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6th International Symposium on Ecosystem Behaviour BIOGEOMON 2009

Conference Programme & Abstracts

Liisa Ukonmaanaho, Tiina M. Nieminen and Mike Starr (eds.)

SYKE

UNIVERSITY OF HELSINKI

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Title

BIOGEOMON 2009

6th International Symposium on Ecosystem Behaviour Conference Programme & Abstracts

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Abstract

The 6th international Symposium on Ecosytem Behaviour, BIOGEOMON 2009, is held at Helsinki, Finland, in June 29th –July 3rd 2009. BIOGEOMON's primary goals are to provide a forum for the dissemination and discussion of recent research findings, to explore future directions for biogeochemical research, and to foster interdisciplinary collaboration between researchers of all ages and countries. There were altogether over 400 registrated participants representing 32 different countries, including both internationally renowned scientists and postgraduate students.The meeting was hosted by The Finnish Forest Research Institute (Metla), the University of Helsinki, and the Finnish Environment Institute (SYKE) in association with the Czech Geological Survey (CR), Villanova University (USA), the University of Reading (UK) , the Geological Survey of Finland (GTK), and the Finnish Meteorological Institute (FMI). The information presented by the speakers during the meeting sessions, as well as by the numerous posters is collected into this publication in the form of abstracts. BIOGEOMON's emphasis is on biogeochemistry as an evolving and integrated discipline, including research at the watershed, landscape and global scales. Beside traditionally emphasized themes, topical issues are raised in each BIOGEOMON symposium. In Helsinki these issues are peatland biogeochemistry, environmental impacts of bioenergy production, atmosphere – forest interactions, and biogeochemistry of trace metals.

Keywords

biogeochemistry, watershed, monitoring, forest

Available at

http://www.metla.fi/julkaisut/workingpapers/2009/mwp128.htm

Replaces

Is replaced by

Contact information

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Other information

www.environment.fi/syke/biogeomon2009

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Welcome to BIOGEOMON 2009

Dear Colleagues,

Welcome to BIOGEOMON 2009, the Sixth International Symposium on Ecosystem Behaviour, jointly organized by the University of Helsinki, The Finnish Forest Research Institute, Metla and the Finnish Environment Institute, SYKE in association with the Czech Geological Survey (CR), Villanova University (USA), the University of Reading (UK), the Geological Survey of Finland, GTK, and the Finnish Meteorological Institute, FMI. This BIOGEOMON meeting is the sixth in the series; the previous five were held in Prague in 1987 and 1993, Villanova University in 1997, the University of Reading in 2002, and University of California (Santa Cruz, USA) in 2006. This year we are hosting over 400 participants from 32 countries around the world.

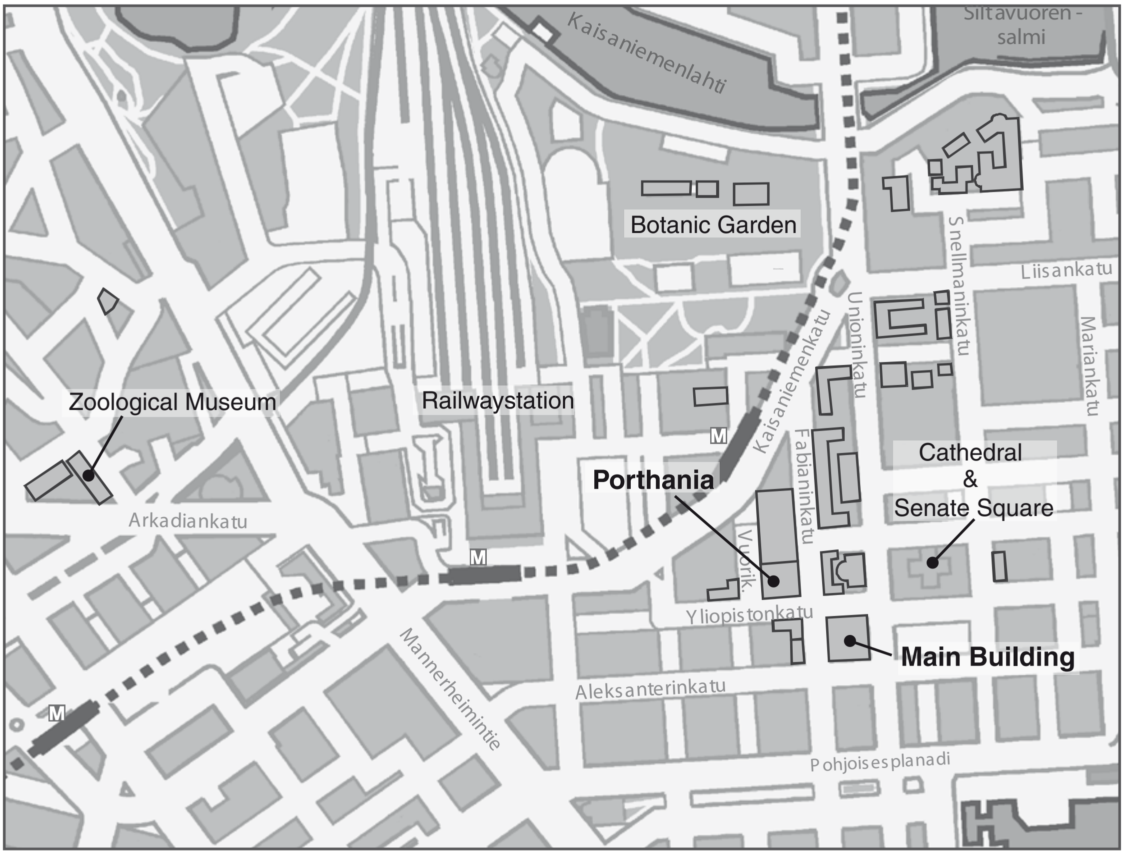
We hope you enjoy the symposium and your visit to Helsinki, the daughter of the Baltic Sea. The venue for BIOGEOMON 2009 is the Porthania Building, in the City Centre Campus of the University of Helsinki. Located in the heart of Helsinki, we hope it provides a wonderful setting for both our scientific and social programmes. Should you have any questions or need of assistance, do not hesitate to ask our staff and visit our information desk located in the lobby of the Porthania Building.

BIOGEOMON's emphasis is on biogeochemistry as an evolving and integrated discipline, including research at the watershed, landscape and global scales. BIOGEOMON's primary goals are to provide a forum for the dissemination and discussion of recent research findings, to explore future directions for biogeochemical research, and to foster interdisciplinary collaboration between researchers of all ages and countries. We are pleased to have attracted a large number of both internationally renowned scientists and postgraduate students, and hope this meeting will provide an opportunity to discuss and to meet and make acquaintances. Beside traditionally emphasized themes, topical issues are raised in each BIOGEOMON symposium. In Helsinki these issues are peatland biogeochemistry, environmental impacts of bioenergy production, atmosphere–forest interactions, and biogeochemistry of trace metals.

We would like to take this opportunity to thank the Plenary Speakers, the Session Chairpersons and Co-chairpersons for their tireless efforts in making BIOGEOMON 2009 such a success. We would also like to thank the generous financial support we have received from our sponsors. Finally, we wish you all a most pleasant and enjoyable stay in Helsinki, and hope you have a stimulating and rewarding meeting.

The BIOGEOMON 2009 Organizing Committee

City Centre Campus



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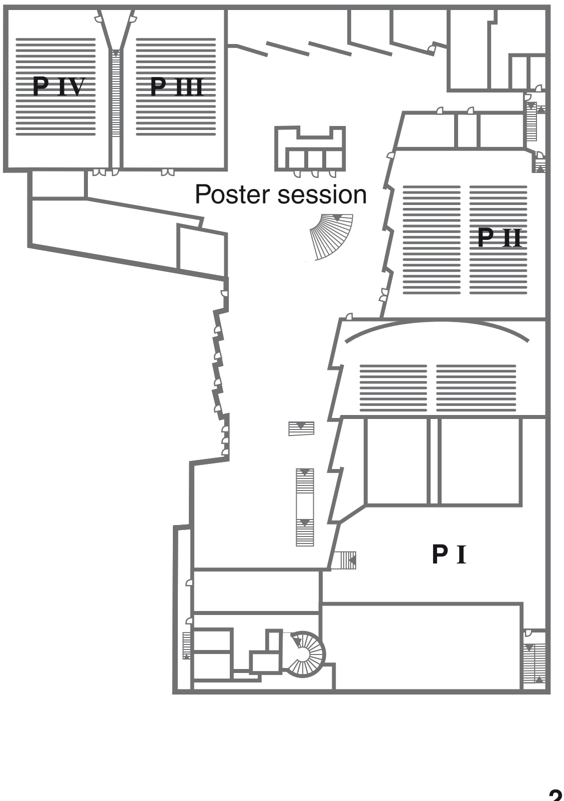

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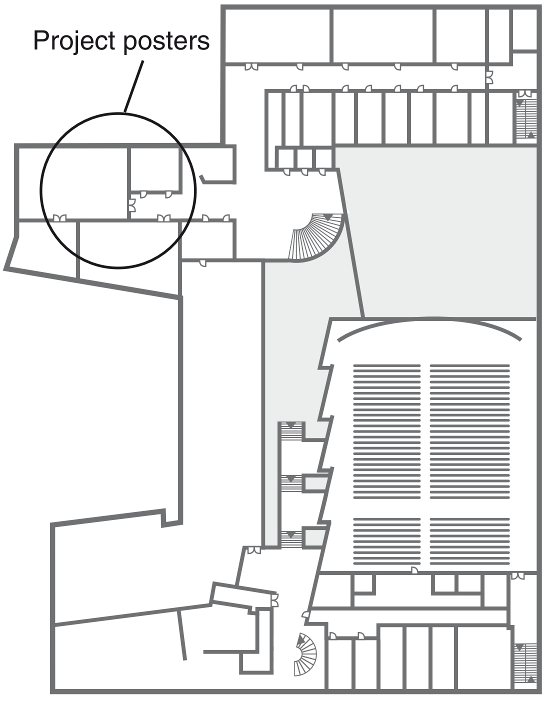

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Ministry of Agriculture and Forestry (MMM)
Maa- ja Vesitekniikan tuki (MVTT)

General information

CONFERENCE VENUE
University of Helsinki, Porthania Building,
Address: Yliopistonkatu 3

Registration and Information Desk in the Lobby
Registration is open as follows:
Monday 29th, June, 15.00–19.00
Tuesday 30th, June, 8.00–18.30
Wednesday 1st, July, 8.00–19.00
Thursday 2nd, July, 8.00–9.00
Friday 3rd, July, 8.00–17.00

Contact information during opening hours
Tel. +358 50 415 0177 (valid only 29.06.–30.06.2009)

Lecture Halls
Location: PI, PII, PIII and PIV (ground floor of Porthania Building)

Speakers' Room
Location: Room P728 (7th floor). Here speakers can test/edit their presentations.

Poster Exhibition
Location: Lobby at ground floor of Porthania Building

Coffee and lunches
All included in the participation fee. Coffee will be served during breaks in the lobby of the Porthania Building (ground floor) and lunches at lunchtime in the UniCafe Restaurant, in the University Main Building (Fabianinkatu 33, ground floor).

Luggage Storage
Room P133 (Ground floor).

Exhibition Area
Location: Lobby of Porthania Building

Laptops
There is a wireless internet access in the whole of the Porthania Building. Please ask for user IDs and passwords from the registration desk.

Internet Bar
Location: Room P318 (3rd floor)

FIELD TRIPS
Field Trips 1–4: Busses leave from the Senate Square at 9.00 am and return
to the same place 5-6 pm.
Field Trip 5: The cruise through the Helsinki Archipelago departs from the harbour Halkolaituri (Pohjoisranta 4), about 0.5 km east of the Senate Square at 9.00 am and returns to the same place after 3 hours.

Instructions for BIOGEOMON 2009 oral presentations

Note: It is intended that all oral presentations will be uploaded to the BIOGEOMON 2009 conference www-site. If you do NOT wish that your presentation is made available on the www-site, would you please inform us (registration desk) when you register.

Contributed speakers

- Contributing speaker's time is limited to 20 min, which includes discussion time (15 min talk + 5 min discussion). Speakers are kindly asked to keep their presentation within the given time!
- PowerPoint presentations are recommended (10–16 slides).
- Please, use PowerPoint 1997–2003 versions!
- Speakers should deliver and view/check their PowerPoint presentation in the Speaker's Room the previous day or at least 2 hours prior to the start of the respective sessions.
- Speakers should locate their session room in advance and be there at least 10 minutes prior the start of the session.
- Speakers should make themselves known to the chairperson before the beginning of the session.
- There will be prizes for the best student oral presentations.
- Name the presentation : session#_lastname_firstname.ppt, e.g. 10_starr_mike.ppt

Invited speakers

- Invited speaker's time is limited to 30 min, which includes discussion time (20–25 min talk + 5–10 min discussion). Speakers are kindly asked to keep their presentation within the given time!
- PowerPoint presentations are recommended.
- Please, use PowerPoint 1997–2003 versions!
- Speakers should deliver and view/check their PowerPoint presentation in the Speaker's Room the previous day or at least an hour prior to the start of the respective session.
- Name the presentation: session#_lastname_firstname_INV.ppt, e.g. 10_starr_mike_INV.ppt

Plenary speakers

- Plenary speaker's time is limited to 45 min, which also includes discussion time.
- PowerPoint presentations are recommended
- Please, use PowerPoint 1997–2003 versions!
- Speakers should deliver and view/check their PowerPoint presentation prior to the start of the plenary session.
- Name the presentation: lastname_firstname_PL.ppt, e.g. starr_mike_PL.ppt

Instructions for BIOGEOMON 2009 posters

- The area of the poster stand is 95 cm (wide) x 115 cm (height). You can make your posters to fit this size. The poster may be attached by thumb tacks, which will be made available.
- Besides the title, the poster should clearly indicate the author(s) and affiliation, but otherwise you are free to make the layout as you wish. Prizes will be awarded for the best student posters.
- Your poster will be issued with a number and this number will be used to identify your poster stand.

Social programme

Monday 29th of June 2009
Welcoming Party
Porthania Building, Lobby, ground floor
19.00–21.00
Address: Yliopistonkatu 3

Tuesday 30th of June 2009
Opening Ceremony
University Main Building, the Great Hall, 1st floor
09.00–c. 12.00
Address: Aleksanterinkatu 5

Tuesday 30th of June 2009
Helsinki City Reception
Helsinki City Hall
18.30-20.00
Address: Pohjoisesplanadi 11–13, (opposite the harbour Market Square)

Wednesday 1st of July 2009
Conference Banquet
Old Student House (Vanha Ylioppilastalo)
19.30-
Address: Mannerheimintie 3

Friday 3rd of July
Closing Ceremony
Porthania Building, PI
15.20–16.15

Arrival/departure at Helsinki-Vantaa international airport

Bus stops are situated in front of the International Terminal and Domestic Terminal.
Please take a look at Finavia map to find the right bus stop:
http://www.helsinki-vantaa.fi/files/efhk/EFHK_kartat/TaksitBussit_T2.pdf

Taxis are also available from outside the International and Domestic Terminals

Buses to / from Helsinki City
Helsinki City buses 415, 451, 615 to/from the main railway station; and bus 519 to/from Itäkeskus Metro Station (East Helsinki). For timetables visit transport website of Helsinki Metropolitan Area: http://www.ytv.fi/ENG/transport/timetables/
You can also take the Finnair City Bus to/ from downtown Helsinki from/to the airport. For timetables visit Finnair's website: http://www.helsinki-vantaa.fi/bybus

Information about Helsinki

Helsinki City Transport

Timetables and routes for bus connections in the Helsinki Metropolitan Area: http://www.ytv.fi/ENG
Telephone number for taxi: 0100 0700

Helsinki City Tourist & Convention Bureau
Pohjoisesplanadi 19, Helsinki,
Tel. +358 (0)9 3101 3300, Fax +358 (0)9 3101 3301, tourist.info@hel.fi
http://www.hel2.fi/tourism/EN/matko.asp
Tourist Information Offices are open: 2.5.–30.9.2009 Mon-Fri 9am-8pm, Sat-Sun 9am-6pm.

