TOO MUCH OF A GOOD THING: ENVIRONMENTAL IMPACTS OF INCREASING ATMOSPHERIC NITROGEN DEPOSITION ON PEATLANDS

Luca Bragazza[1,2,3]

[1]WSL-Swiss Federal Institute for Forest, Snow and Landscape Research, Site Lausanne (Switzerland)

[2]Laboratory of Ecological Systems, EPFL - École Polytechnique Fédérale de Lausanne (Switzerland)

[3]Department of Life Science and Biotechnologies, University of Ferrara (Italy)

e-mail: luca.bragazza@wsl.ch

CAPER
Committee on Air Pollution Effects Research

Sheffield (UK), 25-27 March 2013

Global Change Biology

Global Change Biology (2012) 18, 1197–1215, doi: 10.1111/j.1365-2486.2011.02590.x

REVIEW

Impacts of atmospheric nitrogen deposition: responses multiple plant and soil parameters across contrasting ecosystems in long-term field experiments

GARETH K. PHOENIX*, BRIDGET A. EMMETT†, ANDREA J. BRITTON‡, SIMON J. M. CAPORN§, NANCY B. DISE§, RACHEL HELLIWELL‡, LAURENCE JONES†, JONATHA LEAKE*, IAN D. LEITH¶, LUCY J. SHEPPARD¶, ALWYN SOWERBY†, MICHAEL G. PILKINGTON*, EDWIN C. ROWE†, MIKE R. ASHMORE|| and SALLY A. POWER**

*Department of Animal and Plant Sciences, University of Sheffield, Western Bank, Sheffield, S10 2TN, UK, †Centre for Eco and Hydrology Bangor, Environment Centre Wales, Deiniol Road, Bangor, North Wales LL57 2UW, UK, ‡The James Hutt Institute, Craigiebuckler, Aberdeen, AB15 8QH, UK, §School of Science and the Environment, Manchester Metropolitan University, Manchester, M15GD, UK, ¶Centre for Ecology and Hydrology Edinburgh, Bush Estate, Penicuik, EH26 0QB, UK, ||Environment Department, University of York, York, YO10 5DD, UK, **Division of Biology, Imperial College London, Silwood Park, Ascot, Berkshire, SL5 7PY, UK

AMBIO 2012, 41:235–246
DOI 10.1007/s13280-012-0250-0

REVIEW PAPER

Effects of Atmospheric Nitrogen Deposition on Remote Freshwater Ecosystems

Fabio Lepori, François Keck

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, G03S09, doi:10.1029/2007JG000508, 2008

Nonlinear responses to nitrogen and strong interactions w... and phosphorus additions drastically alter the structure a... of a high arctic ecosystem

Seth J. T. Arens,[1,2] Patrick F. Sullivan,[1] and Jeffrey M. Welker[1]

Long-Term Change in the Nitrogen Cycle of Tropical Forests

Peter Hietz,[1*] Benjamin L. Turner,[2] Wolfgang Wanek,[3] Andreas Richter,[4] Charles A. Nock,[5] S. Joseph Wright[2]

4 NOVEMBER 2011 VOL 334 SCIENCE

Environmental Pollution 159 (2011) 2265–2279

Contents lists available at ScienceDirect

ELSEVIER

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

ENVIRONMENTAL POLLUTION

Review

Nitrogen deposition effects on Mediterranean-type ecosystems: An ecological assessment

Raúl Ochoa-Hueso[a,*], Edith B. Allen[b], Cristina Branquinho[c], Cristina Cruz[c], Teresa Dias[c], Mark E. Fenn[d], Esteban Manrique[a], M. Esther Pérez-Corona[e], Lucy J. Sheppard[f], William D. Stock[g]

[a] Department of Plant Physiology and Ecology, Centro de Ciencias Medioambientales, Consejo Superior de Investigaciones Científicas, C/Serrano 115 Dpdo., 28006 Madrid, Spain
[b] Department of Botany and Plant Sciences and Center for Conservation Biology, University of California, Riverside, CA 92521, USA
[c] Universidade de Lisboa, Faculdade de Ciencias, Centro de Biologia Ambiental, Campo Grande, Bloco C4, 1749-016 Lisboa, Portugal
[d] US Department of Agriculture (USDA) Forest Service, Pacific Southwest Research Station, 4955 Canyon Crest Drive, Riverside, CA 92507, USA
[e] Department of Ecology, Faculty of Biology, Universidad Complutense de Madrid, C/José Antonio Novais 2, 28040 Madrid, Spain
[f] Centre of Ecology and Hydrology, Bush Estate, Penicuik EH26 0QB, UK
[g] Centre for Ecosystem Management, School of Natural Sciences, Edith Cowan University, 100 Joondalup Drive, Joondalup, Perth, WA 6027, Australia

Mountain Research and Development Vol 28 No 3/4 Aug–Nov 2008: 210–215 doi:10.1

Rachel Helliwell
Andrea Britton
Sheila Gibbs
Julia Fisher
Julian Aherne

Who Put the N in PristiNe?

Impacts of Nitrogen Enrichment in Fragile Mountain Environments

Overview

1. **Worldwide trends of N deposition**

2. **Effects at organism level**

   2.1 *Sphagnum* mosses and vascular plants

   2.2 Soil microbes

3. **Effects at community level**

   3.1 Litter and organic matter decomposition

   3.2 Gas exchange

4. **Interaction of N with climate warming**

5. **Open questions**

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   - 3.2 Gas exchange

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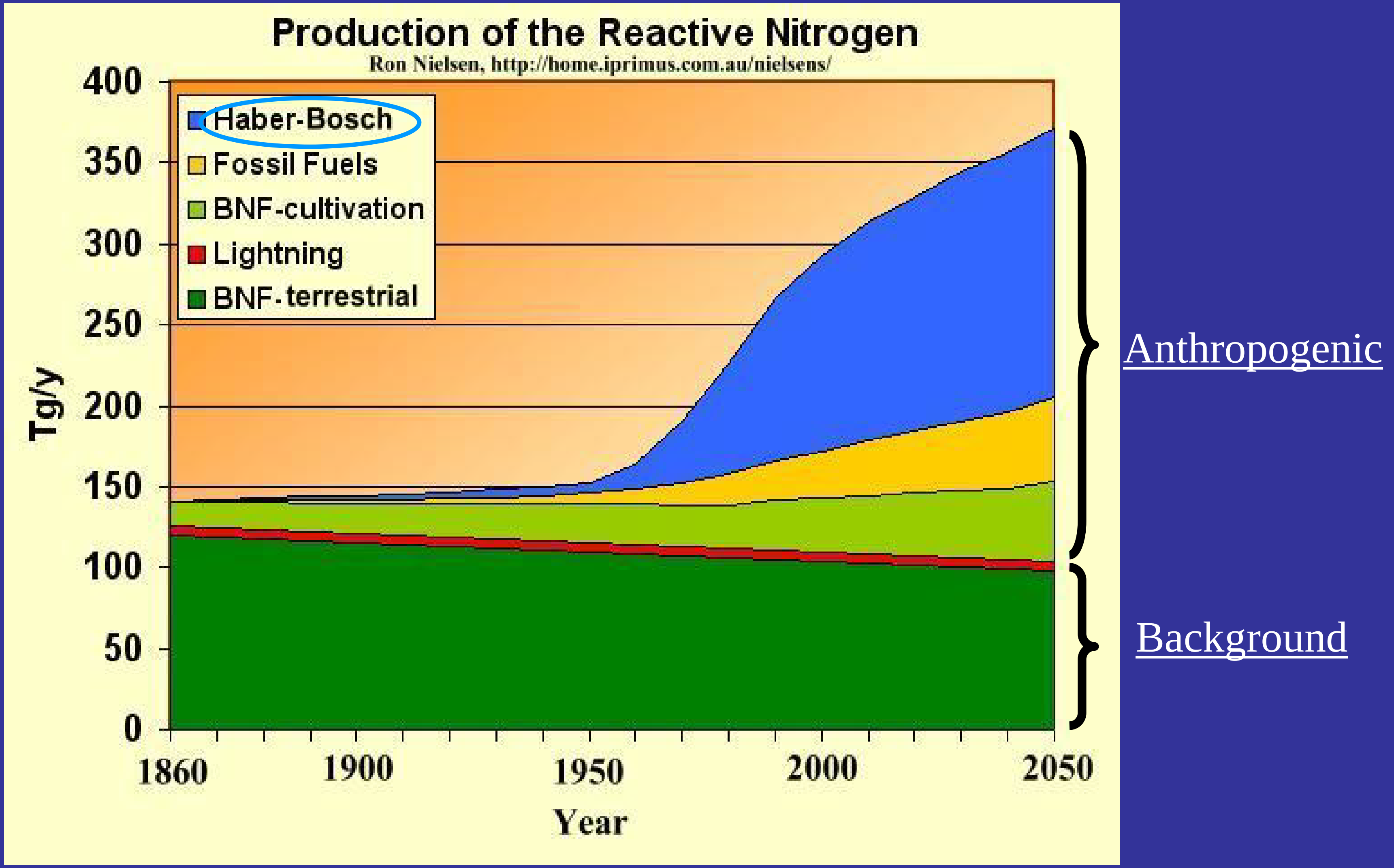
5. Open questions


Production of the Reactive Nitrogen
Ron Nielsen, http://home.iprimus.com.au/nielsens/
Haber-Bosch
Fossil Fuels
BNF-cultivation
Lightning
BNF-terrestrial
Tg/y
400
350
300
250
200
150
100
50
0
1860
1900
1950
2000
2050
Year
Anthropogenic
Background

Fritz Haber (1868-1934)

Carl Bosch (1874-1940)

Past, present and future of nitrogen deposition

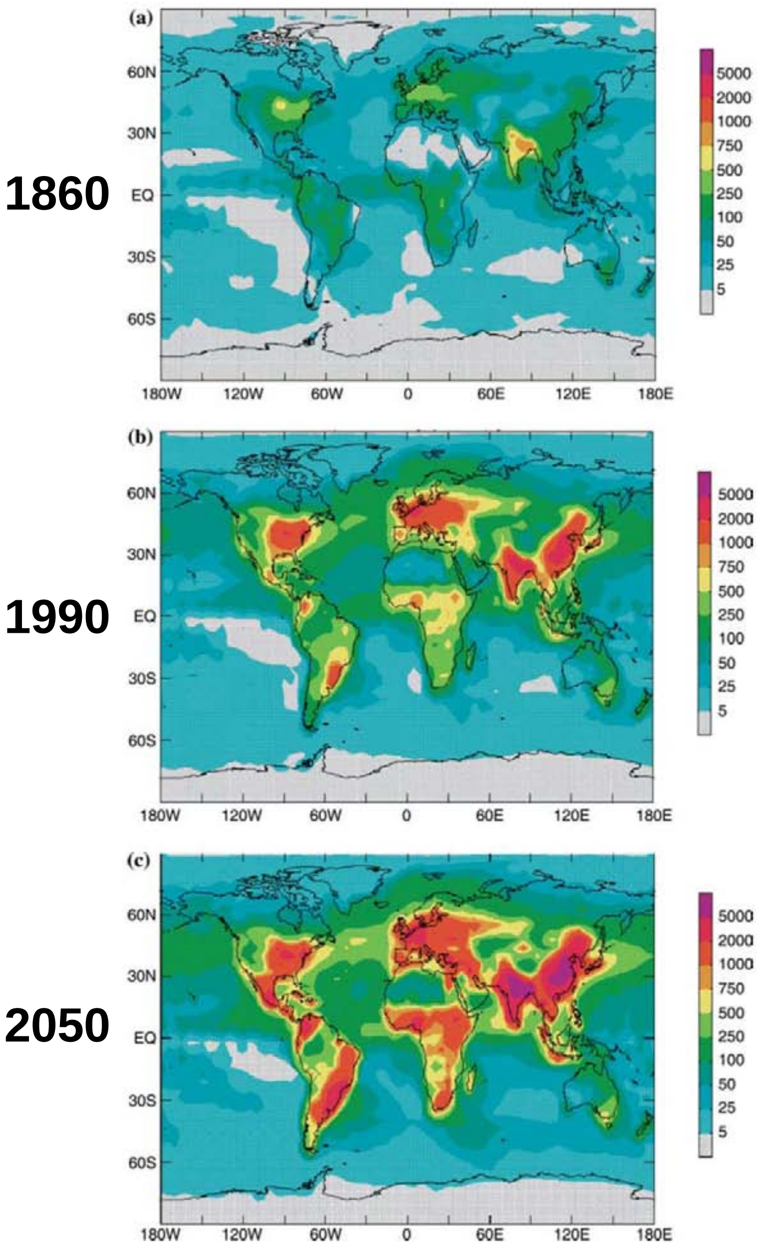


Figure 2. Spatial patterns of total inorganic nitrogen deposition in (a) 1860, (b) early 1990s, and (c) 2050, mg N m^{-2} yr^{-1}.

