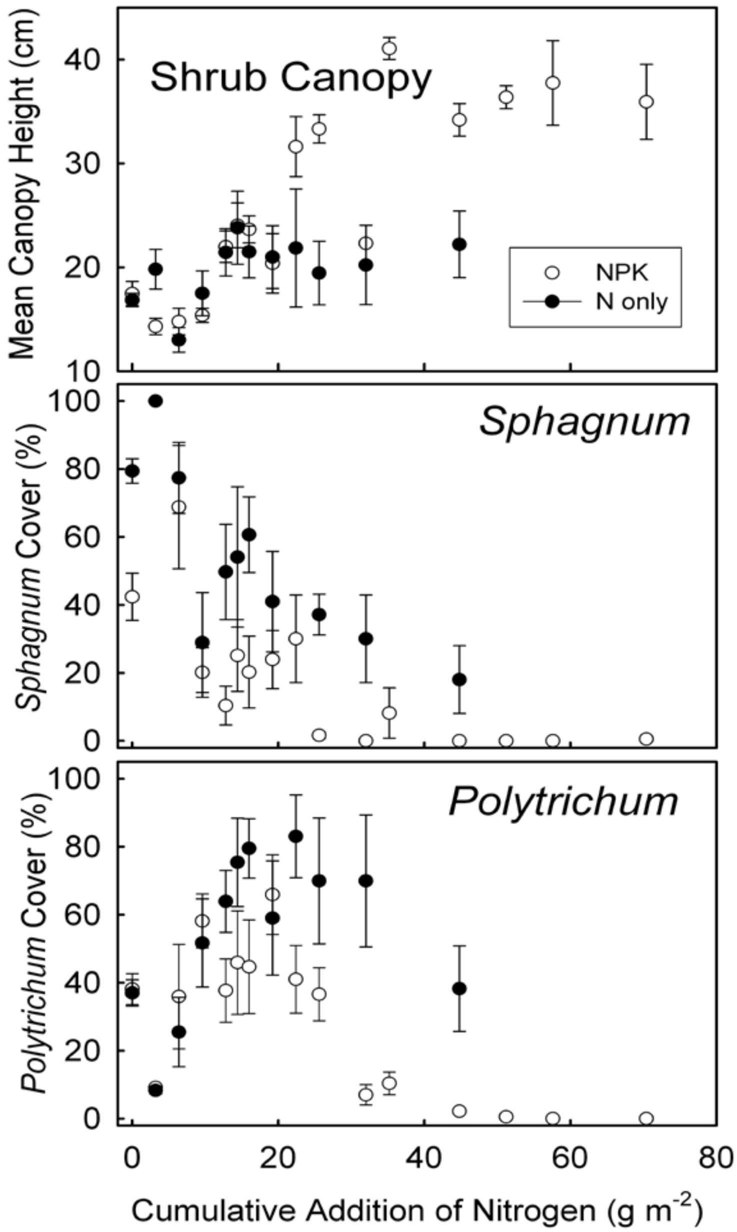

Figure 1. Vegetation changes associated with increasing nitrogen influx 2001-2011 at Mer Bleue Bog. Measurements from different years with the same cumulative nutrient addition are averaged. The error bars indicate standard error of mean. Data 2001−2009 are from studies by Bubier *et al.* (2007), Juutinen *et al.* (2010), Juutinen *et al.* unpublished.