Information about the history, present day activities and public transport:
http://www.hel.fi/wps/portal/Helsinki_en/?WCM_GLOBAL_CONTEXT=/en/Helsinki/
Weather in Helsinki
Check what the weather is like in Helsinki: http://www.fmi.fi/en/index.html

Helsinki City Map
http://kartta.hel.fi/opas/main/?lang=en

BIOGEOMON 2009 – Helsinki, Finland, Speakers' Schedule

Monday, June 29

15.00-19.00	Registration	Porthania
19.00- 21.00	Welcoming Party	Porthania

Tuesday , June 30

09.00 -10.00	Opening Ceremony	The Great Hall, University Main Building
10.00-10.45	Plenary Lecture	The Great Hall, University Main Building
	Prof. Wolfgang Cramer	Potsdam Institute for Climate Impact Research, Germany
	Biosphere responses and feedbacks from the global to the continental scale – examples from recent vulnerability assessments	
11.00-11.45	Plenary Lecture	The Great Hall, University Main Building
	Prof. Cindy Prescott	University of British Columbia, Canada
	The decomposition process in forest ecosystems – what controls it? Can we change it?	
11.45 - 13.10	Lunch	UniCafe Restaurant, University Main Building

	Session 7 (PI)	**Session 14 (PII)**	**Session 2 (PIII)**	**Session 3 (PIV)**
	Carbon cycling in upland (well drained) soils	Biogeochemical aspects of ecosystem restoration and rehabilitation	Forest – atmosphere interactions and exchange: gases and aerosols	Hydrological drivers of ecosystem functioning
	Chaired by Egbert Matzner (University of Bayreuth, Germany) and co-chaired by Kate Lajtha (Oregon State University, USA)	Chaired by Nicholas Dickinson (Liverpool John Moores University, UK) and co-chaired by Ülo Mander (University of Tartu, Estonia)	Chaired by Michael Boy (University of Helsinki, Finland) and co-chaired by Janne Rinne (University of Helsinki, Finland)	Chaired by Melanie Vile (University of Villanova, USA) and co-chaired by Leon Lamers (University of Nijmegen, The Netherlands)
	Concurrent Sessions			
13.10 - 13.40	Högberg Peter: Forest soil respiration: Identifying sources and controls	Suman George: Soil carbon dynamics along a reconstructed Australian jarrah forest chronosequence following bauxite mining	Noe Steffen M: Biosphere-Atmosphere exchange of a mixed forest stand in a hemiboreal ecosystem at Järvselja, Estonia	Gibson John: Hydrologic variability, critical loads and relationship to wetland characteristics and permafrost melt in Western Canada: an isotopic perspective
13.40 -14.10	Nadelhoffer Knute: Long-term movements of 15N-labelled ammonium and nitrate additions to oak and pine forest plots constrain estimates of C sequestration resulting from atmospheric N deposition	Mitsch William J: Creating and restoring wetlands: Enhancing ecosystem services	Bonn Boris: Biosphere-atmosphere feedback processes within the climate system: Aerosol formation as potential stress result on boreal forests	Arvola Lauri: Do long-term patterns in pH and water colour in small boreal lakes differ between lakes of varying hydrological and landscape settings?
14.10 - 14.30	Haei Mahsa: DOC dynamics at a boreal riparian zone: Implications of winter processes	Ritter Eva: The role of afforestation in soil restoration: effects on soil nutrients in degraded volcanic soils on Iceland	Blei Emanuel: Methyl halide emissions from a SE Asian tropical rainforest	Allott Tim EH: Eroding blanket peat systems as analogues for long-term water table lowering: impacts on dissolved organic carbon
14.30-14.50	Karhu Kristiina: Temperature sensitivity of soil organic matter decomposition – implications for soil carbon storage in a warming climate	De Schrijver An: Recovery of post-agricultural forest: Tree species determines soil properties and possibilities for ecosystem restoration	Moore Tim: Atmospheric Exchanges of N_2O and CH_4 with Deciduous and Boreal Forest Soils in Eastern Canada	Ro-Poulsen Helge: Responses of carbon and water fluxes following drought events in combinations with warming and elevated CO_2
14.50-15.10	Kammer Adrian: Wintertime C-fluxes in a forest soil of the Swiss Jura: clues from a ^{13}C labeled litter experiment	Beesley Luke: Experimental manipulation of urban soils: stability and mobility of heavy metals and arsenic in relation to soil carbon	Kupper Priit: Free air humidity manipulation (FAHM) in a deciduous tree canopy – experimental set-up and some preliminary results	Buckeridge Kate: Spring flush of soil nutrients in low arctic tundra and the influence of snow depth
15.10-15.30	Break			
15.30-15.50	Park Ji-Hyung: Differential responses in hydrologic export of particulate and dissolved organic carbon from a mountainous watershed to rainfall variability and extremes	Nieminen Tiina M: Biowaste and native woody plants in remediation of Cu-Ni polluted forest soil	Wuyts Karen: Impact of forest type and edge structure on patterns of throughfall deposition in forest edges	Laudon Hjalmar: Linking the Terrestrial and Aquatic System at Various Scales in a Heterogeneous Boreal Landscape: A Tool to Assess the Vulnerability of Surface Waters
15.50-16.10	Kothawala Dolly: Controls on the adsorption and fate of dissolved organic carbon within forested mineral soils	Van Nevel Lotte: Tree species affect soil metal redistribution: implications for phytoremediation	Aaltonen Hermanni: BVOC emissions of fungal species occurring in boreal forest soils	Leuzingen Sebastian: Rainfall distribution is the main driver of runoff under future CO_2-concentration in a temperate deciduous forest
16.10-16.30	Don Axel: Controls on DOC fluxes in temperate grasslands	Zhang Li: Impact of hydrological process on ecosystem services in mitigation wetlands: Case studies in Ohio, USA	Karlsson Per Erik: Extensive biomass burning in Russia during spring 2006 resulted in high deposition of ammonia in throughfall over northern Sweden	Linkosalo Tapio: Predicting the probability of severe droughts under changing climate
16.30-16.50	Wunderlich Steve: Spatial variation of CO_2 efflux and partitioning of soil respiration at Bavarian forest sites	Richardson Curtis: Restoring biogeochemical functions in highly degraded riparian wetlands: A comparison of degraded ecosystem responses	Glatzel Stephen: Improving regionalisation of CO_2 efflux with estimated root biomass distribution maps - failures and achievements	Ojala Anne: Effects of extreme rain events on carbon gas fluxes from boreal lakes

16.50-18.00	Poster Session	Porthania Lobby
18.30-	Reception at Helsinki City Hall	

Wednesday, July 1

08.45-09.30 Plenary Lecture Porthania, PI

Prof. Pekka Kauppi University of Helsinki, Finland

Returning the ability of forests to capture and store carbon. How much and for how long?

09.30- 09.50 Break

	Session 6 (PI)	Session 4 (PII)	Session 10 (PIII)	Session 8 (PIV)
	Biogeochemistry of peatlands	Linkages between biogeochemical cycles	Microbial/rhizosphere dynamics	Experimental manipulations of ecosystems
	Chaired by Tim Moore (McGill University, Canada) and co-chaired by Raija Laiho (University of Helsinki, Finland)	Chaired by Heleen de Wit (Norwegian Institute of Water Research, Norway) and co-chaired by Ed Rowe (Centre for Ecology and Hydrology, UK)	Chaired by Heljä-Sisko Helmisaari (Finnish Forest Research Institute, Finland) and co-chaired by Krista Lõhmus (Tartu University, Estonia)	Chaired by Claus Beier (Risø National Laboratory, Denmark) and co-chaired by Filip Moldan (Swedish Environmental Research Institute, Sweden)
	Concurrent Sessions			
09.50- 10.20	Martikainen Pertti: Atmospheric impact of nitrogen turnover processes in northern peatlands	Hagedom Frank: Interactions between carbon and nitrogen cycling	Tibbett Mark: The curious effects of mycorrhizas on the plants of the unique Jarrah forests of Western Australia	Larsen Klaus S: CLIMAITE – consequences of multifactor climate change on the carbon and nitrogen cycles
10.20-10.40	Limpens Juul: How atmospheric N deposition affects peatland vegetation composition, production and Sphagnum N concentration: an analysis of 30 fertilization studies across the Northern Hemisphere	Zetterberg Theresa: Decreasing concentrations of dissolved organic carbon (DOC) in the soil solution in southern Sweden during the 1990's	Berthrong Sean: Afforestation, microbial metagenomics, and biogeochemistry in Southern South American Grasslands	Matzner Egbert: Effects of experimental soil frost on fluxes of C and mineral elements in a temperate forest soil
10.40-11.00	Roobroeck Dries: Dynamics of nitrate limitation on gaseous nitrogen exchanges from pristine peatlands	Kaste Øyvind: Possible linkages between surface water stoichiometry and nuisance growth of the aquatic macrophyte Juncus bulbosus	Boeckx Pascal: Seasonal variation of the abundance and carbon assimilation activity of rhizosphere soil microbial communities in a temporal wetland	SanClements Michael D: Decadal responses in stream and soil Ca and Mg in an experimentally acidified watershed in the eastern United States
11.00-11.20	Bragazza Luca: Seasonal nutrient partitioning between microbes and plants in peat bogs	Piirainen Sirpa: Effects of harvesting and site preparation on nitrogen and carbon biogeochemistry in boreal forests	Ostonen Ivika: Fungal species-specific impacts on ectomycorrhizal root traits in Alnus	Navrátil Tomáš: Seasonal and long-term variation of stream water chemistry at Bear Brook Watershed, Maine USA
11.20-11.40	Strack Maria: Size and spatial variability of subsurface peatland methane stock	Clark Joanna: Link between increased DOC in freshwaters and decline in atmospheric sulphur deposition: Evidence of soil processes from laboratory experiments	Heinonsalo Jussi: The carbon balance of Scots pine, Norway spruce and silver birch in changing climate: the effects of temperature and ectomycorrhizal fungal communities	Duan Lei: Contribution of simulated nitrogen deposition to forest soil acidification in area with high sulfur deposition
11.40-12.00	van Winden Julia F: Assessing global microbial methane oxidation in peat moss through biomarker analyses and compound specific isotope labelling	Xingkai Xu: Dissolved N_2O and CO_2 concentrations in soil solutions under a temperate old-growth forest and their associated mechanisms	Leski Tomasz: Ectomycorrhizal community structure on roots of trees planted in the mixture of soils and ashes from the thermal power plant	Rejmánková Eliška: Nutrient enrichment in tropical wetlands: ecosystem changes after six years of phosphorus addition

12.00-13.00 Lunch

13.00-14.00 Plenary Lecture Porthania, PI

Prof. Kevin Bishop Swedish University of Agricultural Sciences, Sweden

Water through the looking glass of landscapes: can we see the future in the different climate?

Concurrent Sessions

14.00-14.20	Larmola Tuula: Role of Sphagnum mosses in methane cycling of a boreal mire	Merilä Päivi: Relationships between needle nutrient composition in Scots pine and Norway spruce stands and the respective concentrations in the organic layer and in percolation water	Nietfeld Heino: Modeling of the mineral nutrient uptake of forest tree roots as affected by the ion dynamics in the rhizosphere	Rask Martti: Does thermocline change affect methyl mercury concentrations in fish in small boreal lakes?
14.20-14.40	Gunnarsson Urban: The function of ombrotrophic bogs as active carbon sequesters under different environmental conditions	Fleischer Siegfried: An interaction between N and C cycling with consequences for the global carbon budget	Huygens Dries: Microbial community functioning drives nitrogen biogeochemistry in drought stressed pastures	Lajtha Kate: Detrital inputs influence stabilization of soil organic matter
14.40-15.00	Dinsmore Kerry: Carbon and GHG budgets of an ombrotrophic peatland – importance of surface drainage water as a flux pathway	Vanguelova Elena: Impact of N deposition on soil and tree biochemistry in both broadleaved and coniferous stands in the UK	Aponte Cristina: Microbial C, N and P in a Mediterranean oak forest soil: influence of abiotic conditions and canopy composition	Kitzler Barbara: Tree Girdling as well as Nitrogen Fertilization Increase N_2O-Formation and Decrease CH_4-Uptake in a Beech Forest

15.00-15.20 Break

	Session 6 (PI)	**Session 4 (PII)**	**Session 5 (PIII)**	**Session 11 (PIV)**
	Biogeochemistry of peatlands	Linkages between biogeochemical cycles	New insights into nitrogen cycling	Innovative uses of isotopes and tracers
	Chaired by Tim Moore (McGill University, Canada) and co-chaired by Raija Laiho (University of Helsinki, Finland)	Chaired by Heleen de Wit (Norwegian Institute of Water Research, Norway) and co-chaired by Ed Rowe (Centre for Ecology and Hydrology, UK)	Chaired by Christine Goodale (Cornell University, USA) and co-chaired by Bridget Emmett (Centre for Ecology & Hydrology, Bangor, Wales)	Chaired by Martin Novák (Czech Geological Survey, Czech Republic) and co-chaired by Bernhard Mayer (University of Calgary, Canada)
	Concurrent Sessions			
15.20-15.50	Lamers Leon PM: The restoration of minerotrophic peatlands based on biogeochemical insights	Kopáček Jiří: Long-term trends in aluminium export from acidified, nitrogen-saturated, forest catchments and its impact on phosphorus cycling in lakes	Rütting Tobias: New insights on N transformations by 15N tracing technique	Schiff Sherry: Going down the river: Isotopic insights into the biogeochemical cycling and ecology along an impacted river in southern Canada
15.50-16.10	Kolka Randall: Controls on long-term increases in TOC concentrations and fluxes in peatland catchments in northern Minnesota, USA	Hruška Jakub: Increased dissolved organic carbon (DOC) in Central European streams is generated by ionic strength reductions rather than decreasing acidity or climate change	Goodale Christine: New estimates of nitrogen deposition effects on forest carbon storage	Alewell Christine: Stable carbon and oxygen isotopes as an indicator for soil degradation
16.10-16.30	Rowson James: The effects of burning on long term gaseous and fluvial carbon fluxes, and the use of fire and heather cutting as a carbon management techniques	Bünemann Else K: Are soil organic phosphorus and carbon cycling linked?	Zeller Bernd: Long term fate of litter ^{15}N in forest soils: mineralization vs. stabilization	Gebauer Gerhard: The fate of N_2O in a Norway spruce forest soil investigated by concentration and isotope profiles
16.30-16.50	Blodau Christian: Impact of small-scale changes in soil moisture on redox dynamics and trace gas emissions in mesocosmos of alpine fen and northern bog peat	Norton Steve: Evolution of controls on phosphorus availability in aquatic ecosystems: peri-glacial to recent times	Winder Richard: Quantification of nitrogen cycling functional gene abundance in soil of variably-retained stands of Douglas-fir (Pseudotsuga menziesii ssp. menziesii (Mirb.) Franco)	Gicquel Aurélien: Visualization and quantification of the C-N-S transfers by soil engineers using NanoSIMS
16.50-18.30	Poster Session	Porthania Lobby		
19.30	Banquet	Old Student House “Vanha”		

Thursday, July 2

09.00-c.18.00	Field Trips

Friday, July 3

08.45 -09.30	PlenaryLecture	Porthania, PI
	Prof. Joshua Schimel The biogeochemistry of drought	University of California, USA
09.30 -09.40	Break	

	Session 9 (PI)	**Session 1 (PII)**	**Session 12 (PIII)**	**session 13 (PIV)**
	Trace element biogeochemistry and ecosystem impact	Integrated monitoring and modelling	Bioenergy production impacts on biogeochemistry	Archives of past environmental change
	Chaired by Tiina Nieminen (Finnish Forest Research Institute, Finland) and co-chaired by Ping Lu (EWL Sciences Pty Ltd, Australia)	Chaired by Paul Whitehead (University of Reading, UK) and co-chaired by Jack Cosby (University of Virginia, USA)	Chaired by Andrew M. Gordon (University of Guelph, Canada) and co-chaired by Göran Berndes (Chalmers University of Technology, Sweden)	Chaired by Richard Bindler (Umeå University, Sweden) and co-chaired by Harald Biester (Technical University Braunschweig, Germany)
	Concurrent Sessions			
09.40 - 10.10	Rinklebe Jörg: Fate of metals in frequently flooded soils	Moldan Filip: 100 000 lakes in Sweden: monitoring data and the MAGIC library of 1200 modeled lakes used to assess past and future lake chemistry	Hazlett Paul W: Bioenergy production, site productivity and forest sustainability	Martínez-Cortizas Antonio: Spatial variability in Hg and Pb accumulation in the Chao de Lamoso bog (Xistral Mountains, NW Spain)
10.10-10.30	Alekseeva-Popova Natalia: Biogeochemistry of trace elements in tundra ecosystems of Polar Urals	Evans Chris: Removing the disconnect between maps and time series: can long-term monitoring data be used more effectively as a basis for model upscaling?	Vanguelova Elena: Long term effects of whole tree harvesting on soil nutrient sustainability in the UK	Biester Harald: Modelling Past Mercury Deposition from Peat Bogs – The Influence of Peat structure and 210Pb mobility
10.30 -10.50	Burton Andrew: Trace metals in small Irish lakes	Thouvenot-Korppoo Marie: Modelling of denitrification flux over a whole drainage network	Luiro Jukka: Nutrient removal in logging residues in thinnings in boreal forests: long-term impact on tree growth	Saether Geir Henrik: Accumulation of trace metals in lakes with different catchment area and input of organic matter