Galloway et al. (2004) *Biogeochemistry* 70: 153.

Overview

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5. Open questions

Nitrogen deposition and *Sphagnum* tissue chemistry

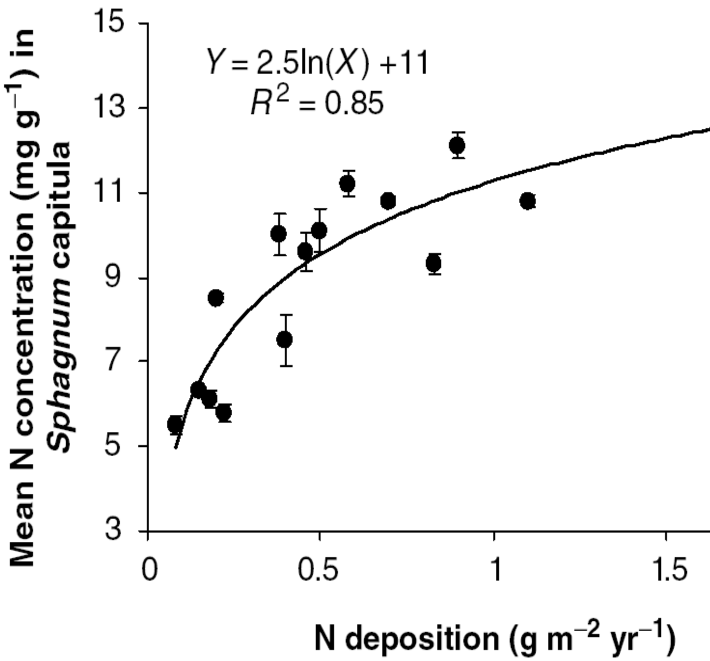


Fig. 1 Trend of mean (± SE) nitrogen (N) concentration in *Sphagnum* capitula along the gradient of atmospheric N deposition.

Bragazza et al. (2005) *Global Change Biology* 11: 106

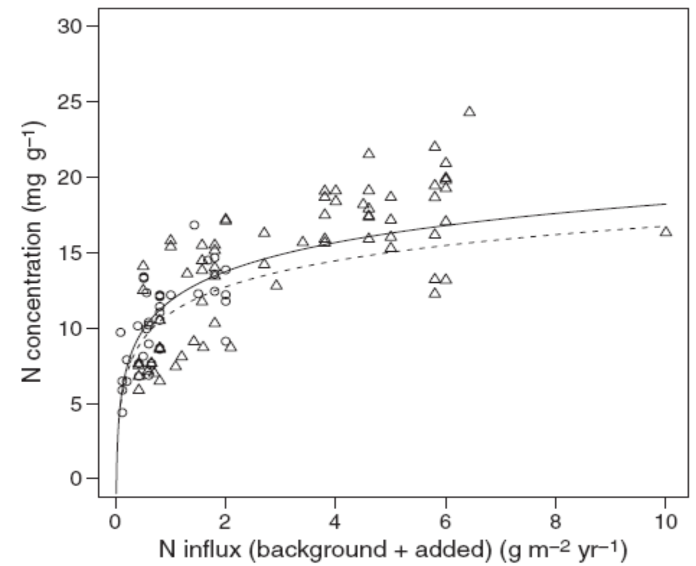
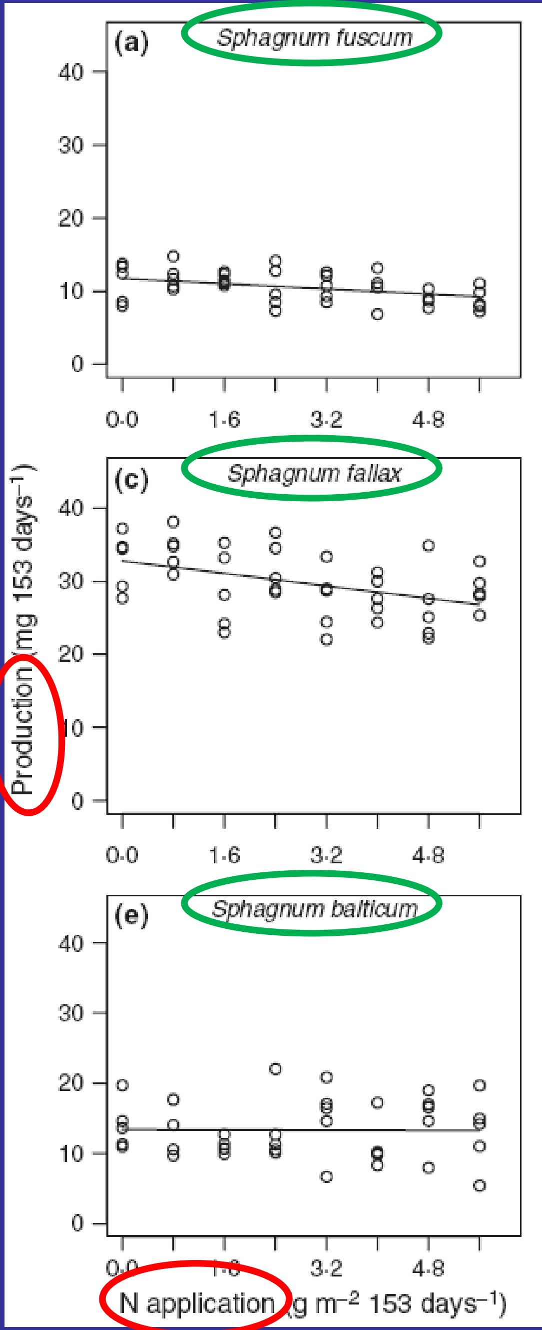


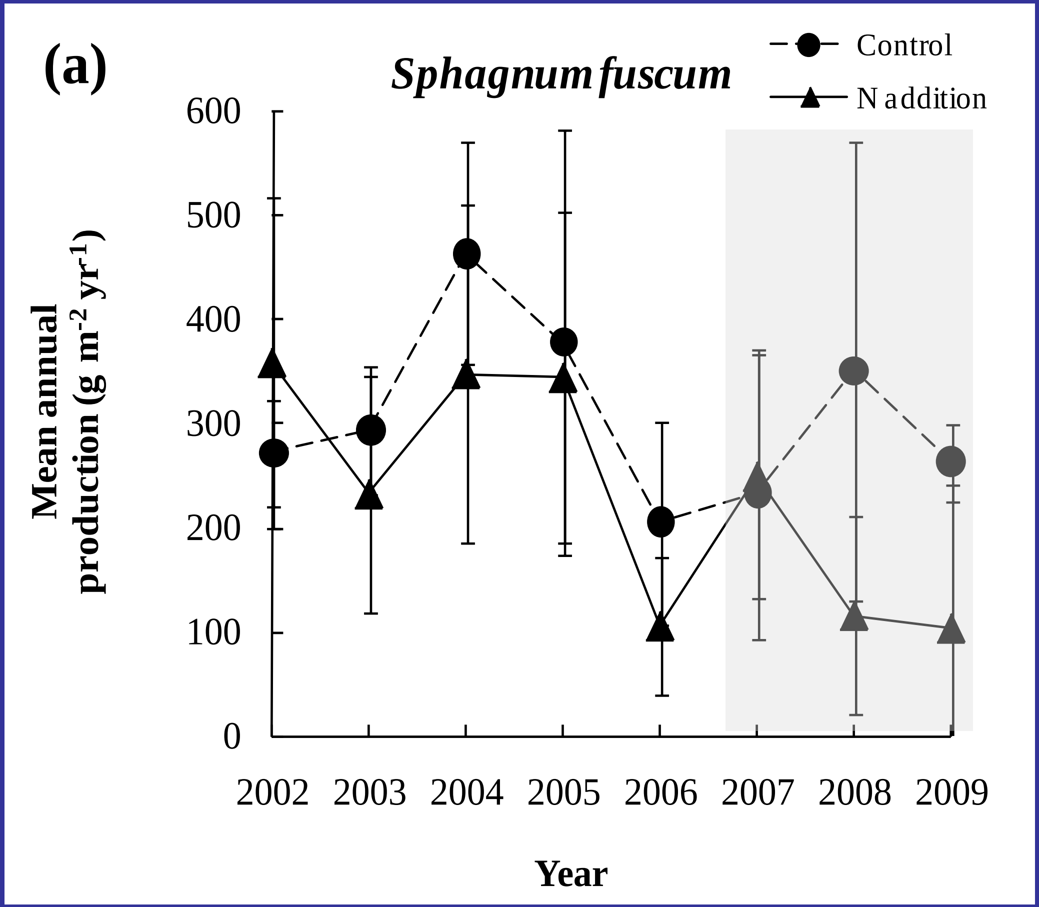
Fig. 1 Relationship between *Sphagnum* nitrogen (N) concentration and sum of background wet deposition and applied N. We included data on *Sphagnum* N concentrations (upper 0–3 cm shoot, DW basis) from both control (circles) and N treatments (triangles) from our dataset (n = 109). The solid line indicates the best fit through our data (N concentration = 11.8 + 2.8 × $\log_e$(N influx)). The dashed line indicates the relationship reported by Bragazza *et al.* (2005) for *Sphagnum* collected at unfertilized sites and includes an extrapolation beyond the range of collection sites (with a maximum of 2 g N m^{-2} yr^{-1} in background deposition). There is no evidence for N-induced toxicity below *Sphagnum* N concentrations of 20 mg N g^{-1} DW (Granath *et al.*, 2009).