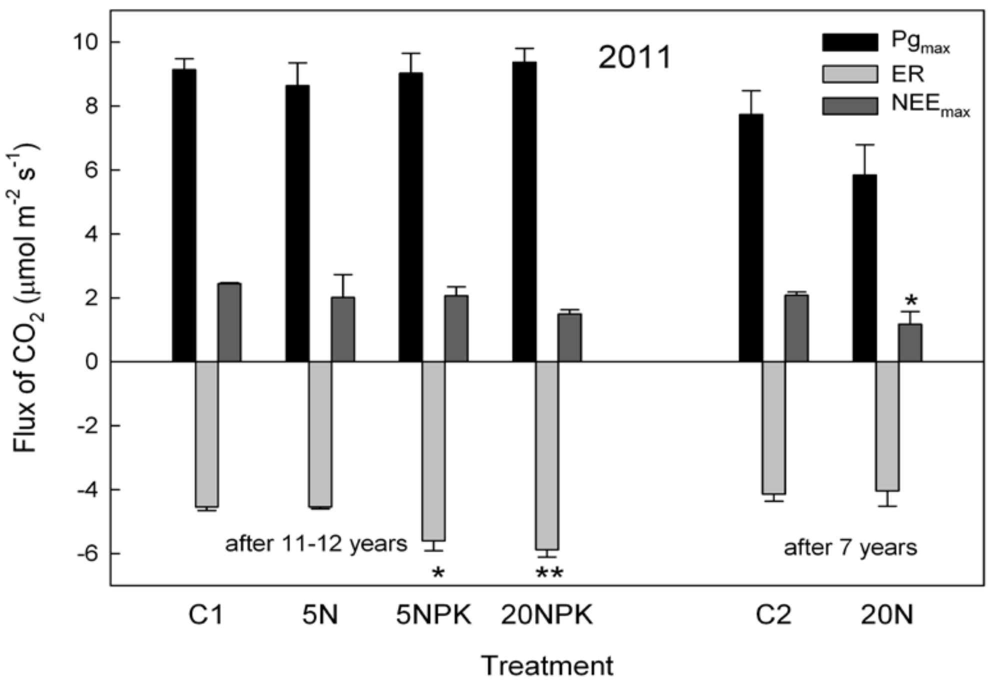

Figure 2. Seasonal averages of maximum gross photosynthesis (Pg_{max}, PAR> 1000 µmol m^{-2} s^{-1}), maximum net ecosystem CO_2 exchange (NEE_{max}) and ecosystem respiration (ER). Significant differences from control are indicated (* $p<0.05$, ** $p<0.01$). Data are measured treatment averages±standard error (n=3) for May−September. Negative sign is used for CO_2 efflux from the ecosystem to the atmosphere.

The two sets of treatments revealed contrasting patterns: in the NPK additions, a diminished C sink potential was due to a 20-30% increase in the ecosystem respiration, while gross photosynthesis was not significantly altered. There, increased gross photosynthesis from increased vascular plant biomass compensated for the loss of peat mosses. In the highest N only addition, the respiration was slightly increased, but the gross photosynthesis was reduced. This resulted in significant net CO_2 loss during the growing season.

Our results suggest that the loss of moss would be the key vegetation feedback leading to reductions in net atmospheric CO_2 uptake. Vascular plants gain a competitive advantage when the moss layer no longer restricts supply of nutrients limiting vascular plant growth (e.g., Lamers *et al.* 2000, Heijmans *et al.* 2001). Despite increased vascular plant biomass, the altered shrub-only community may be a net C source or a weaker C sink owing to enhanced decomposition and excess CO_2 release from C accumulated on site. Shrub litter has been found to decompose at a faster rate than moss litter. At Mer Bleue Bog, the exponential decay constant (*k*-value) for shrub leaves is 0.02 where as for *Sphagnum* it is 0.05 (Moore *et al.* 2007).

Stronger response of both shrub biomass production and decomposition to NPK than N only addition suggests that the plant and microbial communities of this bog ecosystem are N-P/K co-limited rather than N limited, likely due to prolonged elevated atmospheric N deposition in the region. Our results agree with the findings that gross photosynthesis (Lund *et al.* 2009) and litter decomposition (Bragazza *et al.* 2011) were P limited rather than N limited in bog ecosystems under high N deposition. Collectively, our results suggest that in the long term, the vegetation feedbacks of N deposition are likely to lead to a weaker C sink in a nutrient limited peatland ecosystem.

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REFERENCES

Alm, J., Talanov, A., Saarnio, S., Silvola, J., Ikkonen, E., Aaltonen, H., Nykanen, H., and Martikainen P.J. (2007). Reconstruction of carbon balance for microsites in a boreal oligotrophic pine fen, Finland. *Oecologia* **11**, 423-431.

Bragazza, L., Buttler, A., Habermacher J., Brancaleoni, L., Gerdol, R., Fritze, H., Hanajik, P., Laiho, R., and Johnson, D. (2011). High nitrogen deposition alters the decomposition of plant litter and reduces carbon accumulation. *Global Change Biology*, in press.

Bubier. J., Moore, T., and Bledzki, L.A. (2007). Effects of nutrient addition on vegetation and carbon cycling in an ombrotrophic bog. *Global Change Biology* **13**, 1168-1186.

Burrows, E.H., Bubier, J.L., Mosedale, A., Cobb, G.W., and Crill, P.(2005). Net ecosystem exchange of carbon dioxide in a temperate poor fen: a comparison of automated and manual chamber techniques. *Biogeochemistry* **76**, 21-45.

Chong, M., Humpreys, E., and Moore, T.R. (2012). Microclimate response to increasing shrub cover and its effect on *Sphagnum* CO_2 exchange in a bog. *Ecoscience*, in press.

Heijmans, M.M.P.D., Berendse, F., Arp, W.J., Masselink, A.K., Klees, H., de Visser, W., van Breemen, N. (2001). Effects of elevated carbon dioxide and increased nitrogen deposition on bog vegetation in the Netherlands. *Journal of Ecology* **89**, 268-279.

Juutinen, S., Bubier, J.L., and Moore, T.R. (2010). Responses of vegetation and ecosystem CO_2 exchange to 9 years of nutrient addition at Mer Bleue Bog. *Ecosystems* **13**, 874-887. DOI: 10.1007/s10021-010-9361-2

Lamers, L.P.M, Bobbink, R., and Roelofs, J.G.M. (2000). Natural nitrogen filter fails in polluted raised bogs. *Global Change Biology* **6**, 583-586.

Lund, M., Christensen, T.R., Mastepanov, M., Lindroth, A., and Strom, L. (2009). Effect of N and P fertilization on the greenhouse gas exchange in two northern peatlands with contrasting N deposition rates. *Biogeosciences* **6**, 2135-2144.

Moore, T.R., Bubier J.L., and Bledzki, L. (2007). Litter decomposition in temperate peatland ecosystems: the effect of substrate and site. *Ecosystems* **10**, 949-963.