10.50-11.10	Sjöstedt Carin: Iron and aluminium phases in softwater lakes: identity and significance for copper binding	De Wit Heleen: A carbon budget of a low-productive boreal forested catchment	Posch Maximilian: Biofuels and sustainable forest ecosystems: evaluating biomass removal under climate change and atmospheric deposition	Hermanns Yvonne: Influence of peat decomposition on distribution of major and trace elements in peat
11.10-11.30	Break			
11.30-11.50	Vymazal Jan: Trace elements in sediments from constructed wetlands treating municipal wastewater	Jurasinski Gerald: Net ecosystem exchange in a rewetted, episodically flooded brackish fen - modelled potential vs monitored field data	Uri Veiko: Nitrogen budget of short-rotation grey alder (Alnus incana) stand on abandoned agricultural land	Cooke Colin: Lake-sediment archives of preindustrial mercury pollution in the Andes
11.50-12.10	Lambrechts Thomas: Methods comparison of heavy metal bioavailability assessment in contaminated soils from a former mining area (La Union, Spain)	Worrall Fred: The Flux of Nitrate from Great Britain 1974 – 2005 in the context of the terrestrial nitrogen budget of Great Britain	Hruška Jakub: Biomass removal will significantly decrease soil base saturation in acidified ecosystems	Zaccone Claudio: Investing the role of humic acids from ombrotrophic peat in the accumulation of Pb and Hg along a Swiss bog profile
12.10-12.30	Naftz David L: Diel Mercury-concentration variations in wetlands adjacent to great Salt Lake, Utah, USA	Granlund Kirsti: Inorganic nitrogen leaching from two Finnish research catchment under future climate conditions	Hazlett Paul W: Biomass removal from jack pine forests: impact of harvesting levels on nutrient pools across a gradient in site productivity	
12.30-13.30	Lunch			
	Session 9 (PI)	**Session 1 (PII)**	**session 5 (PIII)**	**session 11 (PIV)**
	Trace element biogeochemistry and ecosystem impact	Integrated monitoring and modelling	New insights into nitrogen cycling	Innovative uses of isotopes and tracers
	Chaired by Tiina M. Nieminen (Finnish Forest Research Institute, Finland) and co-chaired by Ping Lu (EWL Sciences Pty Ltd, Australia)	Chaired by Paul Whitehead (University of Reading, UK) and co-chaired by Jack Cosby (University of Virginia, USA)	Chaired by Christine Goodale (Cornell University, USA) and co-chaired by Bridget Emmett (Centre for Ecology & Hydrology, Bangor, Wales)	Chaired by Martin Novák (Czech Geological Survey, Czech Republic) and co-chaired by Bernhard Mayer (University of Calgary, Canada)
	Concurrent Sessions			
13.30-13.50	Ettler Vojtěch: Experimental in situ transformation of smelter fly ash in acidic forest soils	Kram Pavel: Stream benthic macroinvertebrates of nine selected catchments of the Czech GEOMON network	Andresen Louise C: Nitrogen uptake in temperate heath vegetation and soil microbes is influenced by elevated temperature, CO_2 and drought	Novák Martin: Vertical changes in $\delta^{13}C$ of chemically separated carbon forms in peat cores from Central and Northern Europe: A temperature effect
13.50-14.10	Dominiguez Maria T: Soil-plant interactions in metal polluted Mediterranean woodlands	Lundin Lars: Forest ecosystem leaching in a climate change perspective for the Nordic region	Rosamond Madeline: N-cycling in a large eutrophic river, Canada: sources and processes	Bottrell Simon: Insights into sulfur cycling in lowland peats from novel sulfur isotope tracer experiments
14.10-14.30	Pruvot Christelle: Heavy metals in topsoils of woody habitats around a former lead smelter in the North of France	Futter Martyn: Linking litter to lakes: A modelling study of the effects of climate change on carbon cycling and lake thermal properties in a boreal catchment	Evans Chris: Nitrogen saturation in upland catchments – what have we learned in the last 15 years?	Mayer Bernhard: The impact of land use on sources of riverine sulfate, nitrate and chloride in a large watershed in western Canada
14.30-14.50	Almeida Marisa: Influence of surfactants on the Cu phytoremediation potential of a salt marsh plant	Koseva Ina: Assessing critical load and exceedance in south-central Ontario: application of new weathering determination methods to the Steady-State Mass Balance and MAGIC models	Dillon Peter: Organic nitrogen cycling in lakes and catchments	Giesler Reiner: δ^{34}S-DOS as a tracer to separate different sources of DOM in freshwater and marine ecosystems
14.50-15.10	Alirzayeva Esmira: Lichens as bioindicators of air heavy metal pollution in city stands	Whitehead Paul: Dynamic modelling of the potential impacts of climate change on water quality and ecology in six UK rivers	Dise Nancy: Modelling Controls on Nitrogen Leaching from European Forests using Partitioning Tree Analysis	Wagener Angela: Mapping Provenance of Organic Carbon and Nitrogen in Guanabara Bay by Means of $\delta^{13}C$ and $\delta^{15}N$ in Particulate Matter and End Members
15.10-15.20	Break			
15.20- 16.15	Closing Ceremony	Porthania, P1		

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2. Forest – atmosphere interactions and exchange: gases and aerosols

3. Hydrological drivers of ecosystem functioning

4. Linkages between biogeochemical cycles

5. New insights into nitrogen cycling

6. Biogeochemisty of peatlands

7. Carbon cycling in upland (well drained) soils

8. Experimental manipulations of ecosystems

9. Trace element biogeochemistry and ecosystem impact

10. Microbial/rhizosphere dynamics

11. Innovative uses of isotopes and tracers

12. Bioenergy production impacts on biogeochemistry

13. Archives of past environmental change

14. Biogeochemical aspects of ecosystem restoration and rehabilitation

Plenary speaker

Litter Decomposition in Forest Ecosystems: What controls it? Can we change it?

Cindy E. Prescott

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In the last decade, we have witnessed a tremendous amount of research on the topic of litter decomposition, driven by recognition of the pivotal role that this process plays in carbon fluxes, hence global climate change. Findings from this plethora of research have challenged some of our thinking about the factors that control rates of litter decomposition (or at least the manner in which they influence decay rates), which has important implications for strategies for sequestering additional carbon in forest soils. Perhaps of greater importance in predicting global carbon budgets, many studies have examined the proportion of litter that is transformed to more stable organic matter (rather than being decomposed), the fate of this material, and the factors that determine its rate of decay.

With respect to litter quality, evidence has demonstrated that lignin and nitrogen contents, while useful for predicting relative decay rates of different litter types, do not control rates of decomposition as directly as we had thought. Nitrogen does appear to stimulate early decay of litters (as long as carbon is readily available), but often leads to greater stabilization into humus through a combination of chemical reactions and enzyme inhibition. While the amount of acid-unhydrolyzable residue remaining after proximate analysis is still a useful measurement for predicting litter decay rates, we now recognize that much of this material in not actually lignin, and that lignin *per se* is not as recalcitrant as formerly thought. Transformations of materials into increasingly recalcitrant compounds through microbial and biochemical reactions appear to play a greater role in determining the amount of stable organic matter produced, rather than initial litter quality. Finally, viewing litter quality through the lens of plant functional traits has provided a refreshing counterpoint to purely chemical indicators, and an effective means of predicting relative rates of decomposition of litters.

The results of a number of cross-biome litter decomposition studies have provided insights into the influences of various climatic and litter quality variables on decay rates, and the scales at which they operate. Meta-analysis of data from hundreds of litterbag studies indicates that the primary influence of climate is temperature, and that it operates largely by determining the plant forms present, which (through “afterlife effects”) determines the decomposability of the litter. The large amount of data on short-term litter decay rates now available should allow us to adequately predict early-stage decomposition rates in most ecosystems without need for additional litterbag studies. Late-stage decay remains an enigma, and we need to better understand the factors that determine how much of litter will enter the slow stage of decay and how fast it will decay thereafter. There is evidence that 20-30% of the initial mass of litter is transformed to humus rather than decomposition in northern forests (and probably in other less favourable conditions), and will remain as surface organic matter for decades or centuries. A critical gap in our understanding of long-term decomposition and stabilization of organic matter is our currently poor understanding the effects of soil fauna. Several recent studies have indicated that soil faunal activities actually make litter more recalcitrant, and contribute to stabilization of organic matter in soil, contrary to earlier thinking about their effects. Finally, new techniques in characterization of humus and soil organic matter are providing much-needed insights into the chemical nature of humus and soil organic matter, the transformations that create it, and its sensitivity to climatic factors.

The implications of these findings for development of strategies such as fertilization, site preparation, assisted migration, and genetic manipulation to manage carbon fluxes from forests will be discussed.

Plenary speaker

Returning the ability of forests to capture and store carbon: How much and for how long?

Pekka Kauppi

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The evolution of woody plants has solved the problem of CCS (carbon capture and storage) in an elegant manner. Photosynthesis is the process for “capture”, and the subsequent formation of durable cells provides the “storage”. Chemical engineers of contemporary time cannot yet challenge the “organic CCS” of woody plants in terms of cost-efficiency or sequestration volume. - Research on CCS is a multi-billion industry aiming at reducing fossil emissions of CO_2, especially those from coal-fired power plants.

The expansion of woody biomass that is, organic CCS, sequesters approximately 400 million tons CO_2 annually from the atmosphere in the European Union. This is five times more than the fossil CO_2 emissions of Finland. It has been debated in scientific literature whether such a removal of carbon dioxide is only a temporary phenomenon, a process merely to “buy time” for implementing efficient reductions of fossil CO_2 emissions. There are several empirical, theoretical and modelling approaches, which can address this important question.

First, it is important to understand the historical evolution of “organic CCS”, such as the one within the EU. The *historical evolution* of biomass carbon sink is the main scope of this presentation. Forest transition, a concept introduced by Alexander Mather (1992) and Alan Grainger (1995), is a key to understanding carbon sequestration in forests in the recent past.

Climate change itself appears as a main threat to future evolution of organic CCS. A recent publication presented an alarming message: The critical role of forests as massive “sinks” for absorbing greenhouse gases is *“at risk of being lost entirely”* to climate change-induced environmental stresses that threaten to damage and even decimate forests worldwide. The report was presented at a session of the United Nations Forum on Forests (UNFF),which took place 20 April-1 May 2009 at the UN Headquarters in New York City.

Given the impact of green house gases on the radiative forcing of the atmosphere, the Planet will either survive or perish. Survival scenario implies an expansion of the global forest biomass; while losses of biomass, in response to a changing climate, would indicate a final tail spin of the biosphere. If the survival scenario becomes reality, massive co-benefits in terms of provisioning, regulating, cultural and supporting services of ecosystems will follow.

Plenary speaker

The Biogeochemistry of Drought

Joshua Schimel

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The world is a dry place: roughly 1/3 of the terrestrial land surface has arid, semi-arid, or Mediterranean climates. Climate models also suggest that drought is likely to become more prevalent with climate warming. However, the biogeochemistry of the dry season has usually been studied only implicitly – as “antecedent conditions” that regulate the pulses of biological activity that occur with the following rains. However, rarely have the biogeochemical processes that occur during the dry season been studied explicitly to understand what creates the conditions at the beginning of the wet, “growing season.”

In California, summer can go for 6 months without any rain and temperatures that can exceed 40 °C. We naturally expected, therefore, that the winter growing season would be a season of high microbial biomass and activity but summer was a period of dormancy and mere survival. Native grasses senesce, some shrubs are drought-deciduous, and microbial respiration rates drop to levels of 0.1 to 0.3 g C m^{-2} d^{-1} as soils dry to as low as 5% H_2O.

Surprisingly, however we observed patterns distinctly at odds with those predictions. Over the summer, microbial biomass increased, net mineralization rates shifted from negative to positive, the N pool shifted from NO_3^- to NH_4^+ domination, nitrification potentials increased, and even denitrification potentials more than doubled. These surprising results beg an explanation. Why, at a time when activities are lowest and conditions appear worst, does it appear that many groups of organisms are doing best?

In this talk, I will discuss the dynamics that appear to drive dry season processes. I hypothesize that the surprising ecosystem-level summertime dynamics result from two micro-scale phenomena: a) the physiology of microbial drought survival and b) the hydrological connectivity/disconnectivity of the “microbial landscape.” As soils dry, microbes experience direct physiological stress, increased resource demands to “pay” for stress-acclimation responses, and resource limitation from hydrological disconnections in their environment. For example, at soil matric potentials down to -0.6 MPa, NH_4^+ diffusion is a greater limitation on nitrification than is physiological stress. At water potentials of -10 MPa (easily attainable in dry soil), the only available water is in capillaries and water films of <1 μm diameter, creating potentially extreme limitations for resource diffusion and movement. On the other hand, microbes may experience reduced predation pressure because microbial predators also rely on a “connected” landscape for foraging.

Atmospheric lifetime of methane in a chemistry climate model

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Methane, which has the second-largest radiative forcing of the long-lived GHGs after CO_2, has increased significantly as a result of human activities related to agriculture, natural gas distribution and landfills. Both CO_2 and CH_4 concentrations are far higher than during at least the last 650 000 years (Spahni et al. 2005). In contrast to the low growth rates seen in the last decade, recent results show a rapid growth in the global CH_4 concentrations for 2007 (NOAA 2008). This could possibly be attributed to rapidly growing industrialization in Asia and rising wetland emissions in the Arctic and tropics. The thawing of Arctic permafrost could give rise to a large increase in CH_4 emissions, however it is still unclear whether this has had any significant contribution to the observed increase.

Methane concentrations display relatively large variations in space and time and the interannual variability in the global growth rate of CH_4 is significant. The variability may reflect changes in source emissions or variability in the major sink (atmospheric OH), however the effect of meteorology may also be significant. A better understanding of the relative importance of sources and sinks is needed to predict future changes in atmospheric CH_4 and its impact on the climate. The sources include wetlands, rice agriculture, biomass burning, ruminant animals, fossil fuel mining and distribution.

The principal tool for these studies is the ECHAM5-HAMMOZ chemistry climate model (Pozzoli et al. 2008), and the practical goal is to improve the parameterization of CH_4 sources. The long-term goal is to develop a coupled biosphere-CCM including a realistic description of the response of CH_4 emissions from wetlands for different hydrological conditions.

The first studies are related to the effect of meteorology on the global and local variability of CH_4. Comparisons are made to data from observational sites. The model can be run at a nudged mode to follow observed meteorology using e.g. ECMWF reanalysis data. In addition, results from CH_4 lifetime studies are shown, i.e. the sensitivity of CH_4 abundance and trends to changes in atmospheric OH. These studies will improve the understanding of observed CH_4 growth rates, and will also show how realistic the simulated CH_4 life times are in the model.

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The satellites data use for monitoring the degradation process of natural resources in semi arid zones (algeria)

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The semi-arid region of the Aurès presents an undeniable diversity of flora and fauna, however weather conditions and actual adverse anthropogenic, caused degradation of the physical environment, which have the form of a regression in the natural forest cover.

The objective of this study is to determine the contribution of satellite images in detecting changes in land use and monitoring of the degradation processes in the southern part of the Aurès region.

As far as that goes, we used images: Landsat ETM + for 2001 and TM 1987.These last cover the southern region of the Aurès which presents a landscape exposed to the phenomena of degradation including forest Beni-Mloul, Dj.Mezbel and Dj khaddou Ahmar, characterized by endemic species.

The adopted step is to treat multi-dates satellite imagery by the method of supervised classification of Maximum likelihood to see global changes of land use that have occurred in this area.

The results of treatment of satellite images show that the forest cover, rangelands and soil are being the object of advance degradation.

This study is a multi temporal diagnosis, which has allowed us to identify at a time the degradation affecting vast semi-arid areas, causing regression of plant cover, and also the pace of its development.

Keywords— Satellite Data multi-dates - Degradation of natural resources - semi-arid areas - Aurès.

Estimating river-sediment discharges in the Red River (Vietnam) using rating curves and impact of reservoirs on transport

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Data on river sediment fluxes are essential for studies on soil erosion and -loss, natural geochemical cycles and mass balances of contaminants transported in the particulate phase. Long-term time series are needed for assessing temporal variability and understanding impact of global climatic change and/or anthropogenic activities on sediment flux (Farnsworth and Milliman, 2003). Nevertheless, less of 10% of the world's rivers have been monitored for their sediment delivery to the ocean (Syvitski et al., 2005). In the absence of (i) continuously measured suspended particulate matter (SPM) concentrations or (ii) long-term time series, sediment rating curves have been used to estimate SPM data and predict river-sediment discharges (Walling and Webb, 1981; Horowitz, 2003; Doomen et al., 2008).