Limpens et al. *New Phytologist* (2011) **191**: 496–507

Sphagnum productivity

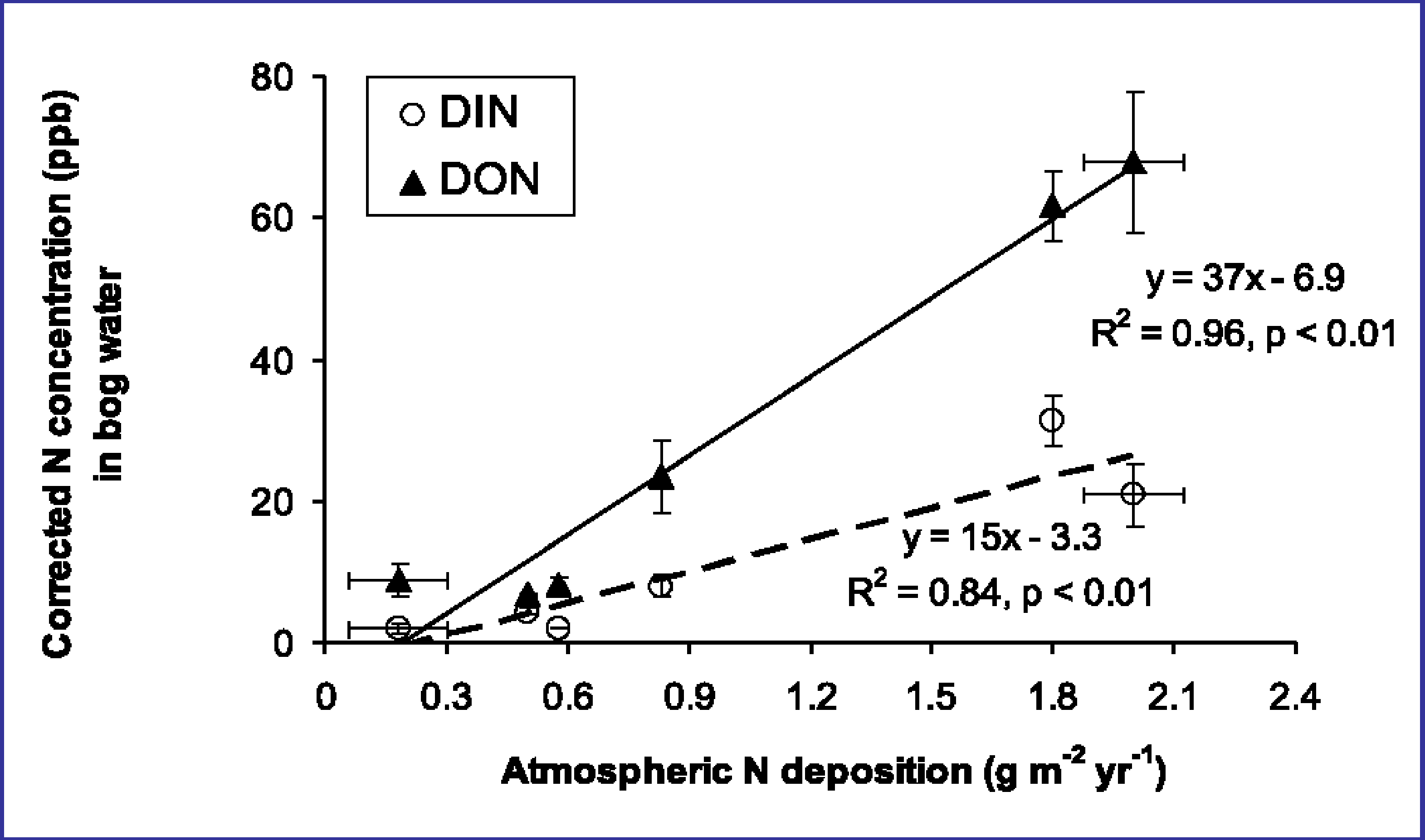


Granath et al. (2012) *Functional Ecology* 26:353



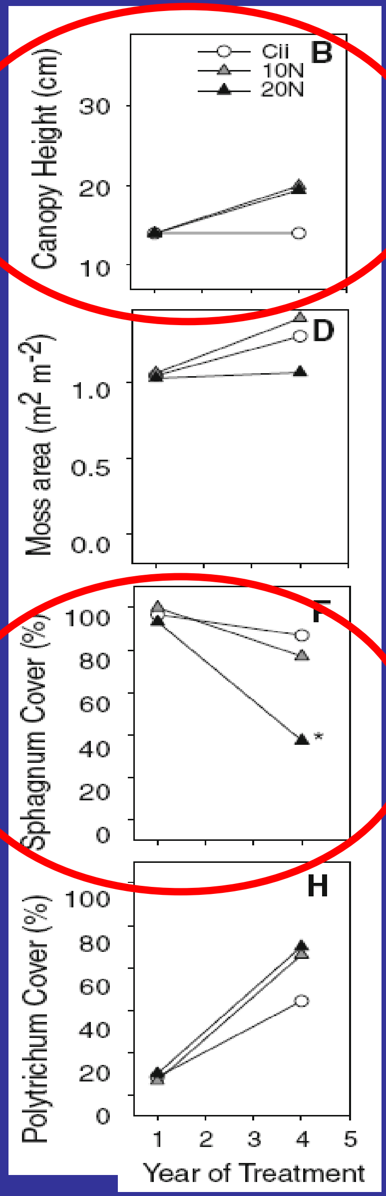
Bragazza et al. (2008) *Global Change Biology* 18:1163

Reduced *Sphagnum* filtering ability

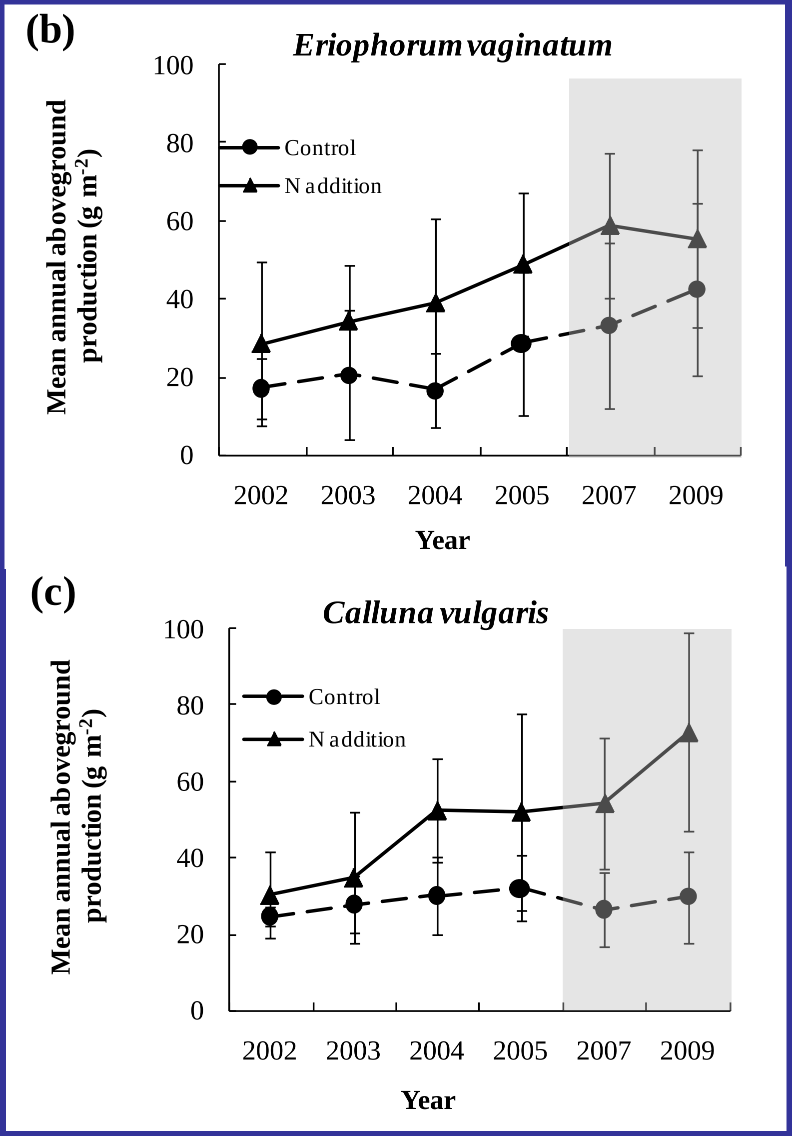


Bragazza & Limpens (2004) *Global Biogeochemical Cycles* 18: 1.

Response of vascular plant cover



Juutinen et al. (2010) *Ecosystems* 13: 874 (redrawn)



Bragazza et al. (2012) *Global Change Biology* 18:1163

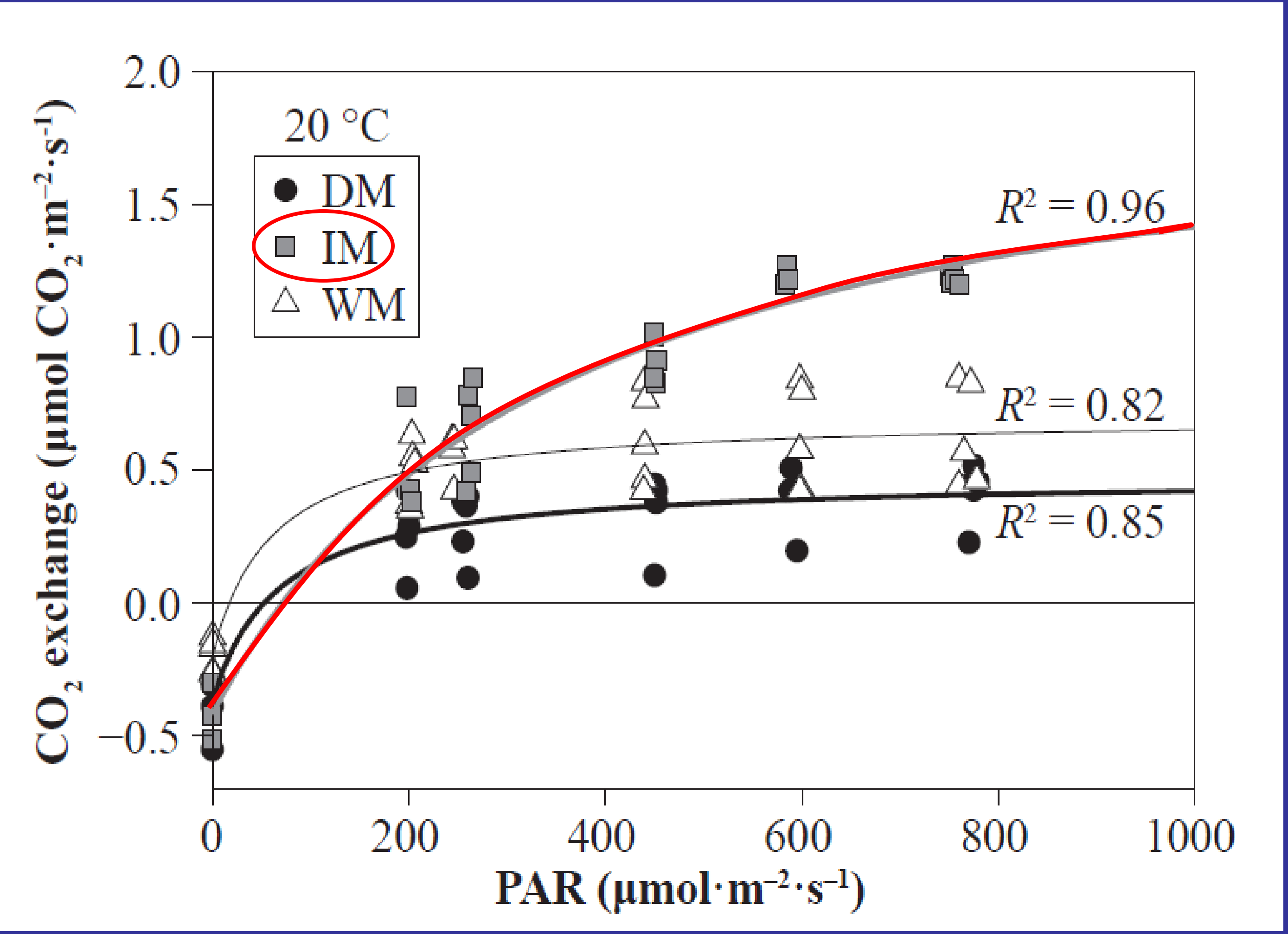
The “revenge of vascular plants”

Control
(ambient N dep. = 0.2 g m^{-2} yr^{-1})

After 8 years of N fertilization
(ambient N dep. + 3 g m^{-2} yr^{-1})

Wiedermann et al. (2007) *Ecology* 88: 454.