The Red River (China/Vietnam; A=155 000 km^2) is strongly affected by monsoon with a rainy season from May to October cumulating 85–95% of the total annual rainfall. Daily discharge (Q) and SPM concentrations were measured during 1960 to 2007 by the Institute of Metrology, Hydrology and Environment at the SonTay gauging station (watershed outlet). Daily SPM concentrations varied from 20 to 15,000 mg/l with Q values ranging from 160 to 33,600 m^3/s. Based on these data, the mean annual SPM flux of the Red River is estimated to 90 Mt/yr, corresponding to a sediment yield of 600 t/km^2/yr, similar to that of the Ganges/Brahmaputra system (e.g. Ludwig and Probst, 1998). The temporal variability of annual SPM fluxes (24–200 Mt/yr) is strongly related to the interannual hydrological conditions. However, some years of high water flow dis not account for high sediment fluxes, especially after 1986 when the HoaBinh dam was built on a major tributary of the Red River. Based on Q and SPM measurements over the 1960–1985 period covering a wide range of hydrological situations, we have fitted different sediment rating curves and selected the regressions describing best the sediment load. A single sediment rating curve derived from data spanning the 1960–1985 period was used to simulate the annual variability of sediment delivery generating excellent cumulative flux estimates (error of <0.6%). In contrast, applying the same rating curve to the 1986–2007 data resulted in systematic and important (up to 94%) overestimation of cumulative SPM flux. Analysis of the pre- and post-1986 sediment rating parameters (a and b) of power functions (SPM=aQb) suggests a down shift of a-parameter values after 1986, attributed to decreased sediment supply (Wang et al., 2008). These results obtained from analysis of long-term observation data strongly suggest that the Hoa Binh dam has reduced annual SPM delivery to the delta by half.

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A carbon budget of a low-productive boreal forested catchment

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Dissolved organic carbon (DOC) concentrations in freshwaters have increased considerably in boreal ecosystems in the past decades, possibly as a response to reduced acid deposition. Climate warming is expected to be associated with more precipitation and rain storms of higher intensity in summer and autumn, leading to more surface run-off. Both of these phenomena suggest that losses of soil C through fluvial transport may become more significant compared with C sequestration in soils and vegetation, especially in upland forests of low productivity which are typical for boreal areas.

Here, we aim to link estimates of terrestrial C uptake and losses with aquatic fluxes of DOC for a small, forested boreal lake catchment in southeastern Norway. These more detailed and process-oriented estimates are compared with estimates on aquatic C-flux from a wide range of catchments over the entire mainland of Norway, inferred from data on runoff, DOC-concentrations and Differential Vegetation Index (NDVI).

The catchment (Langtjern; 4.8 km^2; 500–750 m.a.s.l.) is dominated by old unproductive pine forest on thin mineral and organic soils, in addition to wetlands. Flow-weighted DOC has increased with 20% over the last 20 years. Mean annual discharge is 600 mm, and mean annual export of DOC is 6 g C m^{-2}.

Estimates of terrestrial C pools (soils and vegetation) and fluxes (uptake in forest and fens, losses of CO_2 from soils, in-lake production, sedimentation and mineralization of CO_2) will be presented.

The C pool in standing tree biomass was estimated by using airborne remote sensing (Lidar), single-tree segmentation and allometric functions for pine. Tree growth was estimated based on forestry yield tables and wetland C sequestration on literature values. Litter production was estimated from biomass turnover factors.

Ground returns from the Lidar runs have also been used to generate a high-precision digital elevation model, which served as input for a spatially distributed hydrological model. Input of DOC to the lake was assessed from discharge monitoring and DOC-concentrations in the two inlets, plus hydrological estimates on diffuse runoff. Monitoring of the outflow allowed for mass balance calculations of DOC. Annual sedimentation rates were estimated using sediment traps, and separate estimates were made for mineralization losses (bacterial oxidation plus photooxidation). Also degassing of terrestrially derived CO_2 was estimated in the highly supersaturated inlets. Soil CO_2 and CH_4 effluxes were estimated using closed chambers.

Some of the flux estimates are uncertain with a coefficient of variation exceeding unity. In order to estimate the carbon budget at the whole catchment level, upscaling from point measurements as well as temporal aggregation of discontinuous measurements to the annual scale is required. The investigation aims to evaluate the relative importance of uncertainties of individual fluxes and the degree in which uncertainties are constrained by the whole-catchment perspective.

Removing the disconnect between maps and time series: can long-term monitoring data be used more effectively as a basis for model upscaling?

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Long-term monitoring sites provide key process understanding, and are frequently the basis for detailed biogeochemical model applications. Implicitly or explicitly, the information provided by both monitoring and modelling must be upscaled in order to have wider scientific and policy application. However, upscaling models inevitably requires trade-offs between scale of application and data quality. Across Europe, work under the UNECE Convention on Long-Range Transboundary Air Pollution has aimed to simulate the effects of atmospheric S and N deposition on semi-natural ecosystems at large spatial scales. In general, the approach taken has been to parameterise models to large numbers of individual locations (surface waters) or grid squares (soils). Such modelling involves high uncertainty, is difficult to test, and makes no direct use of long-term monitoring data.

Significant changes have occurred since large-scale modelling was first undertaken in the 1990s. Firstly, biogeochemical models have developed to include more accurate process descriptions, including. better representation of the influence of climatic as well as deposition drivers, and more sophisticated methods for parameter estimation, notably those including uncertainty estimation such as Markov chain Monte Carlo analysis. These changes provide the capability to more accurately reproduce observed temporal variations in long-term data. Secondly, monitoring datasets have increased in duration. Although spatial variations are often large, reflecting gradients in deposition, climate, soil and land-use, many key chemical variables show remarkable temporal coherence among sites (e.g. Fig. 1), linked primarily to consistent large-scale changes in deposition and climate. We propose that this temporal coherence provides the potential for more effective utilisation of long-term monitoring data in model upscaling. More sophisticated models can be accurately parameterised from individual monitoring sites to reproduce observed temporal changes. Changes at unmodelled sites can then be predicted through identification of suitable modelled analogues, and application of statistical models incorporating space and time components. The utility of this method will be critically evaluated by testing 1) the ability of the statistical model to predict long-term changes at one site based on measured data from other sites, and 2) the performance of 'low data quality' model applications direct to survey sites, relative to 'high data quality' model applications extrapolated from long-term monitoring sites.

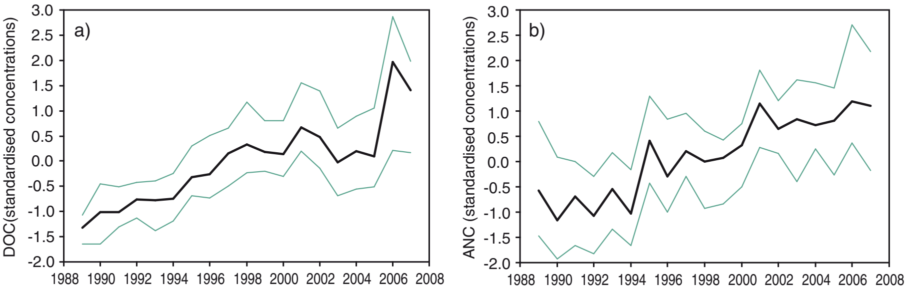

Figure 1. Coherent temporal variations in standardised annual mean concentrations of a) dissolved organic carbon and b) acid neutralising capacity for the lakes and streams in the UK Acid Waters Monitoring Network. Lines show 10th, 50th and 90th percentile values for the 22 sites.

Linking litter to lakes: A modelling study of the effects of climate change on carbon cycling and lake thermal properties in a boreal catchment

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The combined effects of reductions in acid deposition and a changing climate are leading to increases in surface water dissolved organic carbon (DOC) concentrations in the boreal ecozone. Climate change is also affecting the timing of ice cover, water temperature, and stratification period for boreal lakes. The concentration of DOC in a lake exerts a major influence on its thermal behaviour, affecting degree and timing of stratification as well as heat storage. Recently two models have been developed to simulate the effects of changing climate on catchment-scale cycling of DOC and lake thermodynamics. A catchment-scale model of carbon cycling (Futter et al. 2009) was able to produce long-term (1961–2100) simulations of DOC concentration in surface waters but would have benefited from improved estimates of litter fall to drive the model. A model of lake thermodynamics (Saloranta et al. 2009) was calibrated to current conditions and used to provide estimates of lake thermal behaviour under baseline (1961–1990) and future (2071–2100) climate scenarios and constant DOC concentration. Here we present a modelling study in which empirical models of litter fall are used to drive a catchment-scale, process based model of DOC cycling which in turn is used to drive a physically-based model of lake thermodynamics. Our study links the effects of climate change on biological processes occurring in the catchment to lake thermal behaviour and discusses the uncertainties in model projections.

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Inorganic nitrogen leaching from two Finnish research catchments under future climate conditions

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The semi-distributed dynamic INCA-N (Integrated Nutrients from Catchments – Nitrogen) model (Whitehead et al., 1998; Wade et al., 2002) was applied to two research catchments in Finland, within the EU Euro-limpacs project. The aim was to simulate nitrogen (N) loads under different climate change scenarios. The Mustajoki catchment (78 km^2) is a forested upstream catchment located in highlands in southern Finland where the soil types are mostly coarse (till 68%, sand and silt 11% of the catchment area). The Savijoki catchment (15 km^2) is representative of intensively cultivated lowlands in south-western Finland. Fields cover 36% of the catchment area and are located on clay soils along the stream network.

In both catchments, the calibrated and tested model was used to simulate the hydrological pattern and inorganic N losses in the new equilibrium climate (representing period 2071–2100) with four climate change scenarios developed within the PRUDENCE-EU project (Christensen et al., 2007). The selected scenarios suggest an increase of 2.8–4.7 ºC in annual mean temperature and 10.1–23.6% increase in annual precipitation. The considerable increase in winter (December-February) temperatures (3.4–6.2 ºC) and precipitation (26–56%) predicted by the different scenarios influenced strongly the hydrological regime in both catchments. In Savijoki, the modelled snow water equivalent (SWE) decreased and the winter runoff increased considerably. In Mustajoki, the air temperature in winter remained below zero during most scenario years and therefore, the increased precipitation caused higher SWE and snowmelt runoff peak compared to present conditions.

The modelled annual inorganic N load increased by 32–68% in Savijoki and 9–32% in Mustajoki according to different scenarios. This was due to higher mineralization rate and increased water flow through the catchment soils. The changes were more pronounced in agricultural Savijoki than in forested Mustajoki particularly during dormant period, from November to February (Fig. 1). Efficient catchment scale mitigation measures are needed, especially on the agricultural sector, to prevent eutrophication of surface waters in future climate conditions.

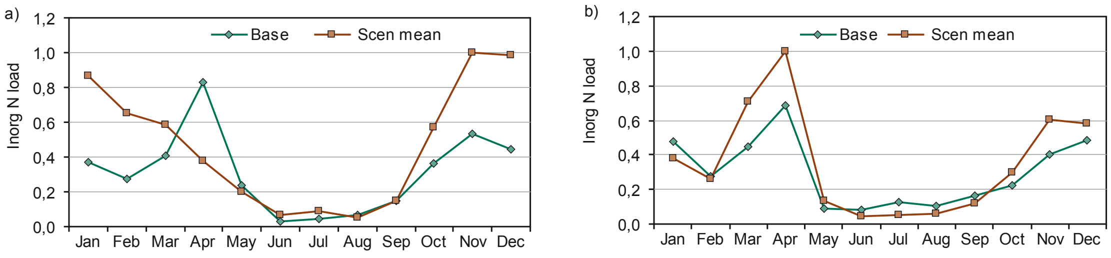

Figure 1. Simulated inorganic N loads from a) Savijoki and b) Mustajoki catchments in present (Base) and future (Mean of four scenarios, Scen mean) climate conditions. Scaled monthly load values are presented.

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Investigation of methyl bromide and methyl chloride flux from Scottish and sub-arctic wetlands

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Methyl bromide and methyl chloride (MeX) contribute to ozone destruction in the stratosphere. These gases are naturally produced from a range of environments which may also act as sinks. The natural source and sink terms for MeX are poorly constrained and a better understanding of these terms is required for predicting ozone recovery. In this research MeX flux has been monitored for more than 1 year at several sites in four Scottish wetlands. Air samples were regularly collected from each site and were analysed for MeX using gas chromatography with electron capture detection. External parameters, including air temperature, soil temperature, water level, solar flux and photosynthetically active radiation, were recorded during each sampling event. In addition, a study over two summers was performed at a sub-arctic wetland near Abisko, Sweden. Our aims were to improve the global database of wetland MeX flux measurements, to study seasonal and diurnal trends in MeX flux and to determine if external environmental parameters drive MeX flux.

Fig. 1 shows the seasonal trends in average MeX net flux from all sampling points in the Scottish wetlands. For all sites there were greater emissions during the growing season compared with the winter, suggesting a plant or a plant-mediated source of MeX. The magnitude of emissions varied between sites and there was also variation within the sites depending on the type of vegetation present. The greatest MeBr emissions were observed from a *Phragmites australis* reed-bed. The average emission was 4700 ng m^{-2} h^{-1} over one year. Large MeBr and MeCl net emissions were observed from raised peat bog sites dominated by *Calluna vulgaris*. The average MeBr emission was 592 ng m^{-2} h^{-1} over one year and the average MeCl emission was 35100 ng m^{-2} h^{-1} over nine months. At some sites, a diurnal cycle of MeX flux, with greater emissions during the day, was observed. No substantive correlation was observed between MeX emission and any of the measured external parameters. Very low rates of MeBr uptake and MeCl emission and uptake were measured at the sub-arctic wetlands, although a seasonal cycle of MeX flux was likewise observed.

Current work includes analysis of the separate plant and soil components of wetlands in order to determine the contribution of each to the overall flux. Geographic Information Systems (GIS) are also being used to up-scale MeX flux from site measurements more accurately to global budgets.

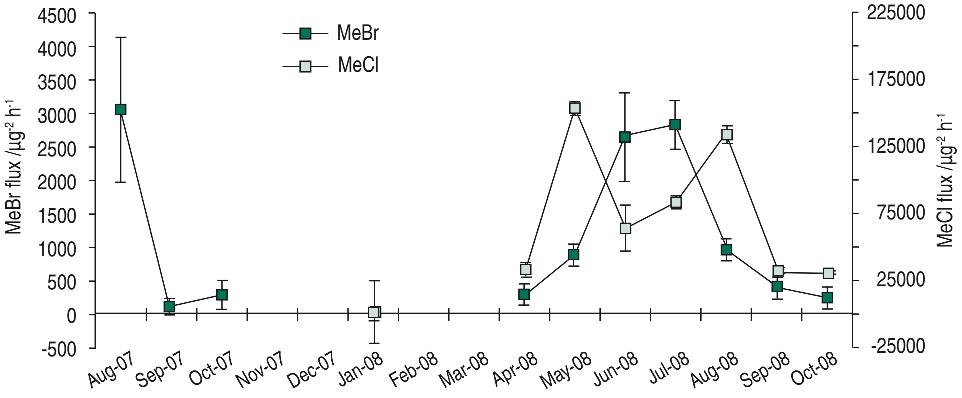

Fig. 1. Average MeBr and MeCl net fluxes over time from sites at four Scottish wetlands. Error bars represent the standard error in MeX analysis. Note the different scales for MeBr and MeCl.

Optimal Land Use Pattern of Zhifanggou Watershed on Hilly Region of Loess Plateau, China: application of a Process-Based Water Balance Model

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For purpose of landscape sustainability of hilly region of Loess Plateau, optimal land use pattern based on water balance was addressed in Zhifangou watershed of Shaanxi Province in northwestern China. A process-based water balance model for loess landform was developed, and soil water movement, evaporation, transpiration, and runoff could be simulated both in ecosystem and watershed scales. Up-scaling from ecosystem to watershed was in terms of spatial variability of landform, soil type, and vegetation. Four scenarios of land use pattern were designed, two based on actual situation in 1975 and 1997, respectively, and the others according to the suggested plans of returning cropland to woodland and grassland, with the allocation proportions of cropland, woodland, and grassland area being 1:0.13:0.84, 1:0.88:0.85, 1:4.6:6, and 1:28:17, respectively. Modeling results show that more woodland and grassland there are, more precipitation is intercepted in the watershed, and more water returns to the atmosphere by soil evaporation and plant transpiration within the current year, with the decrease of average annual soil water content. As a result, the ecosystem would be unstable due to the severe water deficit in dry years when the proportion of woodland reached about 55%, although it might be optimal for the water-and-soil conservation. Preliminary conclusion may be drawn that, to make sustainable use of water resource and achieve optimal ecological benefit, the reasonable proportion of woodland should be around 36% in the Watershed, while the suitable ratio of cropland, woodland, and grassland area be 1:4.6:6.

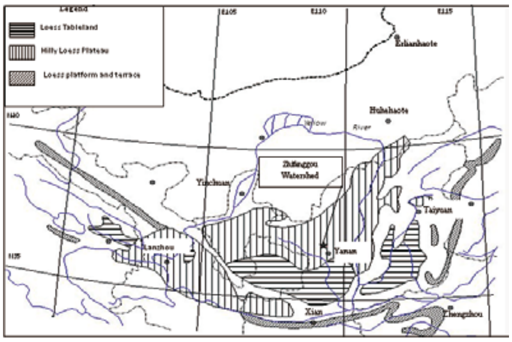
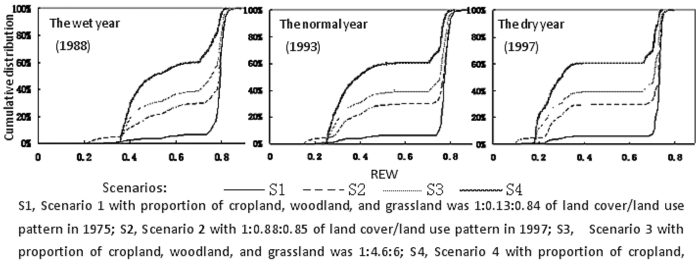


Fig. 1. Loess landform of China and research site.



S1, Scenario 1 with proportion of cropland, woodland, and grassland was 1:0.13:0.84 of land cover/land use pattern in 1975; S2, Scenario 2 with 1:0.88:0.85 of land cover/land use pattern in 1997; S3, Scenario 3 with proportion of cropland, woodland, and grassland was 1:4.6:6; S4, Scenario 4 with proportion of cropland,

Fig. 2. Cumulative distribution of relative available soil water (REW) in 0–250 cm depth under different scenarios.

Net ecosystem exchange in a rewetted, episodically flooded brackish fen - modelled potential vs monitored field data

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Whilst there is a number of studies regarding carbon stocks and exchange in intertidal saline wetland soils (Chmura et al. 2003), coastal freshwater peatlands have been rarely investigated (Henman & Poulter 2008). However, they might be susceptible to inundation driven peat consumption that possibly feeds back to climate change. Our investigation site in the Northeast of Rostock (Germany) is episodically flooded with brackish baltic sea water. Therefore the vegetation as well as the according biogeochemical processes can be seen as representative for coastal ecosystems susceptible to flooding because of future sea level rise and the expected developments can already be studied here in detail. Enduring protection against flooding might be very expensive. Furthermore, a reanimation of naturally provided ecosystem services (as carbon storage) may be aspired. Therefore it is crucial to investigate what happens to vegetation composition, matter (carbon) storage and GHG emissions in these ecosystems under dynamic flooding regimes and therewith potentially higher salinities.

We will present one year eddy covariance flux data from the site and compare the annual net ecosystem exchange to the modelled annual net ecosystem exchange that can be expected from litter incubation experiments in the lab. This data is derived from 25 litter samples (5 vegetation types with 5 replicates each) that have been taken in the area that is covered by the eddy flux measurements. 10 g of the litter samples (plant material, soil, etc..) are filled into 500 ml Erlenmeyer flasks and 50 ml of original water are added so that the litter material is covered with water. These samples are stored in the lab (they are weighed every day and dest water ist added if necessary to keep liquid/solid relation stable). Air sampling from these flasks is carried out for 40 days beginning with daily sampling and decreasing the rate subsequently depending on GHG development to stay in the measurable range. The air samples are analyzed with gas chromatography for CH_4, N_2O, and CO_2. The same laboratory setup is repeated with adding 25 ml of original water and 25 ml of Baltic Sea water. Thus, future higher salinity can be evaluated regarding its influence on potential trace gas emissions.

The resulting CO_2 emissions are scaled up to the eddy tower scale using a detailed vegetation map of the site reflecting the distribution of the litter (vegetation) types. The map is derived from a combination of field sampling within a systematic grid of plots and remotely sensed data (multi-spectral airborne imagery). The latter is subjected to a object-oriented supervised classification under consideration of the vegetation field data. Eddy flux and lab data are compared to compare field fluxes against potential fluxes and modelled future potential fluxes.

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Modeling of calcium dynamics in north taiga forest soils

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Calcium is a major nutrient regulating metabolism in a plant. Deficiency of calcium results in a growth decline of plant tissues. Plant-available calcium compounds are in the soil cation exchange complex and soil waters. We simulated calcium dynamics in the northern taiga forest soils linking it with the model of soil organic matter dynamics ROMUL (Chertov et al., 2001). ROMUL describes the mineralization and humification of the fraction of fresh litter which is further transformed into complex of partially humified substance (CHS) and then to stable humus (H) in dependence on temperature, soil moisture and chemical composition of the fraction (nitrogen, lignin and ash contents). Rates of decomposition and humification being coefficients in the system of ordinary differential equations are evaluated using laboratory experiments and verified on a set of field experiments (Chertov et al., 2007).

Main pools of calcium taken into consideration are as follow: L_{Ca} is calcium in the fraction of fresh litter, [kg/m^2]. At mineralization of soil organic matter with monthly rate R1 part of calcium moves into the pool of available calcium Av and rest part is transformed into the pool of calcium F_{Ca} (calcium bonded with CHS) with rate R3. F_{Ca} is mineralized with rate R2 into Av and is also transformed into H_{Ca} (calcium bonded with organic-mineral complex of stable humus). Last transformation goes different ways with monthly rates R4 and R5 in dependence on activities of microorganisms and different groups of soil fauna as it has been done in ROMUL. R5, for instance, describes activity of earthwarms which produce humus with relatively narrow C/N ratio. H_{Ca} is mineralized with monthly rate R6 and comes into Av. Av consists also of calcium weathering from minerals, which could be evaluated from other models, PROFILE (Sverdrup, 1996) as an example.

Calcium input with bulk precipitation and throughfall is also included into Av pool.

Such a model structure allows for describing the calcium dynamics as a system of ordinary differential equations. Moreover, at some assumptions we can link the calcium model with ROMUL through the soil organic matter pool. It allows for using of some ROMUL coefficients and provides a feedback with carbon and nitrogen dynamics. Calcium compounds are related to the soil acidity which regulates the decomposition and humification rates. The dynamics of calcium influences on the carbon and nitrogen cycles in forest ecosystems.

The model is calibrated and verified for the northern taiga forests on the Kola peninsula.

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Evolution and present-day climatic-driven dynamics of the thermokarst lakes in West Siberian cryolitozone

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Lakes, ponds and drained thaw lake basins are major elements of the Northern landscape. These ecosystems are integrators of their surrounding catchment properties including geomorphology, limnology, hydrology, vegetation and permafrost soil dynamics. Many of these properties are strongly dependent of climate thus making boreal lakes sensitive indicators of its changes (Vincent, Pienitz, 2006).

Plateaux palsas cover extensive areas in the West-Siberian sub-arctic. All the stages and the smallest nuances of the endogeneous cyclic succession process are visible over space in remarkable images (Kirpotin et al., 2007). The positions of the edges of the landscape precisely reflect the time series of its development: (1) during the first stage of the cyclic decay of flat palsa complexes, thermokarst lakes may appear as a result of the appearance of different sized melted subsidences; (2) these lakes can increase in size due to shore erosion since lake water acts as a heat source which induces further thawing of permafrost layers; (3) the thermokarst lakes can also turn into a chasyreis (drained lakes without water); (4) at the empty lake basin stage, the heaving by renewed permafrost goes on, the isolated small mounds merge into a uniform system and they turn into typical flat palsa plateaux. We investigated the chemical and microbiological evolution of thermokarst lake water ecosystems chronosequences and found a systematic trend of the decrease of dissolved organic carbon concentration from palsa complex decay stage to the chasyrei stage. At every stage of lake development, important net flux of CO_2 from the lake water to the atmosphere and dominance of the mineralization over primary production was observed.

The thermal karst and the heaving of the permafrost have been peculiar to the Western-Siberian sub-arctic region for a long time. There has been a steady balance of cryogenic processes. These days, we observe that the cyclic succession has taken a linear character directed towards the strengthening of the thermokarst.

During the expedition of 2008 carried out within the framework of Russian-French network project CAR-WET-SIB, one of possible mechanisms of drainage of thermokarst lakes in the north of Western Siberia was revealed. The discovered natural processes are significantly amplified by the climate warming and thus require a special attention.

Satellite monitoring (1973–2008) has revealed zonal specifics of geocryologicat processes. In the zone of continuous permafrost, thermokarst lakes expanded their areas by about 10-12%, but in the zone of discontinuous permafrost the process of their drainage prevails. These features are connected with the thickness of peat layers which gradually decreases to the North, where the lakes have reduced opportunity for drainage.

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Assessing critical load and exceedance in south-central Ontario: application of new weathering determination methods to the Steady-State Mass Balance and MAGIC models

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Previous acidification research in Ontario has focused on a few intensively studied sites with high-resolution data, whereas, regional acidification studies generally rely on low-resolution data from soil maps. In the most recent Canadian Acid Rain Assessment (2004), base cation weathering rates were estimated using a simple empirical clay based model (Ouimet et al. 2006); however the model has not been validated for southern Ontario, which receives some of the highest acid deposition levels in Canada. A new Ontario Weathering Model (OWM) was developed to estimate regional weathering rates ($eq \cdot ha^{-1} \cdot a^{-1}$) for forest soils in south central Ontario using soil clay content (%) and loss on ignition (LOI, %)—soil properties that are available at the regional scale: $r_{weathering} = (1.9798 + 0.3126 \cdot Clay - 0.1567 \cdot LOI) \cdot depth$. Weathering rates obtained using OWM for the rooting zone at 19 forested catchments (252–892 $eq \cdot ha^{-1} \cdot a^{-1}$) were consistent with estimates from catchment mass balance at these sites (273–2,131 $eq \cdot ha^{-1} \cdot a^{-1}$).

Weathering rates obtained using the OWM were used to estimate critical loads and exceedances in south-central Ontario. Steady-state critical loads were estimated at 116 sites using the Steady-State Mass Balance (SSMB). Uncertainty in critical load estimates was addressed with a multi-criterion approach combined with modifications in model parameters. Further, exceedance was estimated using two regional acid deposition fields. Depending on assumptions in the model and deposition estimates, between 0% and 36% of the study sites received acid deposition in excess of the critical load, values much lower than reported in the recent Acid Rain Assessment. Site-specific weathering estimates obtained using PROFILE and mineralogy data estimated from total oxide using the Analysis to Mineralogy (A2M) model (Posch and Kurz 2007) were applied to dynamic simulations at 52 study sites. The response of soil chemistry at these sites to proposed changes in sulphur and nitrogen deposition was evaluated using the Model of Acidification of Groundwater in Catchments (MAGIC).

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Stream benthic macroinvertebrates of nine selected catchments of the Czech GEOMON network

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This contribution examines relationships between stream chemical and physical characteristics, whole-stream metabolism, and the associated biotic communities in nine small (22-261 ha) headwater streams of the GEOMON network of forest catchments (Oulehle et al. 2008). At each catchment, a 100-m reach was established and 3 replicate samples were collected from each major habitat type (pool, riffle, run), for a total of 9 samples per site. Benthic macroinvertebrates were collected using a net and by scrubbing all rocks and disturbing sediment within 30 cm of the net frame. Specimens were usually identified to the family level. The benthic macroinvertebrates found at each site were documented (Kram et al. 2008). Streamwater pH at the time of sampling ranged from 4.0 (Lysina) to 7.7 (Pluhuv Bor). As expected, taxa richness declined with increasing acidity (Fig. 1). The lowest biodiversity (9 taxons) was at Lysina, the highest (22 taxons) at Salacova Lhota. The flies *(Diptera)* from families *Chironomidae* (non-biting midges) and *Simuliidae* (black flies), the stoneflies *(Plecoptera)* from families *Leuctridae* (needleflies) and *Nemouridae* (spring stoneflies), the caddisflies *(Trichoptera)* from families *Limnephilidae* (northern caddisflies) and *Polycentropodidae* (tube-making caddisflies), and the worms (*Vermes)* from class *Oligochaeta* (earth worms) were present in all streams. However, acid-sensitive taxa such as mayflies *(Ephemeroptera)* were absent from the two most acidic streams at Lysina and Loukov.

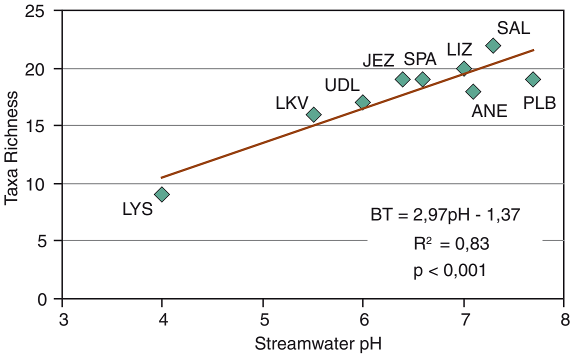

Fig. 1. Taxa richness of benthic macroinvertebrates declined with decreasing pH (increasing acidity) in the forested catchments of the Czech Republic.

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Comparison of backward trajectories of selected elements in samples of wet deposition collected at three differing sites in Bohemia

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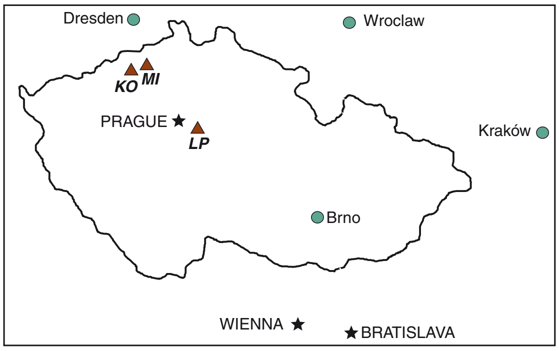
Pathways of major elements representing the bulk chemistry of precipitation over western part of the Czech Republic (CR) were studied in samples collected at three different sampling sites. The study was based on the evaluation of significance of transport trajectories using the HYSPLIT model (Draxler and Rolph 2003). Precipitation samples from individual rain events were collected and concentrations of Na, K, Ca, Mg, S, P, Si, Fe, Al, Mn, Pb, As, Cu, Zn and Cd were analyzed. For the sampled rain events we identified air mass trajectories from the satellite data with respect to the event duration. Precipitation samples were collected at localities Lesni potok (LP, approx. 30 km SE from Prague at 49°58´48´´N, 14°46´12´´E, 420 m a.s.l.), Milesovka (MI, in the Bohemian Central Highlands at 50°33´17´´N, 13°55´57´´E, 837 m a.s.l.), and Kopisty (KO, at 50°32´54´´N, 13°37´31´´E, 240 m a.s.l.) in period 2005–2008 (see Figure).



Sampling site LP represents a typical Central Bohemian background locality located near the forested National Nature Reserve – Voděradské bučiny, affected mostly by the emissions of the industrial urban area of Prague. The site MI is located on the top of conical mountain in one of the most polluted regions of Bohemia. Similarly, the site KO with low altitude is situated also in the heavily industrialized NW part of the CR, characteristic with relatively significant local air pollution.

Chemical composition of monitored precipitation events generally reflects the combined impact of anthropogenic and natural emission sources, affected by the location and orography of the sampling sites. The results indicate that prevailing transport trajectories of the most of monitored elements agree with the location of their supposed sources. The analysis of trajectories indicated major source of Na and Mg marine aerosol, while those of K and Mn signify their most probable and dominant local biogenic origin (Vach *et al*. 2008). There is not a single dominant trajectory, but more important trajectories from different directions for the elements Al and Fe. Correlation of Al and Fe concentrations indicates their probable common source, the terrigenic dust. No significant predominant course of trajectories was identified for S. This is presumably caused by different position of major S sources towards the sampling sites.

The comparison of results obtained at the individual sampling sites shows dominant impact of the principal low-distance emission sources (at MI and KO large extent of coal burning powerplants) and also especially at MI the terrain orography. Predominant courses of transport trajectories were identified from the southwest - northwest directions.