Interspecific competition: *Sphagnum* vs. vascular plants



Chong et al. (2012) *Écoscience* 19:89

Overview

1. Worldwide trends of N deposition

2. Effects at organism level

2.1 *Sphagnum* mosses and vascular plants

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5. Open questions

Response of soil microbes to high N deposition

3.3. *Nutrient deposition*

Our knowledge of how nutrient deposition affects microbial population is rather fragmented. Indeed, while a large number of studies have looked at the long-term impact of nutrient deposition on vegetation and carbon cycling (e.g. Bubier et al., 2007; Juutinen et al., 2010; Limpens et al., 2006; Bragazza et al., 2012), only a few studies have looked at microorganisms and their response to increased nutrient deposition (Table 6). Enhanced N and S depo-

Soil Biology & Biochemistry 57 (2013) 979–994

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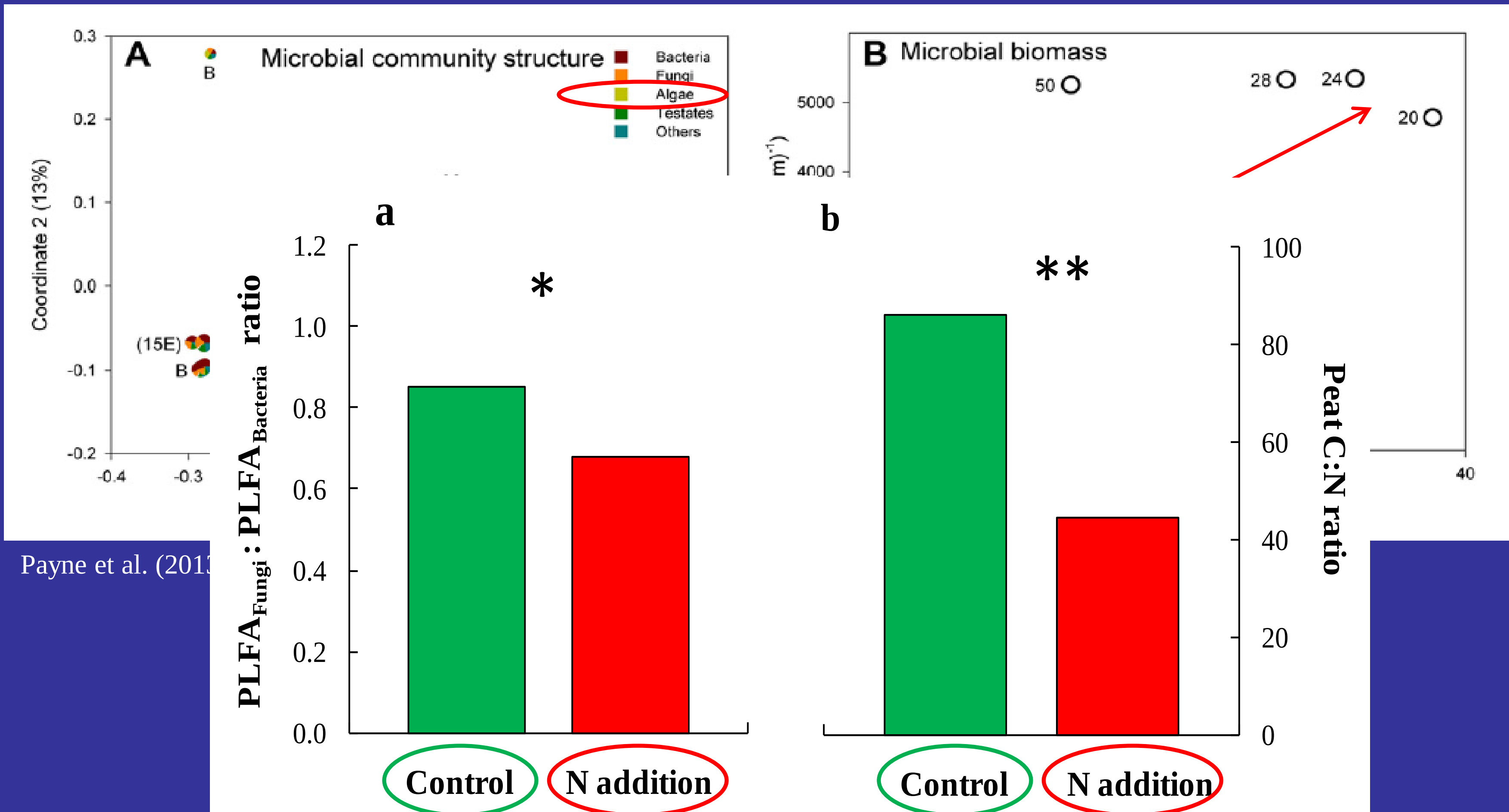
Review paper

Microbial communities in natural and disturbed peatlands: A review

R. Andersen [a,b,*], S.J. Chapman [a], R.R.E. Artz [a]



Payne et al. (2013

Bragazza et al. (2012) *Global Ch. Biol.* 18: 1163

Interspecific competition: *Sphagnum* vs. microbes

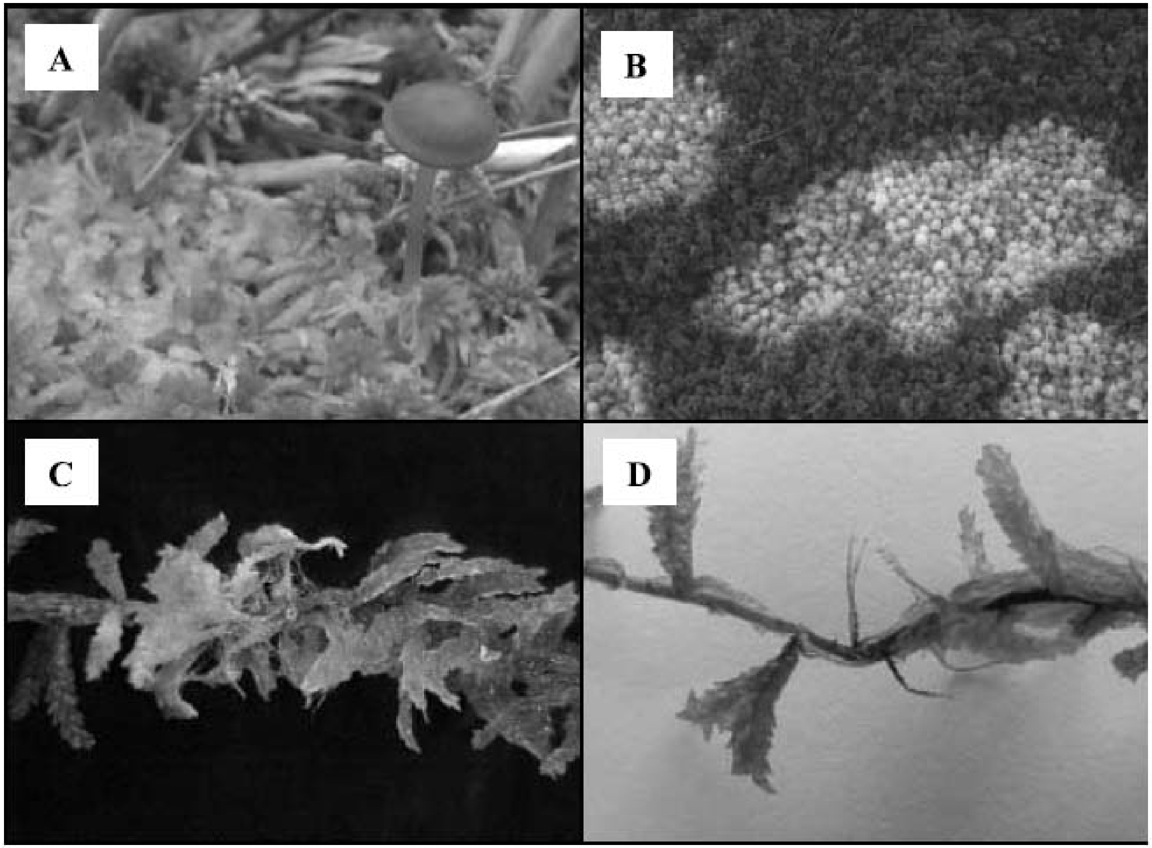


Fig. 1. A Fruiting body of *Lyophyllum palustre*, B Necrotic *Sphagnum cuspidatum*, C Early infection around stem of *S. papillosum* and D Defoliated stem part of *S. papillosum*, also referred to as sign of infection.

Limpens et al. (2003) *Oikos* 103: 59

Overview

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5. Open questions

Increased N content in peat litter enhances CO_2 release under laboratory conditions

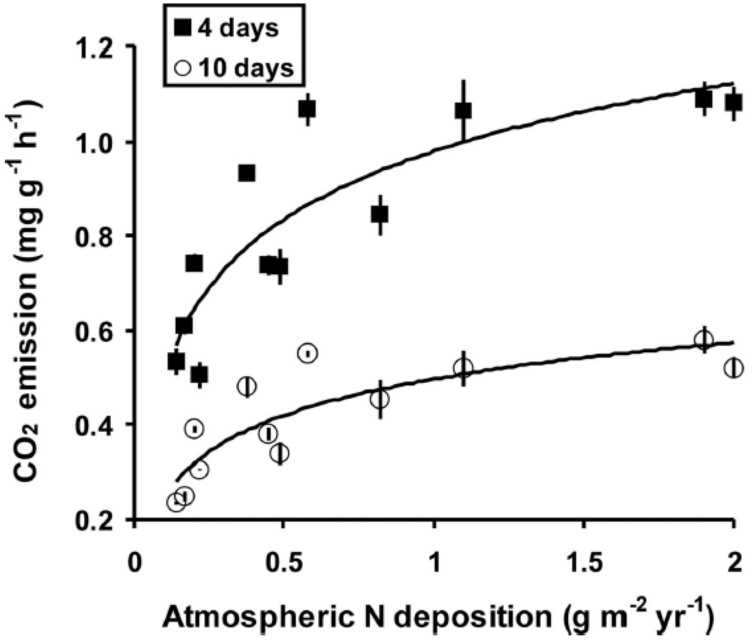


Fig. 1. Hourly CO_2 emission from litter peat samples after 4 and 10 days of incubation in relation to atmospheric N deposition in study bogs. Relationships were explained by a logarithmic regression for both incubation periods [$y = 0.98 + 0.21 ln(x)$, $R^2 = 0.75$, $P < 0.01$ and $y = 0.49 + 0.11 ln(x)$, $R^2 = 0.73$, $P < 0.01$, respectively]. Each value is the mean (± 1 SE) of three to six litter peat samples.

Bragazza et al. (2006) *PNAS* 103: 1936

N content in plant litter and short-term field decomposition

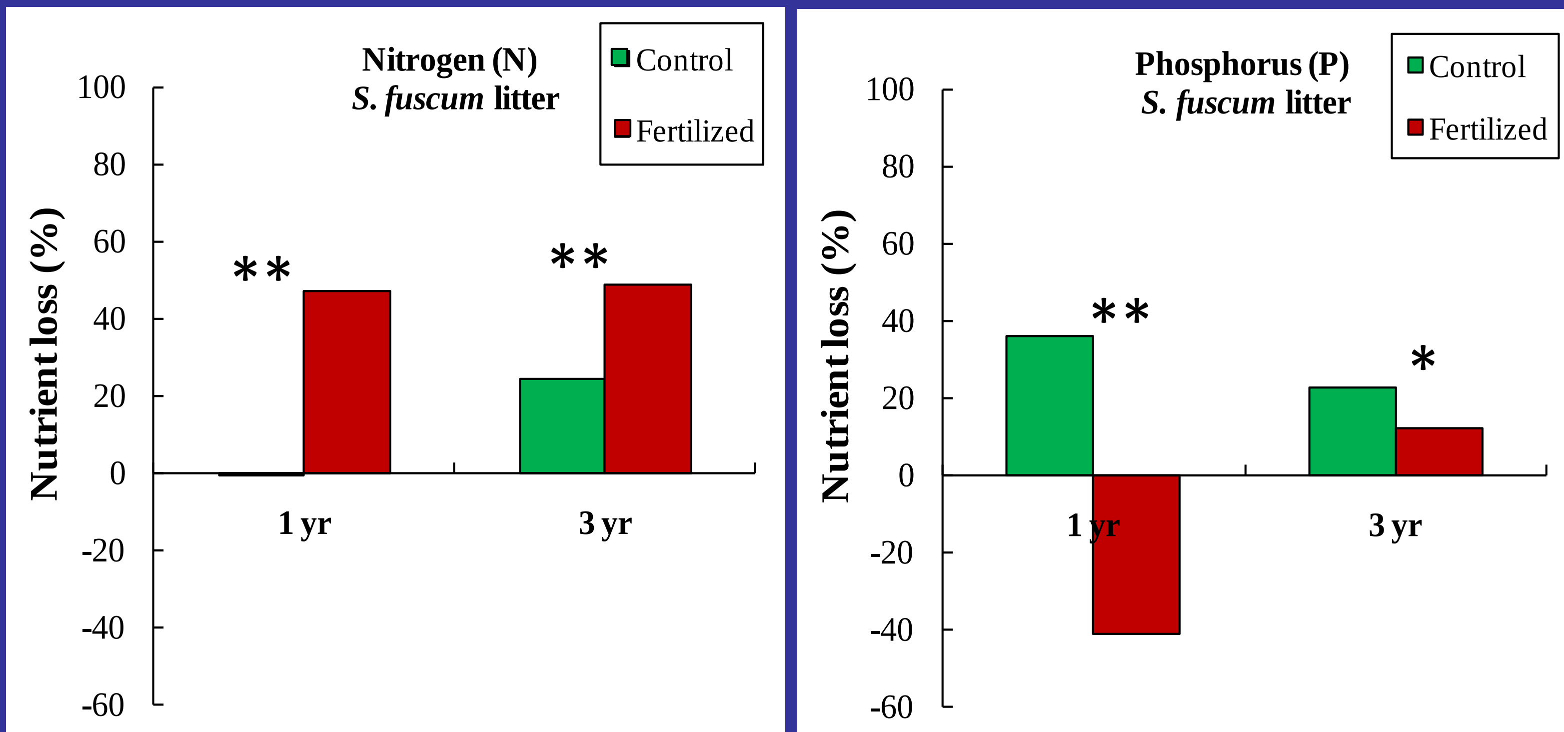
Table 1 Initial nitrogen (N) and phosphorus (P) concentration in litter as well as mean litter mass loss (% of initial mass ± SD) after 1 and 3 years of decomposition in control and N-fertilized plots for plant litter produced under control and N-fertilized conditions respectively. Control treatment received a background deposition of 0.8 gN m^{-2} yr^{-1} whereas the fertilized treatment received an addition of 3 gN m^{-2} yr^{-1}

	Initial N concentration (mg g^{-1})		Initial P concentration (mg g^{-1})		Mass loss 1 year		Mass loss 3 years	
	Control	Fertilized	Control	Fertilized	Control	Fertilized	Control	Fertilized
Calluna vulgaris	$13.0^{b} \pm 0.36$	$15.4^{a} \pm 0.25$	$0.84^{a} \pm 0.05$	$0.76^{b} \pm 0.09$	$38.9^{b} \pm 1.7$	$44.0^{a} \pm 5.7$	$62.8^{a} \pm 4.4$	$66.0^{a} \pm 9.8$
Sphagnum fuscum	$6.6^{b} \pm 0.16$	$15.7^{a} \pm 0.95$	$0.31^{a} \pm 0.01$	$0.29^{b} \pm 0.02$	$9.6^{b} \pm 3.0$	$14.1^{a} \pm 3.4$	$15.8^{a} \pm 6.2$	$18.9^{a} \pm 4.2$
Eriophorum vaginatum	$14.8^{a} \pm 0.41$	$14.2^{a} \pm 0.24$	$0.87^{a} \pm 0.01$	$0.85^{a} \pm 0.04$	$44.9^{a} \pm 6.9$	$37.8^{b} \pm 2.8$	$65.4^{a} \pm 4.9$	$59.7^{b} \pm 14.6$

Different superscripts for the same plant species indicate significant differences between treatments (Student *t*-test; $P < 0.05$). Mean values are based on five replicates for initial litter chemistry and on eight replicates for litter mass loss.

Bragazza et al. (2012) *Global Ch. Biol.* 18: 1163

Nutrient retention in decomposing *Sphagnum* litter

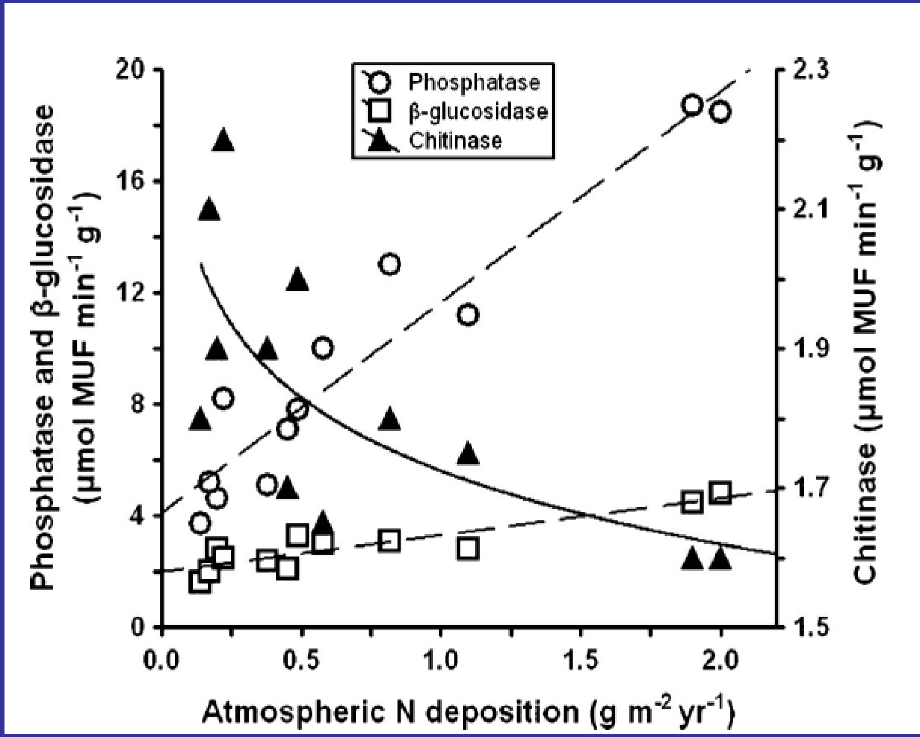


Bragazza et al. (2012) *Global Ch. Biol.* 18: 1163

Positive feedback on increasing soil N availability due to reduced N immobilization