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Decreasing DOC trends in soil solution along the hill slopes at two IM sites in southern Sweden

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Numerous studies report increased concentrations of dissolved organic carbon (DOC) during the last two decades in boreal lakes and streams in Europe, Canada and the US. Many different processes have been proposed to explain these trends e.g. weather induced shallower groundwater flow paths, recovery from acidification due to reduced sulphur deposition, changed land use, increased forest production etc. Swedish surface waters and soils show clear signs of recovery from acidification, indicating that the increased levels of DOC could be attributed to increased soil pH and decreased levels of aluminium in the soil solution, both factors affecting the solubility of soil organic matter (SOM). Additionally, the decreased ionic strength coupled to the reduced sulphate concentrations might increase the DOC-flux. If this recovery hypothesis is correct, the DOC levels should increase both in the soil solution as well as in the surrounding surface waters as pH rises and the input of ions such as sulphate decline. However and in contrast to the surface waters, the soil waters in recharge areas (50 cm soil depth) in southern Sweden exhibits decreased DOC concentrations during the period 1986–2008, indicating increased coagulation of DOC in the upper soil horizon (see Zetterberg & Löfgren this volume). Therefore, it was hypothesized that processes in discharge areas and peat lands rather than dry soils uphill govern the surface water DOC trends (op. cit.). In this study, this hypothesis was tested on soil water data from two transects along the hill slopes at the integrated monitoring sites at Aneboda and Kindla in southern Sweden, covering the time period 1996–2007.

Soil water was collected with tension lysimeters (ceramic suction cups, P80, 1 μm cut-off, installed 1994) in E- and B-horizons in the recharge areas and at 30–40 cm soil depth in the discharge areas. At Aneboda, data origins from April, August and November, while it origins from May, August and October at Kindla. The water from each lysimeter was analysed separately and according to Swedish standards. The non-parametric Seasonal Kendall was used for analyzing statistical significant trends ($p<0.05$) for each lysimeter and the annual trends were quantified with Theils slope. In the table below, the number of statistically significant positive and negative trends as well as the minimum and maximum values on Theils slope are listed. Only 11 out of 28 lysimeters showed statistically significant DOC trends, with predominance of *decreasing* concentrations. pH, sulphate and ionic strength (≈conductivity) exhibit clear signs of recovery from acidification, with slightly increasing (pH) and decreasing (SO_4 and cond.) trends in most lysimeters. Hence, the hypothesis of increased DOC concentrations due to recovery from acidification is not verified by the trends in soil water either in recharge or discharge areas at the IM sites in Aneboda and Kindla. The DOC trends are in agreement with the findings of Zetterberg & Löfgren (this volume). Theoretically and regardless of decreasing DOC concentrations in soil water, shallower groundwater flow paths could compensate for this and explain the surface water DOC trends.

	E-horizon		B-horizon		Discharge area	
	+/- trends	min; max slope*	+/- trends	min; max slope*	+/- trends	min; max slope*
Kindla						
n, lysimeters	4		6		6	
pH	2/0	0.01; 0.02	5/0	0.01; 0.07	5/0	0.01; 0.07
Cond., mS/m	0/4	-0.19; -0.09	0/5	-0.14; -0.09	0/6	-0.23; -0.08
SO_4, µeq/l	0/4	-9; -8	0/6	-12; -7	0/6	-12; -5
DOC, mg/l	0/2	-0.4; -0.3	1/3	-0.1; 1.9	1/2	-0.4; 0.3
Aneboda						
n, lysimeters	0		8		4	
pH	nd	nd	6/1	-0.03; 0.06	2/0	0.03; 0.04
Cond., mS/m	nd	nd	0/6	-0.43; -0.11	no trends	no trends
SO_4, µeq/l	nd	nd	0/7	-37; -4	0/3	-11; -8
DOC, mg/l	nd	nd	1/3	-0.5; 0.5	0/1	0.2

*Annaual change e.g. µeq/l, yr.

Forest ecosystem leaching in a climate change perspective for the Nordic region

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Forest ecosystem conditions are influenced by climate change primarily targeting precipitation and temperature. This will have impacts on hydrology and further among other things organic matter, acidity and nitrogen. Turnover of elements is to a large extent dependent on hydrological conditions. In a climate change perspective, it is foreseen frequently more extreme variations e.g. regarding wetness and drought. In a northern climate, the historically ordinary hydrological pattern includes a dormant period often being snow covered and a vegetation period in summer with relatively high temperature and evapotranspiration. This pattern already has changed to mild winters including snow melt during the whole period, resulting in the absence of a high snow melt spring flood. Instead high element runoffs occur during the dormant period meaning a rather high flow to surface waters and the sea. In summer, variations between high precipitation and periods of drought occur at different geographical locations and with time. The consequences for element turnover could be drastic.

Soil organic matter would play a key role. Increased growth would furnish more litterfall and root production. A higher temperature could change the stand tree composition and in case of a change from pine to spruce increase the soil organic matter storage. In moist and wet areas this would mean enhanced accumulation of organic carbon. A high nitrogen input furnishes additional organic matter storage possibilities. Under moist or wet condition more organic matter would influence water quality with higher colour, lower pH and hazardous conditions for metals. In case of changes in soil moisture conditions, i.e. drier periods, the decomposition of stored organic matter will start and could be considerable. This would release stored elements, increase nitrate production and leakage. After the drier period, again precipitation will fall and flush out the released elements with strong effects on e.g. pH, N and metals.

These conditions need to be followed on the whole ecosystem level where a catchment approach should provide the most appropriate unit and perhaps in several spatial scales. In the Integrated monitoring (IM) approach for natural forests, this is ongoing but for the majority of land, where ongoing land-use such as forestry exists, the monitoring is on a low level and needs development. Future monitoring has to include these facts and address tree composition, forestry activities, especially in a higher biofuel use perspective, and follow the soil organic matter storage change together with its composition.

A 3D structure model of an artificially constructed soil-geo-system

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The initial development stages of artificially constructed soil-geo-systems are characterized by the absence of vegetation, soil organic matter and soil horizons. This results in increased surface runoff and favors erosion processes that dominate the initial phase of structure dynamics. The quantification and visualization of sediment relocation by erosive and depositional processes can be accomplished in a 3D structure model. However, studies in this regard have hardly been undertaken.

The objective of this study was the digital visualization and quantification of sediment mass balances based on the initial 3D structure and exemplified for the small hydrological catchment “Huehnerwasser” near Cottbus, Germany. Photogrammetric surveys of surface and internal structural units (clay basis liner) during the construction phase provided data for digital elevation models (DEM). Interpolated physical and chemical soil properties obtained at a borehole grid (e.g., texture) are used for the visualization of spatial distribution of parameters. The data are merged in a database and visualized in a 3D-GIS application (GoCAD).

The initial internal structure is characterized by the technological construction processes. The resulting differences in bulk density and texture are supposed to have considerable impact on hydraulic properties. Hence, a structure generator program was used to reproduce the initial structure of the sediment layer. The results of digital structure generation are checked with non-invasive geophysical measurements, on-site bore holes data and off-site 2D vertical spoil exploration.

The structure model serves as the base for deriving the 3D-distributions of hydraulic properties for the modelling of surface runoff, erosion and soil water and solute movement. It allows quantification of volumetric mass changes in time and a first approximation of the erosion-affected surface structural dynamic of the developing soil-geosystem. The structure model is strongly interlocked with an intense monitoring program that provides the necessary input data. Long-term observations and their integrative synopsis in the structure model will help to describe the initial development phases of soil-geosystems.

Level II plots in Spain: atmospheric deposition years 1998–2003

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Pan-European Programme for Intensive Monitoring of Forest Ecosystems, also called Level II European grid, provides updated information about forest condition and possible influence of factors as climate, biotic agents or air pollution at global scale. It also constitute a consistent database that support European policies in climate change, forest biodiversity and sustainable management of forest, giving information at general, regional and local level.

Research activity in the level II plots comprises: visual assessment of crown condition, soil and soil solution analysis, foliar nutrient contents, forest growth and increment, atmospheric deposition, including passive sampling of air pollutants, meteorological monitoring and phenology, inventory of ground vegetation, visual Ozone injury assessment, and others studies related to biodiversity, vitality and climate change.

Main goals of the deposition measurements are to obtain an accurate knowledge about the deposition process in forest ecosystems and to give information for the mapping of critical loads. Samples obtained in throughfall and stemflow collectors supplies long series of data about pH, conductivity, base cations, several anions, alkalinity and N total. Also Al, Mn, Fe and heavy metals are analyzed. There are available data from 1997, in 15 days periods as average.

Results show the variation in the atmospheric deposition data assessed in 13 Spanish plots, ranging from wet temperate northwest forest on acid subtract (Galicia) to arid Mediterranean pure calcareous ecosystems (Alicante), from the beginning of the sampling to now. Analysis of the results links the short-term meteorological data variations, mainly rainfall and temperature, with vegetation cover, taking account quality and quantity of atmospheric deposition in several elements, studying in addition variation in time and possible trends in a possible climate change scenario.

100 000 lakes in Sweden: monitoring data and the MAGIC library of 1200 modeled lakes used to assess past and future lake chemistry.

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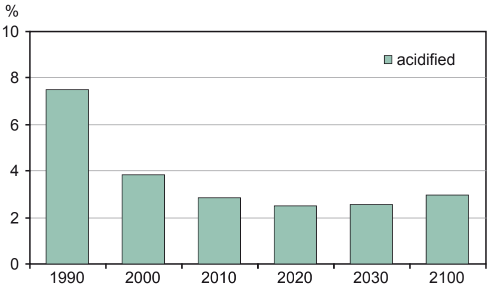
There are about 100 000 lakes in Sweden (lake area > 1ha). During the 1980's it became obvious that many of the lakes are being negatively impacted by air pollution. An ambitious lake monitoring program was put in place to assess lake water chemical changes. Since 1990 the chemistry of thousands of lakes has been monitored throughout the country (info1.ma.slu.se). The monitoring was designed to provide data representative for the country's whole lake population. The sampling program includes lakes sampled repeatedly and lakes sampled only during a certain year. About 50% of Sweden's area is covered by forests. Another monitoring program collects data on forests and forest soils throughout the country (www-markinfo.slu.se). These two programs provided data for 1200 lakes across Sweden for which past, present and future lake chemistry was modeled with the geochemical model MAGIC. Only lakes with time series of observed chemistry were modeled.

The model results were then built in to a database and assessment tool called the MAGIC library (www.ivl.se/magicbibliotek). The MAGIC library is based on the premise that similar lakes are likely to be similarly affected by air pollution. Similarity among lakes is determined by lake chemistry, land use, catchment soils and geology, lake size and geographical location, deposition history, and sensitivity to air pollution. To asses any lake with a known lake chemistry, annual runoff, and location (the assessment lake), the MAGIC library selects a similar lake from the catalogue of lakes (the library lake). The model prediction on the library lake is then assumed valid also for the assessment lake. By this procedure estimates of historical and future lake chemistry are provided for the assessment lake without modeling it directly. The extent to which a lake has been affected by air pollution is based on comparison of the estimated historical lake chemistry with observed present day chemistry. The anticipated future response of the assessment lake can similarly be estimated from the MAGIC simulation on the library lake. Present and future chemistry of the population of all lakes in Sweden was then assessed by using the MAGIC library containing the 1200 calibrated lakes.



Percentage of acidified lakes in Sweden (pH decreased by ≥0.4 units since pre-industrial time) estimated by extrapolating 1200 modeled lakes to ca 100 000 Swedish lakes using the MAGIC library. Limed lakes excluded.

Application of the INCA-N model to a steep forested alpine catchment in Austria

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The Integrated Nitrogen in Catchment Model INCA-N is a process-based model of the nitrogen cycle, and simulates the nitrogen export from different land-use types within a river system and the in-stream concentrations of nitrate and ammonium at daily time steps (Wade et al. 2002). INCA-N model has been successfully applied to various catchments across Europe, and - for the first time - it is here used to simulate the N-export from a steep forested alpine catchment in the Austrian Alps (Piburger See). The catchment has an area of about 1.5 km² and covers an elevation range of 900 to 2400 m a.s.l. More than 80% of the catchment area is covered by coniferous forest. In 2003, the lake tributary has been gauged, and average daily runoff during the calibration period was 8 L/s with minimum and maximum values of 2 and 65 L/s. Both intervals of high discharge, which are generally due to major snow melt or heavy precipitation events in summer, and low discharge periods during winter were simulated reasonably (Fig. 1). The big elevation range of the watershed represents a great challenge to the INCA-N model. In particular, the driving variable HER (hydrological effective rainfall) has to reflect the elevation dependent storage of precipitation in the snow cover during winter months as well as the increased water supply during major snowmelt. The assessment of HER was performed with the GWLF model (Generalized Watershed Loading Functions Model) (Schneiderman et al .2002), which gives daily values of so-called rainmelt, i.e. the sum of rain- and snowmelt, for different elevation bands within the watershed area. Here, we apply INCA-N to simulate in-stream concentrations of nitrate back to the 1960s and we estimate nitrate fluxes under a projected future climate.

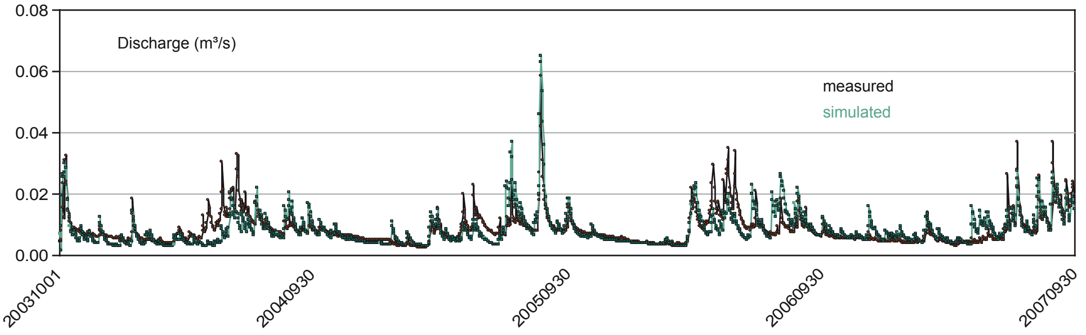

Fig. 1. Daily discharge of Piburger brook, the tributary to Piburger See, October 2003 – September 2007.

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Can trends and short term changes in water quality and phytoplankton of large lakes be explained by land use, point source load and climate?

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The monitoring of lake water quality was started in the 1960s in Finland. We examined the development of water quality and phytoplankton of 10 large (>40 km^2) lakes in eastern Finland during 1975-2007. Four lake types, categorized according to their surface area, natural state water colour, and mean depth were distinguished. Two of the lakes are separate headwaters, and some form a sequence in the same watercourse. The samples were taken both during the open water and winter seasons. Data on water quality (TN, NO_3-N, TP, PO_4-P, colour, conductivity, pH, alkalinity, COD_{Mn}, chlorophyll-*a*) and phytoplankton communities were analysed. In order to explain the trends or short-term excursions in water quality, we collected information on changes in atmospheric deposition, climate and land use. Land use developments in agriculture and peatland drainage within the immediate catchment of the lakes were estimated with help of statistics, map databases, and National Forest Inventory reports. Furthermore, records of loading from pulp mill industry, mines and municipal areas were screened.

The ca. 30 yr time series showed varying signals depending on the lake. Water quality parameters seemed to carry information of changes related to the activities in the catchment and the lake's position in the watercourse below the loadings of rivers and point sources. An overarching trend in the large humic lakes was a decrease in TN and TP in the epilimnion both in winter and in summer, accompanied in some cases by increased Secchi depth. The improvement of water quality, more clear in 1990's, could be a result of stopping the forest drainage and diminishing organic load from past forest drainages, but also of the decrease in atmospheric N deposition and lowered P loads from wood processing industry and municipal waste waters. Alkalinity and COD_{Mn} may indicate a recent change in water quality perhaps related to warmer winters with increased leaching. As an example of a point source impact, effluents from copper mine in the recipient could explain a clear shift in water quality in Lake Juojärvi between 1970-1985, and a fading effect after the cessation. The phytoplankton showed large variability in seasonality and the assemblages differed according to lake's TP concentration and colour. The low biomasses indicated oligotrophy with some exceptions.

The aim of our study is to resolve to what extent the changes in atmospheric deposition, climate, forest drainage, agriculture or point source loading may explain the trends and wiggles in the monitored time series of large lake chemistry and phytoplankton communities. Structural Equation Modelling (SEM) will be used to formulate and test several hypotheses on possible dependencies between water quality data, dynamics of external factors and lake characteristics for the different lake systems.

Changes in oxygen concentration in two small pristine boreal lakes, North Karelia, Finland

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Two small pristine lakes, L. Iso Hietajärvi and L. Pieni Hietajärvi, have been monitored for 21 years (1988–2008) in order to follow the long term variation of limnological parameters. The lakes are situated in the boreal forest zone in the same catchment area in Patvinsuo national park, North Karelia, Eastern Finland, and their immediate catchments belong to the Integrated Monitoring network (Kleemola and Forsius 2008). L. Pieni Hietajärvi is classified as humic-rich, while L. Iso Hietajärvi is a clear-water lake according to the Finnish lake typology. Ice-cover period lasts about 175 days. We discuss the variation of winter-time water quality of the lakes (temperature, oxygen O_2, total phosphorus TP, total nitrogen TN, chemical oxygen demand COD_{Mn} and colour) during the monitoring period. We also describe oxygen conditions in summer and some other water quality features with chlorophyll-*a* data of the lakes. The aim of this work is to identify the effects of varying precipitation and leaching conditions to the rate of oxygen consumption in small lakes.