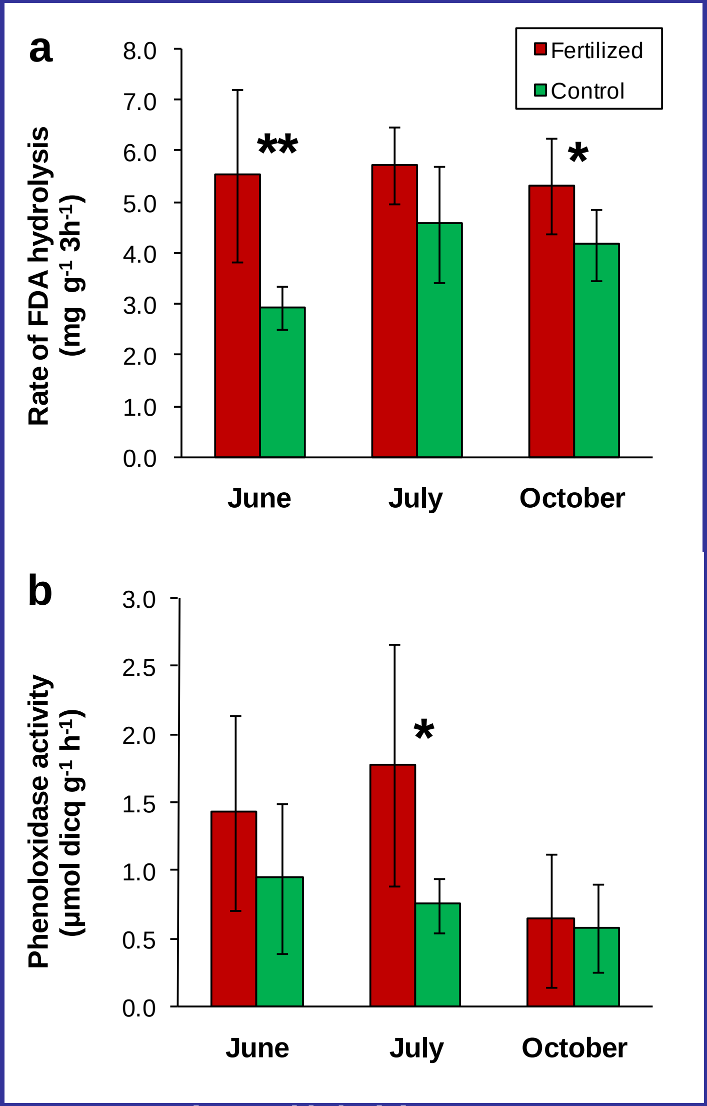
Soil enzymatic activity

...under laboratory conditions



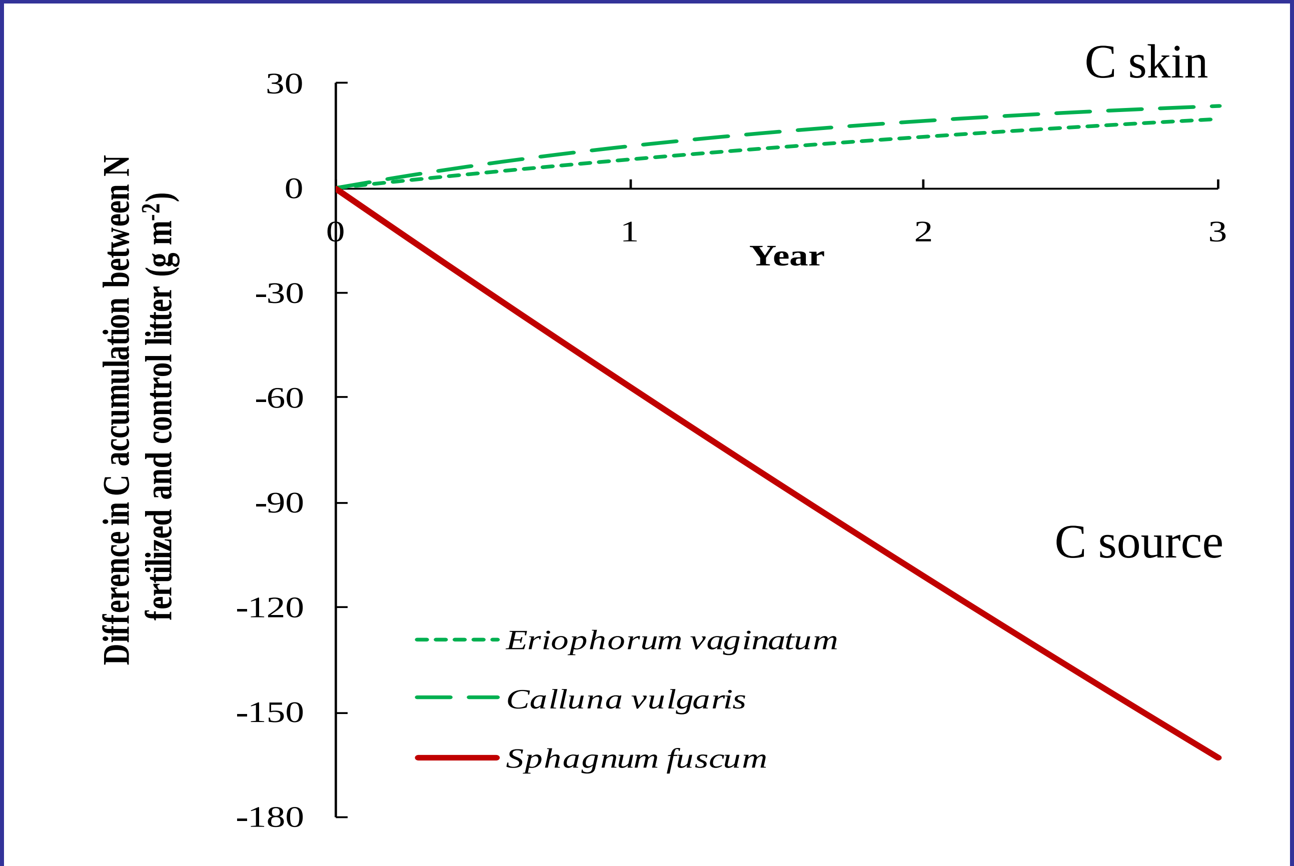
Bragazza et al. (2006) *PNAS* 103: 1936.

...under field conditions



Bragazza et al. *Unpublished data*

Overall trends in litter accumulation with increasing N deposition



Bragazza et al. (2012) *Global Ch. Biol.* 18: 1163

The increased productivity of vascular plants does not compensate for the reduced productivity of recalcitrant litter by *Sphagnum* plants

Overview

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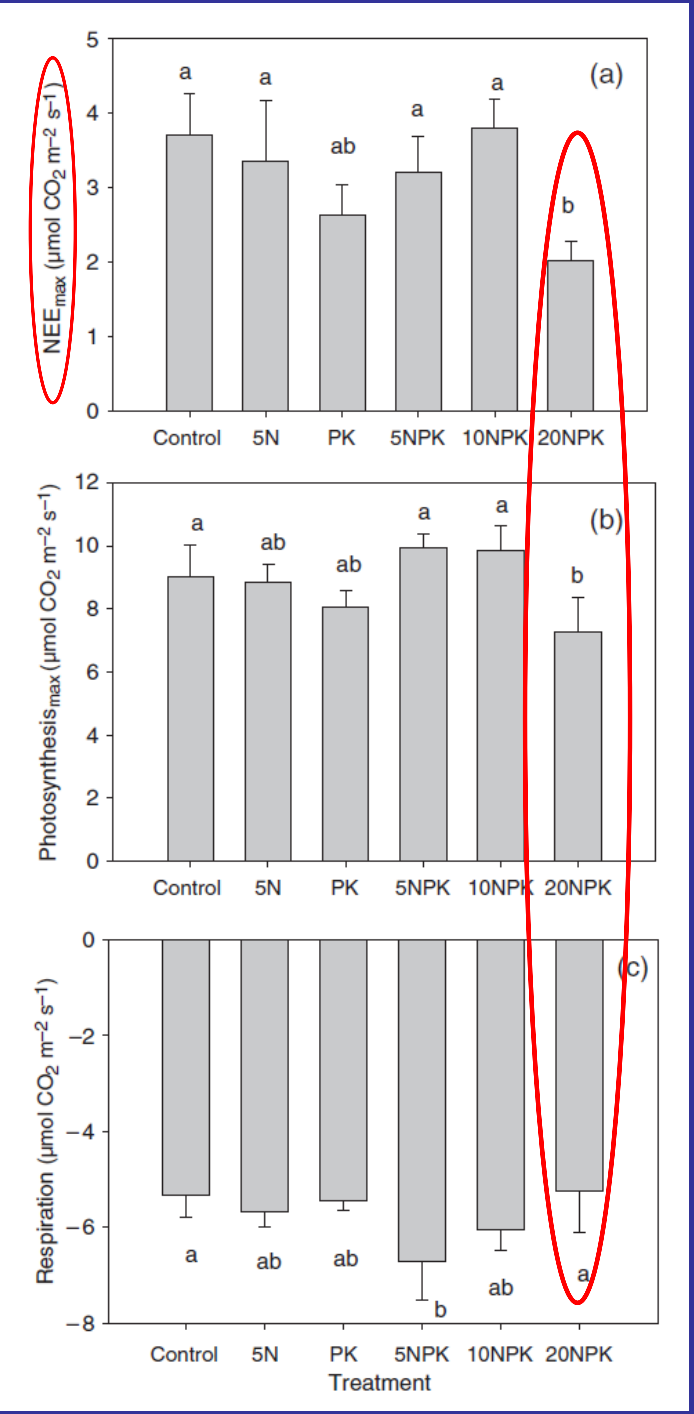
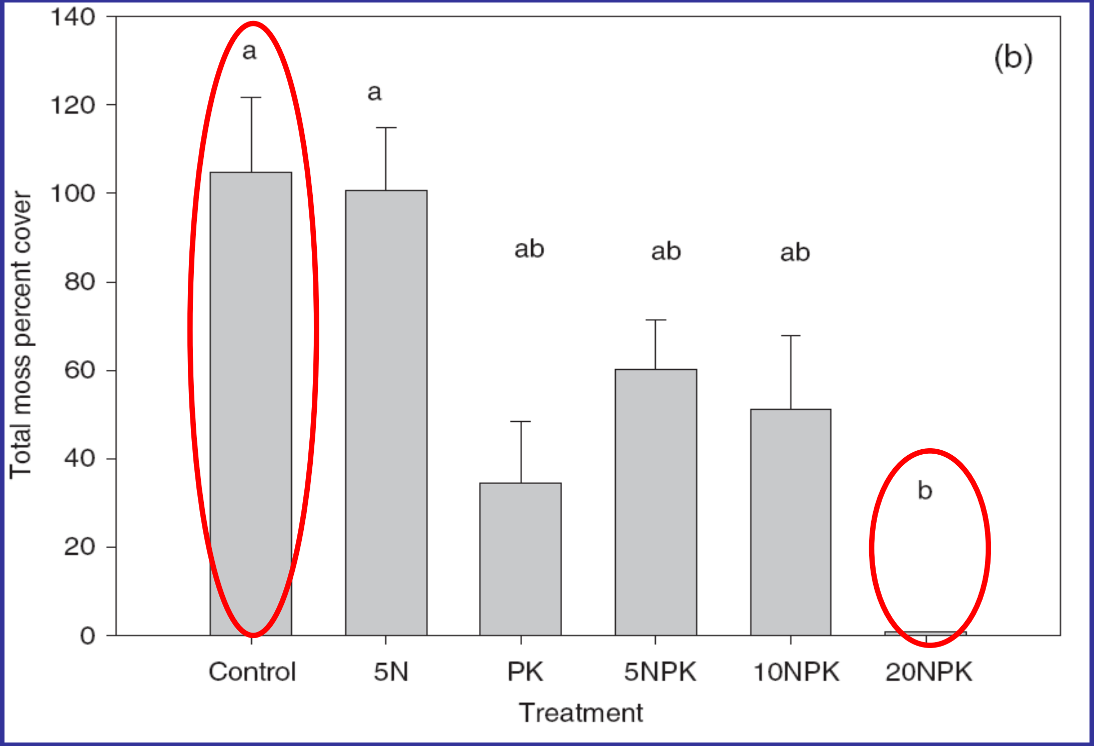
4. Interaction of N with climate warming

5. Open questions



Lower NEE (net ecosystem exchange) after 5 years, but mainly due to a reduced photosynthetic rate of *Sphagnum* plants.



Bubier et al. (2007) *Global Change Biology* 13: 1168.

N deposition and N_2O emission: the role of vegetation as N sink

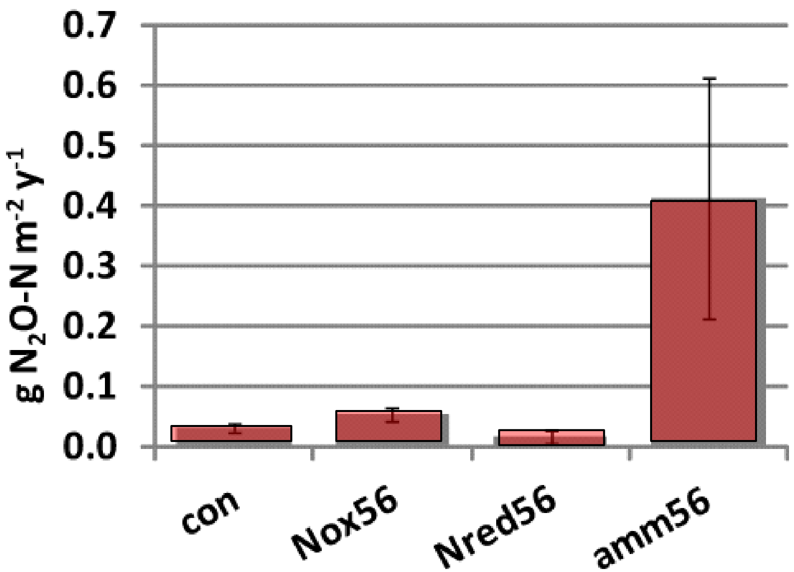


Fig. 6. Mean N_2O-N flux (+/− st err) from the control (no added N) and N treated (oxidised (Nox), reduced (Nred) and ammonia (amm)) plots (~56 kg N ha^{-1} yr^{-1}) at Whim bog in 2009 and 2010.