Table 1. Hydrological features and some water quality characteristic of the study lakes.

Lake	Water area, ha	Mean depth, m	Maximum depth, m	TP* µg l^{-1}	TN* µg l^{-1}	Colour* Pt mg l^{-1}	pH*
Pieni Hietajärvi	2.4	3.5	7.0	12	270	120	5.85
Iso Hietajärvi	82	3.5	8.8	6	190	25	6.68

*epilimnetic median values for period January 1988-September 2008, number of observations 240–260.

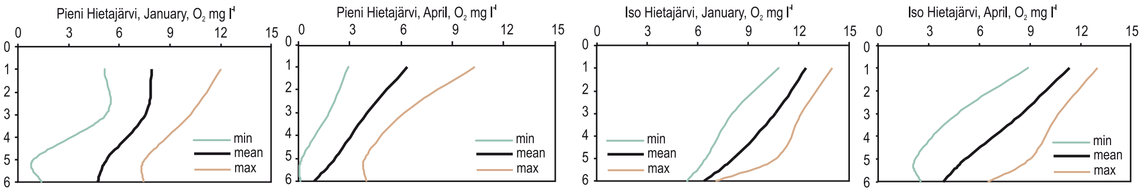

Fig. 1. Vertical oxygen concentration (O2 mg l-1) profiles in Lakes Iso and Pieni Hietajärvi in early and late winter: Mean with minimum and maximum values in January and in April during 1988-2008.

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Influence of dissolved organic matter on stream water chemistry in two forested catchments in central Sweden

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The paucity of knowledge about headwaters has recently been discussed by Bishop et al. (2008) and Temnerud & Bishop (2005) have shown that the variability in stream water chemistry for catchments <15 km^2 may be in the same order of magnitude as the variability in boreal forest streams in all of northern Sweden.

The current study was conducted on two first-order streams in adjacent forested catchments during two growing seasons. The catchments were similar in shape, size and drainage density - all physical characteristics that influences storm runoff. Due to their location, they were also exposed to similar weather conditions and precipitation.

Previous studies (Vestin et al. 2008) conducted in the Fan catchment indicated a high association of cations with high molecular mass (HMM) DOC in soil. To further investigate these findings, the quantity and quality of DOC, its seasonal fluctuations and its influence on cation levels in the stream water of both catchments were studied. Furthermore, the study aimed to apply a recently developed method to analyse the presence of low molecular mass organic acids (LMMOAs) in stream water, an area that essentially lacks previous investigation.

The streams showed significant differences in the content and size distribution of DOC and in the distribution of cations between the different size fractions. The Fan stream, with high DOC concentration and low pH, had a greater amount of HMM DOC to which approximately 50% of the total Ca and Mg and 75% of Al and Fe was associated (Fig. 1a). The Ref stream, with lower DOC levels and a higher pH, had approximately 30% of Ca and Mg and 50% of Al and Fe associated to its HMM DOC fraction. As a consequence of the differences in DOC composition, the two streams also showed significant differences ($p<0.05$) in carboxylic content. Thirteen different LMMOAs were continuously recovered in the stream water, of which oxalic (Fig. 1b) and lactic acid were the most abundant.

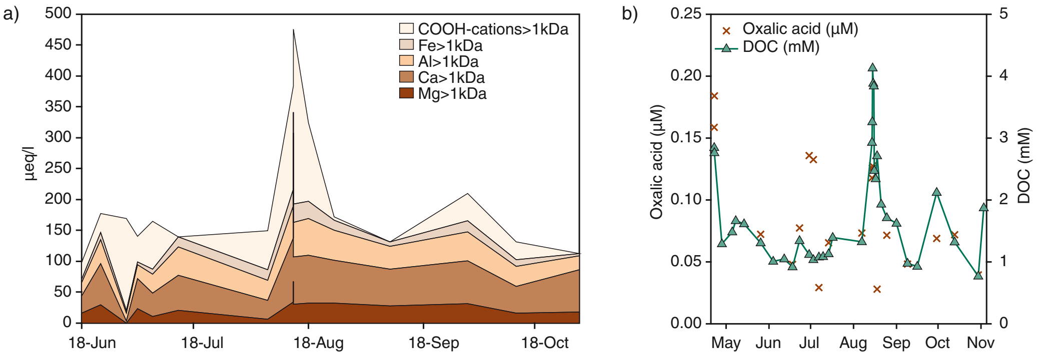

Fig. 1a. Seasonal variation of cations (µeq/l) recovered in the HMM fraction of DOC (cumulative), and the total amount of COOH (µeq/l) (top line) in the Fan stream. b. Oxalic acid (µM) and DOC (mM) in the Fan stream 2003.

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Deposition fluxes, soil and soil solution chemistry in a primeval mountain deciduous forest, Transcarpathia, Ukraine

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In the 1930s, soil chemistry and vegetation was studied in a primeval forest (mixed Fagus sylvatica and Acer pseudoplatanus) at the Javornik site in western Transcarpathia (Zlatnik, 1938). Since 2007, deposition, throughfall fluxes, soil solution chemistry and soil chemistry have been measured at this same site to assess long-term acidification in the area, which is expected to have been historically exposed to low acidic deposition.

Bulk deposition of inorganic nitrogen (N) and sulfur (S) was 13.3 and 8.6 kg ha^{-1} yr^{-1}, respectively, which was more than in the formerly highly polluted western Czech Republic (Načetín) where N deposition was 10.9 kg ha^{-1} yr^{-1} and S deposition 5.7 kg ha^{-1} yr^{-1} in 2007. Precipitation pH was similar in Javornik and Nacetin (4.77 vs. 4.71). Throughfall pH was 5.11 and N and S fluxes were 21.6 and 13.5 kg ha^{-1} yr^{-1}, respectively, in Javornik. At the beech forest at Nacetin, the throughfall pH was 5.13 and N and S fluxes were 17.2 and 8.2 kg ha^{-1} yr^{-1}, respectively. Markedly higher bulk deposition of calcium (Ca) was measured at the Javornik site (5.9 kg ha^{-1} yr^{-1}) compared to the Nacetin site (2.4 kg ha^{-1} yr^{-1}).

A high concentration of Ca and high pH in soil solution (Fig. 1) reflects the well-buffered bedrock (flysch). A surprisingly high concentration of nitrate (NO_3^-) was measured throughout the whole soil profile (Fig. 1). Soil exchangeable concentration of Ca and pH are also remarkably high (Fig. 2). Soil base saturation was 90% in the organic horizon and 28% in the mineral soil. The exchangeable soil pool of Ca, Mg and K was 1945, 200 and 272 kg ha^{-1}, respectively.

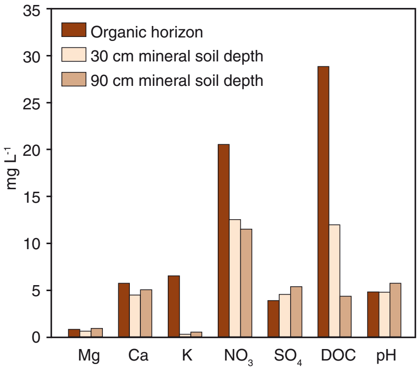

Figure 1. Soil solution concentration and pH (zero-tension lysimeters under the organic horizon and vacuum lysimeters in mineral soil).

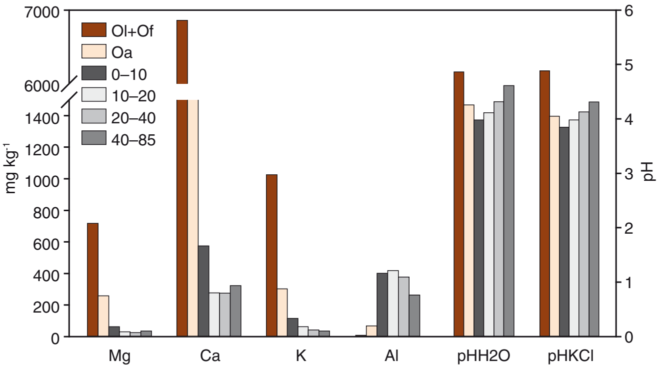

Figure 2. Average exchangeable cation concentrations and soil pH from 8 soil pits.

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Tree age related changes in needle morphology and photosynthesis : Norway spruce chronosequence

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Needle morphological and physiological characteristics were measured in Norway spruce forest chronosequence at Järvselja (eastern Estonia) in August, 2008. Study site is situated on a gleyed pseudopodsol soil formed on a loamy till and is characterized with large water storage capacity. We selected five different tree age-classes (10, 15, 21, 29 and 85 years old) and collected current year shoots growing in high light conditions of the upper canopy: average indirect site factor (ISF, characterizes diffuse light penetration) was 0.88. ISF was estimated by in situ hemispherical photography measurements. The shoots were then cut and photosynthetic (with Ciras-2 portable gas exchange system equipped with automatic conifer leaf cuvette) and morphological measurements were carried out. Trees were also measured for height and diameter at breast height.

ISF was not significantly influenced by tree age ($P=0.092$), indicating that the studied shoots were grown at similar light availability. Leaf mass per projected needle area (LMA) increased significantly with increasing tree age and height. This increase in LMA continued during the whole studied tree age span. Needle area-based photosynthetic capacity (maximum carboxylation rate (V_{cmax}) and maximum electron transport rate (Jmax)) was not significantly influenced by tree age. However, tree age had a significant effect on the mass-based photosynthetic capacity. 10-y-old trees showed the highest values of mass-based Vcmax and Jmax, then a remarkable decrease (about 1.8 times) was evident in 15- and 21-y-old stands, followed by a further increase (1.4 times) in 29- and 85-y-old stands. Thus, the lowest mass-based photosynthetic capacity was detected in these stands that had recently become reproductive and produced cones.

Sensitivity and uncertainty analysis for the INCA-N application to two small Finnish catchments

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The semi-distributed, dynamic INCA-N (Integrated Nutrients from Catchments – Nitrogen) model (Wade et al., 2002; Whitehead et al., 1998) was applied to two research catchments in Finland, within the EU Euro-limpacs project. The aim was to simulate nitrogen (N) loads under different climate change scenarios. The Mustajoki site (78 km^2) is a typical forested upstream catchment located in highlands in southern Finland, while the Savijoki catchment (15 km^2) represents intensively cultivated lowlands in south-western Finland.

As climate change scenarios may lead to extreme conditions outside the circumstances where the model was calibrated, both parameter sensitivity and model structure were analysed. Sensitivity analysis tells how model output changes in response to changes in the model parameters. Uncertainty analysis aims to quantify the accuracy of one or more outputs. In this study the generalized sensitivity analysis of Spear and Hornberger (1980) was used. The method was applied in two stages. First, a set of Monte Carlo simulations with different parameter combinations were divided in to behavioural (10% of the runs) and non-behavioural runs based on the goodness-of-fit value between observations and simulations. Second, the non-parametric Kolmogorov-Smirnov test was used to evaluate difference in parameter values between behavioural (B) and non-behavioural runs.

In general, there were more influential parameters in the agricultural than in the forested catchment. In both model applications, most of the influential parameters were connected to temperature dependencies of N processes, some to N process rates and only few to moisture dependencies. Values of the sensitive parameters were based on long-term measurements, so they covered estimated future climate. In uncertainty analysis highest observed concentrations fell between the modelled minimum and maximum uncertainty bounds (Fig. 1). The lowest observed concentrations did not fall between those bounds indicating that some of the retention processes maybe missing in the current model structure. The lowest concentrations occurred mainly during low flow periods; so the effect on total load was small. Thus INCA-N can be used in climate change simulations as long as the interpretation of results is based on loads.

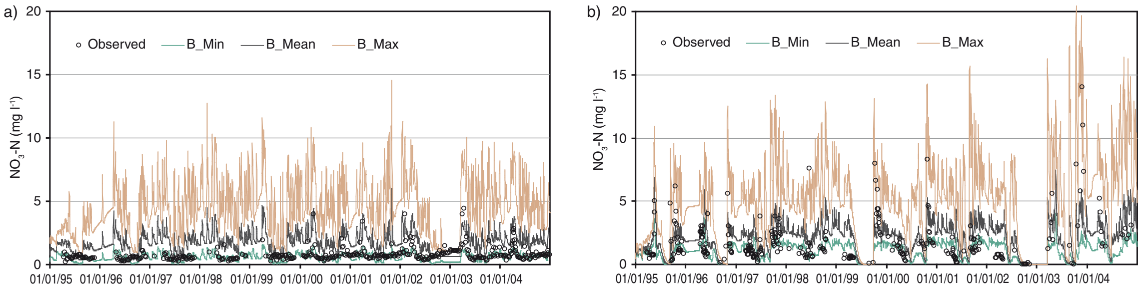

Fig. 1. Observed and simulated nitrate concentrations a) in the forested Mustajoki catchment and b) in the agricultural Savijoki catchment.

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Application of catchment scale erosion and sediment delivery model INCA-SED to four small study catchments in Finland

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The term ‘sediment delivery’ has been widely used to describe the combined processes of sediment movement within a catchment, from soil erosion on slopes through to fluvial export at the catchment outlet. The INCA-SED (Integrated Nutrients from CAtchment- Sediment) model is based on semi-distributed approach which incorporates readily available environmental data of hydrometeorology, land use, erodibility and catchment and channel morphology at an appropriate level of spatial aggregation. In the INCA-SED model the main river channel is divided into series of reaches. The land area that drains into each of these reaches is then defined as a sub catchment. The basic modeling unit of land use specific soil erosion processes is then a land use class in the sub catchment.

The INCA-SED model is applied to four small study catchments in Finland. Three of the study sites are headwater catchments located in central Finland around the lake Pääjärvi. The rivers Mustajoki, Haarajoki and Luhdanjoki have different morphological characteristics varying from a ditch to a small river. Soil types in the area are relatively coarse, mainly moraine and silt loams. The Mustajoki (78 km^2) and Haarajoki (58 km^2) catchments are forested and only 10% of the area is under cultivation. In the Luhdanjoki catchment (25 km^2) agricultural fields cover 40% of the area. The forth study site, the Savijoki catchment (15 km^2) represents intensively cultivated areas in south-western Finland. Fields cover 40% of the catchment area, and they are located on clay soils along the river. The INCA-SED model is calibrated by using information of the Geographical Information System and water quality monitoring databases of Finnish Environment Institute. Hydrological input is derived from the results of the operational Watershed Forecasting and Simulation System.

The INCA-SED model is able to capture both the correct level and seasonal behaviour of suspended sediment concentrations in the rivers as well as the correct level of sediment load from different land use classes. Even small differences in river morphology and soil types between the catchments seem to have an influence on suspended sediment concentration in the rivers (Fig. 1). Correct timing of suspended sediment concentration peaks is not captured, which may be due to stochastic nature of erosion processes in a catchment scale. The highest simulated peaks occur usually in the beginning of runoff events and these peaks are usually missing from observation time series. This indicates that observation program (about 30 water samples per year) is probably not able to give a correct picture of sediment processes in the catchments.

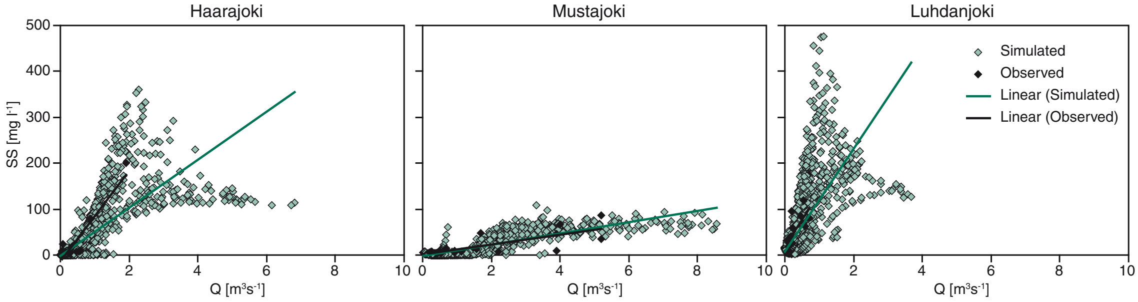

Fig. 1. Simulated and observed suspended sediment concentration vs. discharge in the rivers Haarajoki, Mustajoki and Luhdanjoki

Precipitation amounts and the colour of water - A 25 yrs long study (1983–2008) of a drinking water supply in Norway

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A long term study of Lake Elvåga (59°N, 10°E, 196 m a.s.l.), a raw water source in Østmarka close to Oslo in south-eastern Norway, has revealed a significant increase in concentrations of coloured dissolved natural organic matter (DOM) throughout the past 25 years.