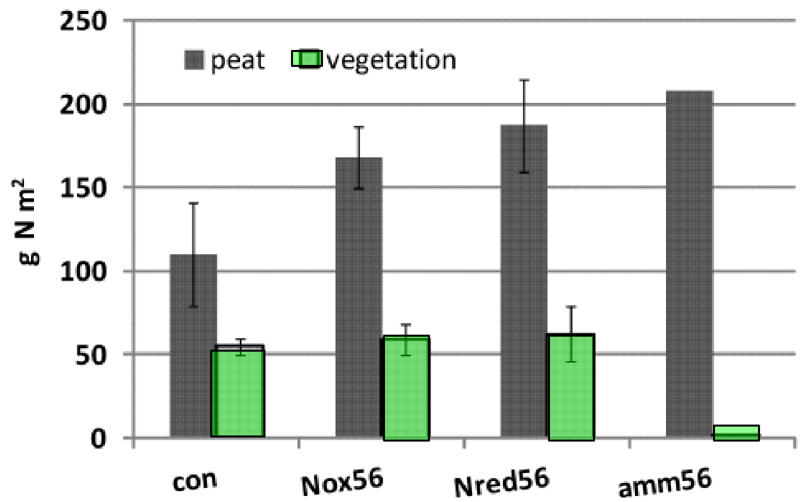
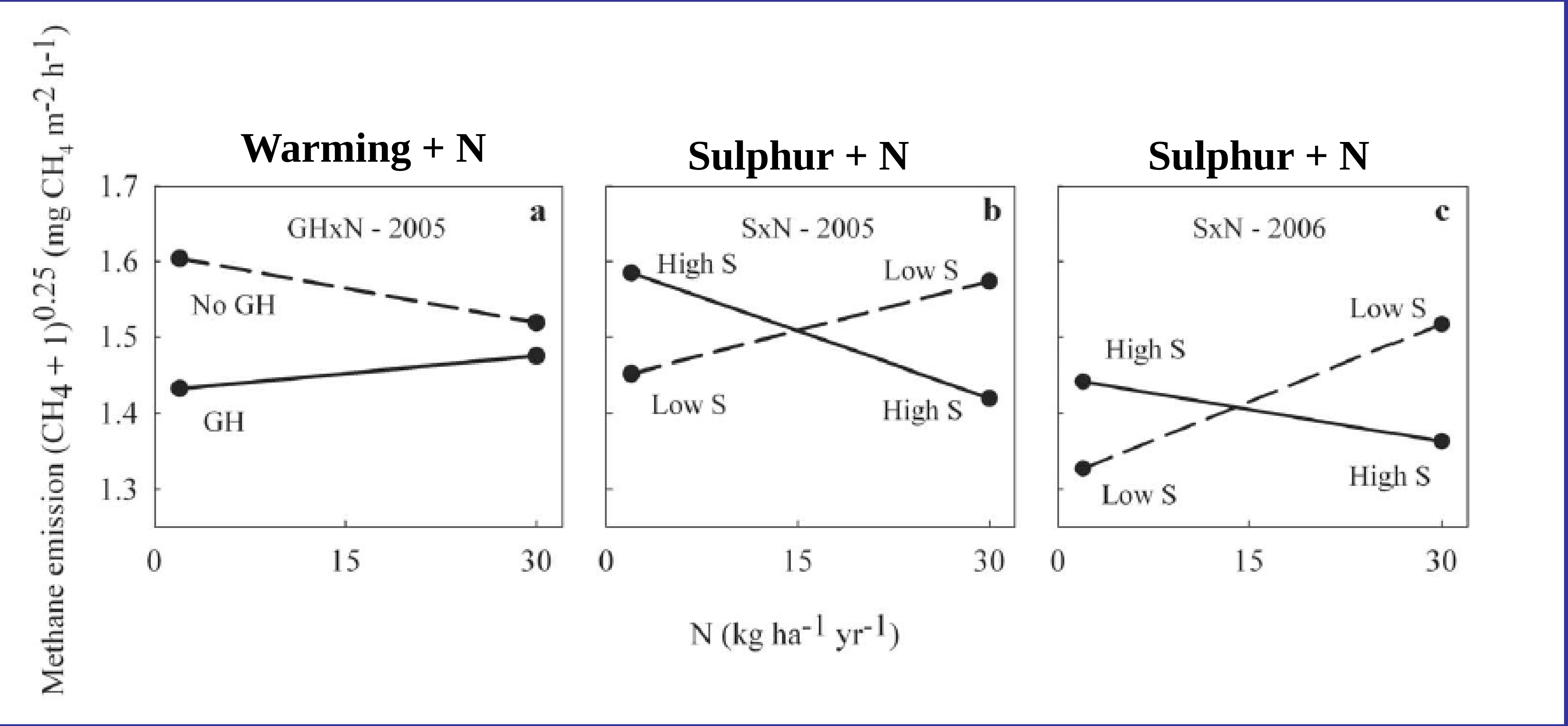


Fig. 7. Immobilization of N above and below ground, in the peat from the control (no added N) and N treated (oxidised (Nox), reduced (Nred) and ammonia (amm)) plots (~56 kg N ha^{-1} yr^{-1}) at Whim bog in 2009.

Sheppard et al. (2013) *Biogeosciences* 10: 1469.

CH_4 and N deposition: the role of pH, soil temperature and vegetation cover



Eriksson et al. (2010) *J. Geophysical Res.* 105: G04036

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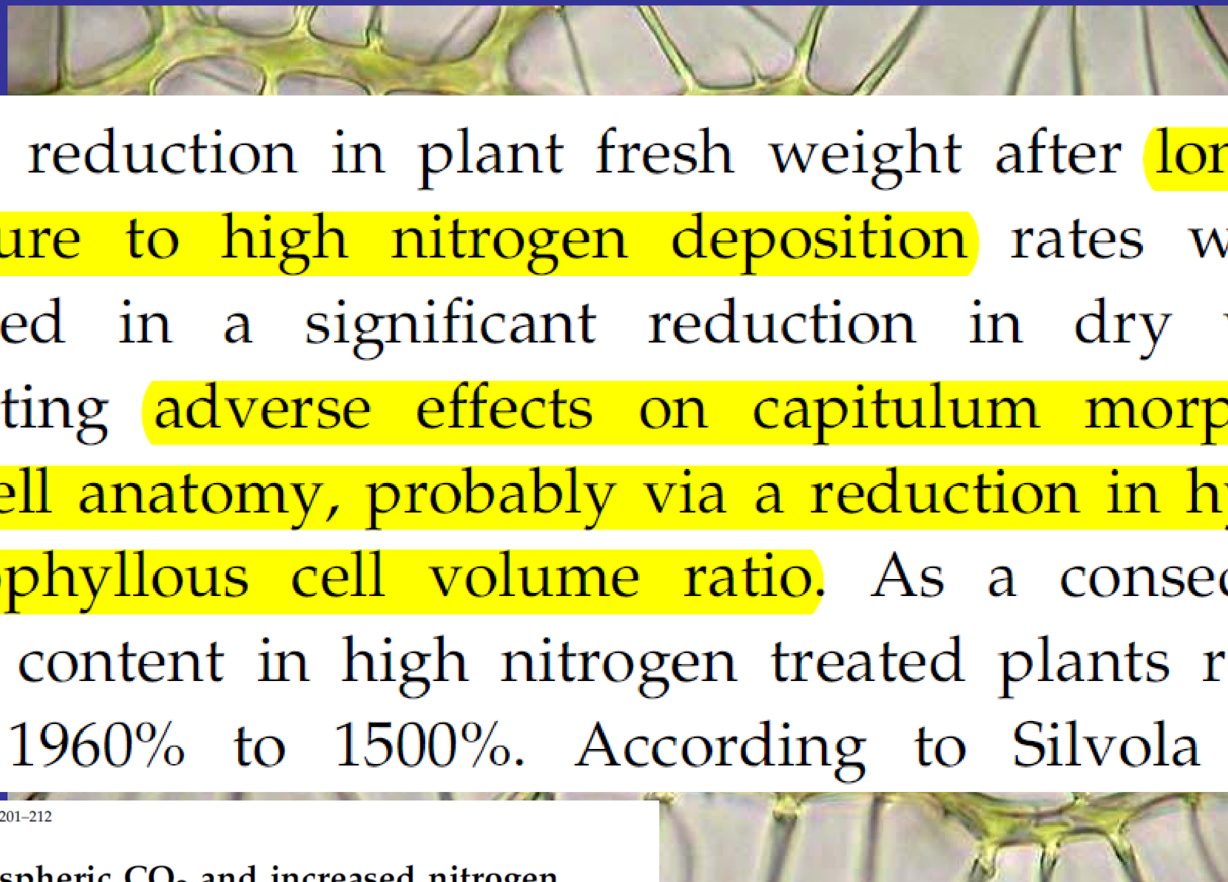
…at cellular level



The reduction in plant fresh weight after long-term exposure to high nitrogen deposition rates was not reflected in a significant reduction in dry weight, indicating adverse effects on capitulum morphology and cell anatomy, probably via a reduction in hyaline/chlorophyllous cell volume ratio. As a consequence, water content in high nitrogen treated plants reduced from 1960% to 1500%. According to Silvola (1990),

Global Change Biology (2000) **6**, 201–212

Elevated atmospheric CO_2 and increased nitrogen deposition: effects on C and N metabolism and growth of the peat moss *Sphagnum recurvum* P. Beauv. var. *mucronatum* (Russ.) Warnst

EDWIN VAN DER HEIJDEN, STEVEN K. VERBEEK and PIETER J.C. KUIPER
Department of Plant Biology, University of Groningen, Kerklaan 30, 9750 NN Haren, The Netherlands

Nutrient additions in pristine Patagonian *Sphagnum* bog vegetation

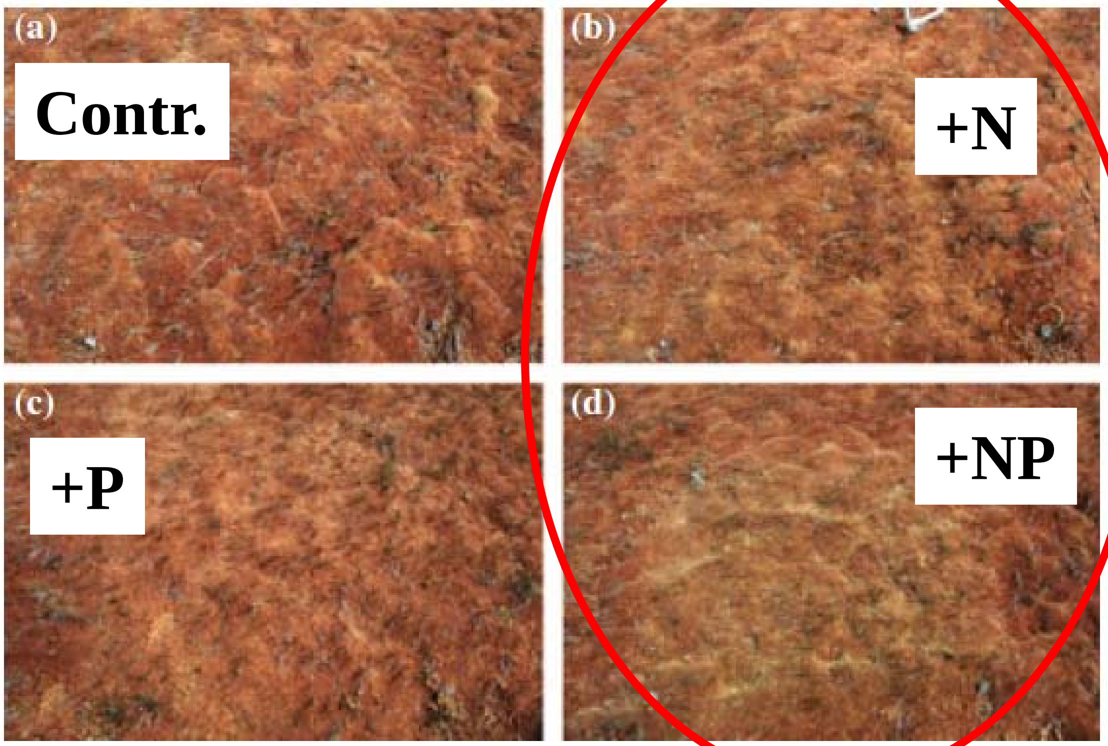
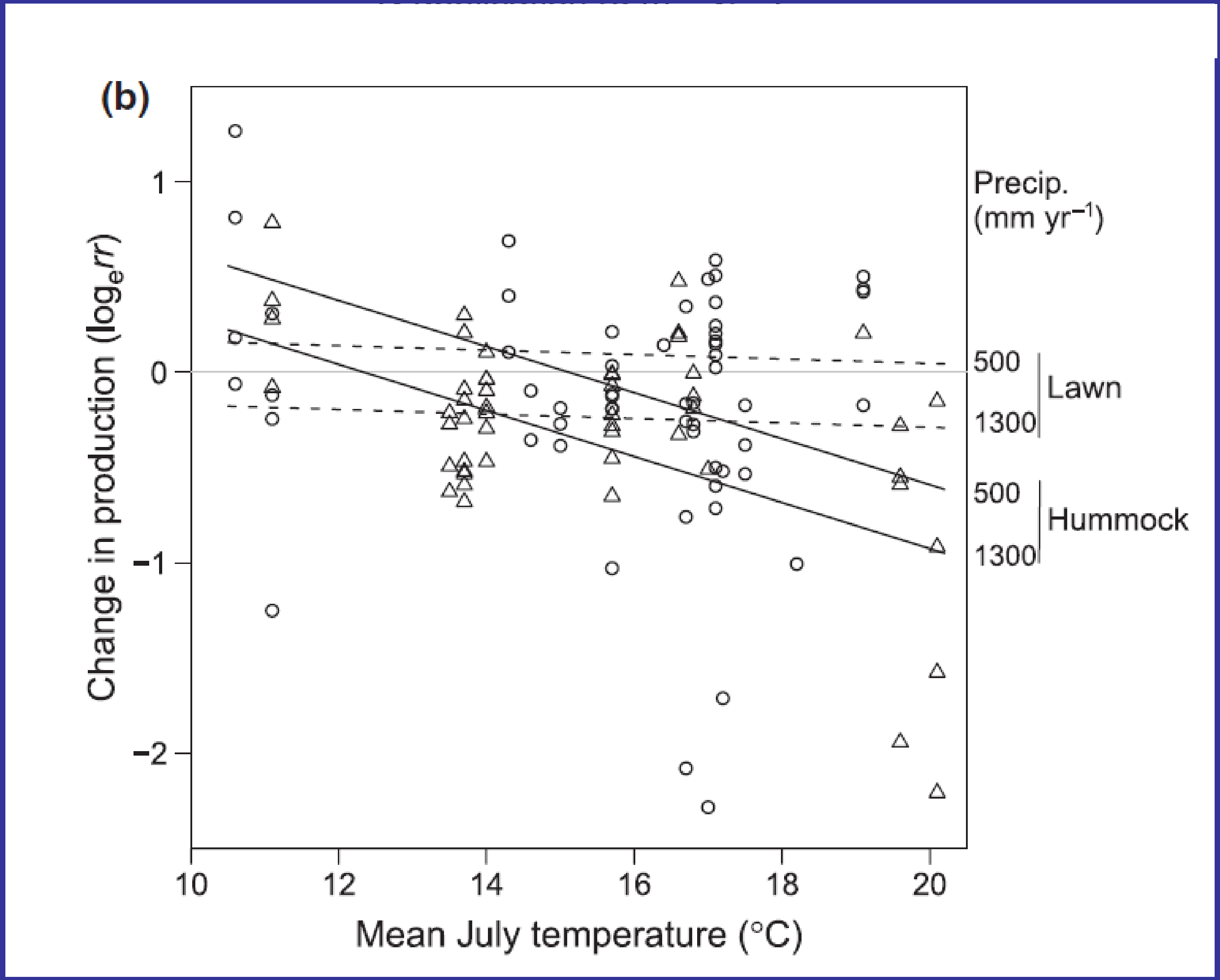


Fig. 2. Visible effects of treatments [Control (a), N-treatment (b), P-treatment (c), NP-treatment (d)] on *Sphagnum magellanicum*–dominated plots. Oblique photographs were taken after a dry spell in January 2009, when water levels were 35 cm below the surface, 15 cm lower than the average summer water level. For treatment details see Fig. 1.

Fritz et al. (2012) *Plant Biology* 14: 491.

…at community level



Limpens et al. (2011) *New Phytologist* 191: 496.

Who we are:

Manchester Metropolitan University, UK:
Prof Nancy Dise (Co-ordinator)
Dr Simon Caporn
Ms Daphne Lai
Dr Richard Payne
Dr James Rowson

Utrecht University, Netherlands:
Prof Jos Verhoeven
Dr Mariet Hefting
Dr Bjorn Robroek

University of Ferrara, Italy:
Dr Luca Bragazza

University of Bayreuth, Germany:
Dr Christian Blodau
Ms Yuanqiao Wu
Ms Kasia Zajac

Linköping University, Sweden:
Dr Per-Eric Lindgren
Prof Bo Svennsson
Ms Magalí Martí Generó
Ms Madeleine Larsson
Dr Carina Sundberg

Energy Research Centre, Netherlands:
Mr Albert Bleeker

To find out more about PEATBOG contact:

Daphne Lai
Research Administrator
Manchester Metropolitan University
Department of Environmental & Geographical Sciences
John Dalton Building
Chester Street
Manchester M1 5GD
United Kingdom

Email: D.Lai@mmu.ac.uk

Or visit our website at:
www.egs.mmu.ac.uk/peatbog

Or visit our interactive blog at:
www.peatbog.org

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http://www.eurobiodiversa.org/

PEATBOG

Pollution, Precipitation and Temperature Impacts on Peatland Biodiversity and Biogeochemistry

biodiversa

SIXTH FRAMEWORK PROGRAMME

Overview

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   3.2 Gas exchange

4. Interaction of N with climate warming

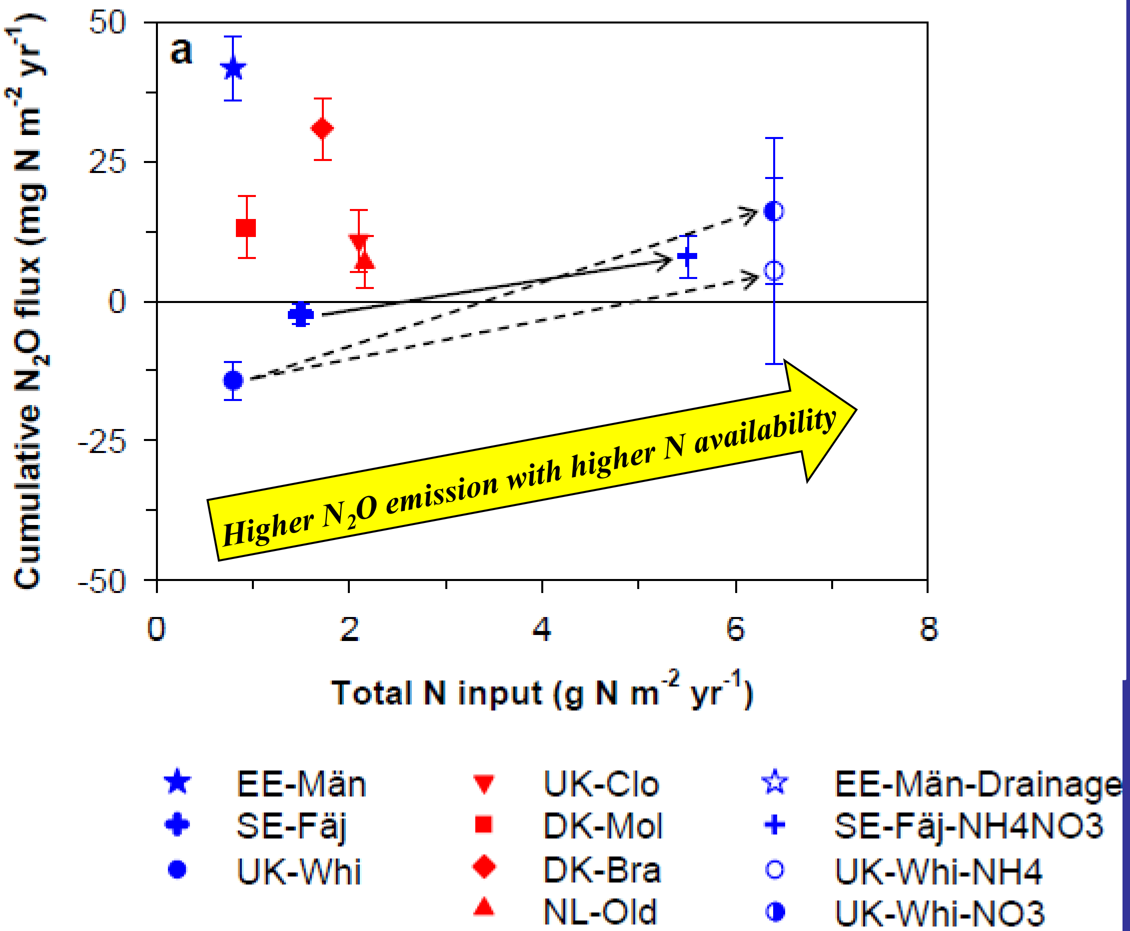
5. Open questions

1. N deposition effect on decomposition of old organic matter
2. N deposition effect on root architecture, morphology and functioning
3. N deposition effect on soil microbial structure and enzymatic activity

Luca Bragazza (luca.bragazza@wsl.ch)

N deposition and N_2O emission

M. S. Carter et al.: Synthesizing greenhouse gas fluxes



Carter et al. 2012: *Biogeosciences* 9: 3739