Along with the reduction of acid rain component concentrations, which was most pronounced in mid 1970s, the colour in Lake Elvåga has steadily increased. The amount of annual precipitation and the annual average sulphate and chloride concentrations in precipitation has for the period 1983 – 2005 been found to be the best predictors for the long term lake colour variation and development, by means of a best sub-set regression analysis among the available metrological and chemical parameters. However, at present the concentration of acid components is now very low and on pre World War II level. Due to the chemical composition of precipitation today, the annual precipitation amounts seem to the most important factor for the organic carbon concentration and the colour of Lake Elvåga.

How important is climate variability in determining the fate of N deposition in a remote Finnish forested catchment?

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Acid deposition loads have strongly declined throughout Europe and North America over the last few decades, mainly as a result of a reduction in sulphur emissions. But while sulphate deposition has decreased, nitrogen (N) deposition loads have largely remained unaltered. Much of the N deposition in Finland is derived from overseas and transported long distances. Meteorological factors therefore play a strong role in determining deposition loads. The annual N deposition load was rather constant during the 1990's (2–3 kg ha^{-1}), which is low compared to western and central Europe.

Because forest ecosystem productivity is usually limited by N, especially in boreal forests, relatively high loads of N are required in order for N deposition to break through into soil water and to appear in ground and surface waters. However, the fate of low but chronic loading of N deposition to boreal forest ecosystems under conditions of changing climate is unclear. We report on the variability in concentrations of N in various aqueous media (bulk deposition, throughfall, soil water, ground water, stream water and lake water) collected at the Hietajärvi Integrated Monitoring catchment over the last 20 years, and evaluate the results in relation to climatic factors. This time period has exhibited considerable interannual variation in climate, particularly in relation to summer rainfall and drought, and in snow cover duration.

Hietajärvi is an undisturbed forested headwater catchment (463 ha) located in the middle boreal coniferous region (63°09'N, 30°40'E). The terrestrial part of the catchment consists mainly of upland mature Scots pine forest and peatland. The climatic zone is continental subarctic. The mean annual temperature is 2 ºC, the warmest month being July (mean 15.8 °C) and the coldest January (mean -12.0 °C). The effective sum of temperature during the growing season varied between 906 and 1328 d °C over the study period. The mean annual precipitation is 600 mm, the highest rainfall occuring during the summer and autumn months. The duration of the snow cover period during 1988–2007 varied between 92 and 195 days. Since there is a rapid release of N deposition from melting snow, we hypothesized that the length of the snow period would be an important factor in explaining the interannual differences in the flow of N through the ecosystem.

Predicting the effects of climate change on agriculture and consequent effects on water quality and quantity in the Kennet Catchment, UK

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There have been numerous studies on the potential effects of climate change on agriculture, and of agricultural change on water quality, and the effect of climate change on water quality is an active research topic. This paper reports a pioneering attempt to integrate all these aspects. The work started from a set of climate change scenarios and used a series of economic models of world and local agriculture to predict agricultural change in the catchment of the River Kennet in southern England. The changed land uses and climates were then used to drive water quantity and quality models to predict changes in discharge and nitrate concentrations in the river.

The A2 ("national enterprise") and B2 ("local stewardship") storylines from the IPCC *Special Report on Emissions Scenarios* (SRES) were used to estimate both climatic and socio-economic changes. Agricultural change was estimated using the University of Reading Climate and Land-Use Allocation Model (CLUAM). This is an established linear programming model of agriculture in England and Wales, which aims to calculate the economically optimum agricultural land use under given conditions. This in turn was fed by models of the world agricultural system driven by the SRES scenarios. Models were run with and without local climate change. The end product was a series of projections of agricultural land use in the Kennet catchment in the years 2020 and 2050 given a) coupled climate and socio-economic changes and b) socio-economic changes alone.

The pattern of predictions was complex. In all scenarios, cereals replaced most other arable crops in 2020 and 2050, but the overall arable area did not change much. In most scenarios, the area of temporary grasslands was significantly reduced, and permanent pasture was essentially eliminated. Fertiliser application was reduced in most scenarios, but more so in the A2 storylines than the B2. Socio-economic changes had the largest impacts, the effects of climate change being to modulate these.

The INCA-N Model was applied to these changes to explore the potential effects on N concentrations and flow in the River Kennet. The model was calibrated to give realistic concentrations under current conditions using observed data Then it was run with appropriate changed land uses and climates, generated by downscaling predictions from the HADCM3 Model. Sixty annual "realisations" of each scenario were generated.

The results showed a reduction in river flows of 15–17% by 2050 due to increased evapotranspiration in the warmer predicted climates. The period during which the river was maintained solely by groundwater increased to over 6 months in 95% of modelled years by 2050. Predicted nitrate concentrations in the river decreased in both 2020 (15–19%) and 2050 (15–25%), depending on the scenario. These reductions were due partly to reductions in fertiliser inputs, and partly because the nitrogen sink processes in the catchment soils and waters were predicted to increase in rate more than the catchment nitrogen sources. These results will be discussed, as will the uncertainties in this chain of predictions, and the extent to which the models can be constrained to give a credible estimate of the effects of climate change on water quality. The results show, however, that potentially changes in the world agricultural system can affect water quality at the catchment scale, but it is hard to predict what that influence might be in individual cases

Air pollution effects on aquatic ecosystems

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Many lakes and rivers are chemically and biologically very sensitive to changes in long-range transported air pollution and are thus highly suitable for monitoring effects of air pollution. This poster presents the major accomplishments from the International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes (ICP Waters) under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP). Long-term monitoring programmes are the basis for all activity in ICP Waters. The ICP Waters network is geographically extensive and includes long-term data series (10–25 years) for more than 200 sites. The sites include background sites in (semi-) natural ecosystems and are valuable also for detecting impacts of climate and global change.

Lakes and rivers show strong signs of recovery in response to reduced acid deposition in Europe and North America since the 1980s. The consistent pattern of chemical recovery across a large number of sites is the strongest evidence that emission control programmes are effective. In many areas, water quality is now sufficient for the return of acid-sensitive aquatic biota. Some areas, however, show a distinct lack of chemical recovery.

Biological monitoring in ICP Waters focuses on acid-sensitive invertebrate species. Improved chemical water quality has resulted in recovery of aquatic biota in the Nordic countries, Canada, the UK and the Czech Republic. Biological recovery is not as evident in other acidified regions in Europe. This may be related to insufficient chemical recovery but also to lacking long-term data biological records.

Chemical recovery of many ICP Waters sites will not be sufficient to sustain biological recovery by 2010. This is predicted by dynamic acidification models that calculate water chemistry assuming that S emissions are reduced according to the Gothenburg Protocol.

Nitrate in surface waters shows upward, downward and neutral trends, unlike the almost universal decreasing trends in sulphate. In some regions, declines in N deposition coincide with downward trends in surface water nitrate. Elsewhere, trends in nitrate in surface waters are thought to be related to climate, forest growth and N saturation, or are simply not understood. Acid-sensitive ecosystems continually enriched with nitrogen which increases the probability of future acidification and eutrophication due to nitrate leaching.

Surface waters in North America and Europe have become browner in the last decades due to increased concentrations of dissolved organic carbon (DOC). ICP Waters data document that upward DOC trends are related to declining deposition of sulphate.

Climate change may significantly influence the behaviour of both terrestrial and aquatic ecosystems significantly. Long-term data series show sea-salt episodes setting back biological recovery several years. Droughts lead to acidic episodes upon rewetting. The extent of N-retention in a warmer climate, and consequently the future influence of N on surface water acidification, represents a key uncertainty in recovery from acidification.

Snowmelt infiltration through partially frozen soil in Finnish Lapland

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Snowmelt timing is critical for tree growth in high latitudes. However, the threshold conditions with respect to root-zone soil water availability in spring are not well understood. We measured snowpack thickness, apparent snow water (ASW), air and soil temperature, as well as soil water content (SWC) in Moskuvaara (67˚37'34''N, 27˚10'30''E) and Järvijoki (68˚02'17''N, 26˚05'49''E) sites in spring 2008. The sites host mature Norway spruce stands underlain by Haplic Podzol developed on silty and sandy tills. Soil temperature probes (T107) and soil water content reflectometers (CS616) were placed at 20-cm-increments into the soil sequence. Snow depth was measured with (SR50A) sonic range sensors (Campbell; see photo below) and ASW with dielectric leaf wetness sensors (Decagon). All parameters were automatically logged with Campbell CR1000 data-logger in 3-h-intervals. The maximum snowpack thickness varied from 84 cm (on 30th of March) in Moskuvaara to 90 cm (on 14th of April) in Järvijoki. Due to air temperature rise notably above zero 0˚C on mid-April, the onset of snowmelt occurred on 29th of April 2008 at both sites. The observed maximum ASW was simultaneous with the maximum SWC on the 2nd of May (see graph below). At 60 cm depth soil remained unfrozen through winter. In contrast, soil temperature at 20-cm-depth was below zero 0˚C until 18th of May in Moskuvaara and 28th of May in Järvijoki. These dates were rather concurrent with snow disappearance; 15th of May in Moskuvaara and 25th of May in Järvijoki. Snowmelt water percolated through the soil such that SWC (at 20-cm-depth) had its maximum 16 days (Moskuvaara site) and 26 days (Järvijoki site) before the soil temperature exceeded 0˚C.

We contend that snowmelt infiltration through partially frozen soil significantly contributes to ground water reserves and soil water availability, rather than soil temperature, is pivotal for the start of height increment of trees in northern boreal conditions

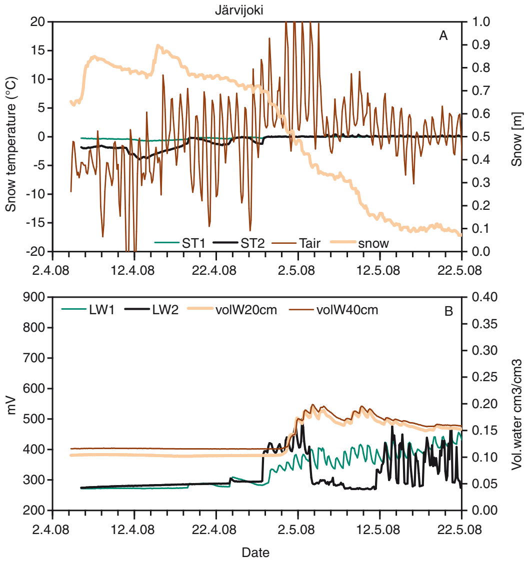

Fig. 1. Changes in climatic variables and soil properties at Järvijoki spruce site during the late spring 2008. A. Snow temperature on ground surface (SWT1) and 30 cm above ground surface (SWT2), air temperature (Tair) as well as thickness of snowpack (snow). B. Apparent snow water on ground surface (LW1) and and 30 cm above ground surface (LW2) as well as soil water content at 20-cm-depth (volW20cm) and 40-cm-depth (volW40cm).

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Modelling of denitrification flux over a whole drainage network

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Denitrification is an important process of nitrogen cycling in river ecosystems as it can regulate nitrogen availability, and therefore primary production, controlling the degree of eutrophication. The strength of denitrification within a river network can alternate very rapidly in space and time and is essentially driven by the interactions between surface water, river geomorphology and microbial process rates. Thus, in order to better predict and quantify the importance of benthic denitrification in the removal of nitrogen from an entire drainage network, a deterministic sediment model (Thouvenot, M., Billen, G., Garnier, J., 2007. Modelling nutrient exchange at the sediment-water interface of river systems. Journal of Hydrology 341/1-2, p.55-78) was linked to a hydrological/biogeochemical model (Riverstrahler). The benthic model includes the calculation of nutrient exchanges across the sediment-water interface as a result of the sedimentation flux of organic material provided by Riverstrahler.

The application of the coupled model over the entire drainage network of the Seine river system, in France, indicated that the model simulated the observed increase of organic matter content in the sediment with stream order and its subsequent increase of oxygen and nutrients fluxes at the sediment water interface. Moreover, in the upper Seine, the model was able to reproduce the impact of point source pollution in terms of ammonium and nitrate concentrations in the river and fluxes across the sediment-water interface at a kilometric step (Fig. 1). The coupling of pelagic and benthic processes allows us to determine low and high denitrification spots/times along the river network during the year and to model benthic denitrification accordingly, in order to quantitatively predict its importance in the removal of nitrogen at the scale of the whole river system. The comparison of nitrogen budgets from two different hydrological years (wet and dry) shows the impact of the hydrology on the denitrification budget in terms of proportion and quantities. It also shows that although riparian denitrification is more important than benthic denitrification, the latter cannot be neglected during dry years as it contributes to up to 10% of the losses from river inputs (Fig. 2).

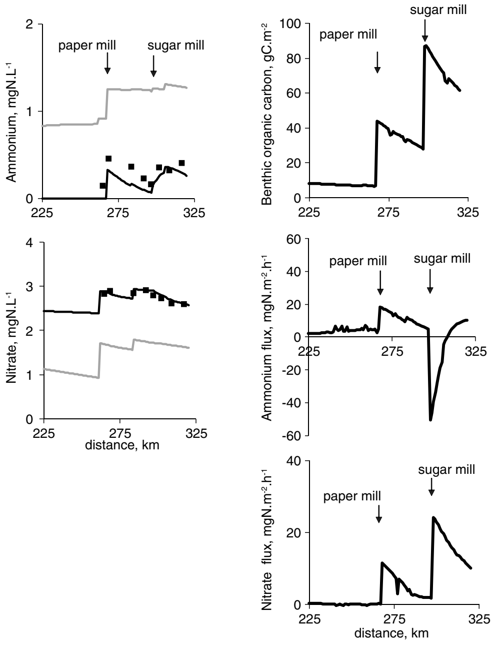

Fig. 1. Simulation of ammonium and nitrate concentration profiles without (grey line) or with (black line) taking into account the diagenetic processes of September 2003 in the downstream sector of the Aisne River subject to two large discharges of organic matter. Observations and simulated values of the benthic organic matter and of the nitrate and ammonium fluxes across the sediment water interface (fluxes are negative when directed to the water column) are shown for comparison.

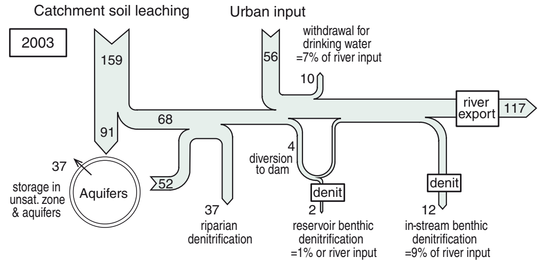

Fig. 2. Annual Nitrogen budget (10^3 TN.yr^{-1}) at the scale of the Seine drainage network under the hydrological conditions of a dry year (2003).

Modelling acidification recovery at long-term monitoring sites: a multi-model evaluation

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Multiple model frameworks have been widely used in air quality (Dentener et al., 2006) and climate (Randall et al., 2007) assessments. Ensemble simulations from multiple models provide an assessment of all possible future states based on current knowledge. In the current study, future soil and surface water chemistry at four long-term monitoring stations (Hubbard Brook, USA; Plastic Lake, Canada; Höglwald, Germany; Birkenes, Norway) were simulated using four process-oriented dynamic acidification models (MAGIC, PnET-BGC, SAFE, VSD). The chosen study sites are rich in data required for model calibration. They also represent different ecosystem types currently under acidification threats despite declining acid deposition.

The multi-model evaluation employed in the current study consists of three steps. First, uncertainty associated with observed model input data was addressed through Monte Carlo simulation wherein data were sampled from distributions based on site observations, and in turn translated into model-specific input formats. This ensured consistent inputs to each of the models. Comparison of the Monte Carlo runs among models provides insights into how structural differences may affect simulations (Tominaga et al., submitted). Second, the models were calibrated against the 20+ years of observations at each study site by filtering the Monte Carlo runs (i.e., criteria were set to assess if a particular model run agreed with observations). The calibrated parameter spaces were compared among the models in order to elucidate the relationship between the model input parameters and the models themselves. Third, soil and surface water chemistry through to 2100 were assessed under a legislated future emissions scenario for North America and Europe using the four calibrated models to assess the impact of current legislated emissions.

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20 years of integrated monitoring at Kosetice Observatory

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Long-term monitoring and research activities in small forest tributary of Anenský brook in the western part of Czech-Moravian Highland have been implementing as a part of integrated monitoring at Kosetice observatory of the Czech Hydrometeorological Institute. The Observatory was established as a station specialised in the problems of regional environmental quality monitoring and research in 1988 and is situated at 49°35´ N latitude and 15°05´E longitude. Elevation above sea level is 534 m. The observatory is involved in following long-term programmes and projects of monitoring and assessment of natural environment at the background scale: ICP-IM (International Co-operative Programme on Integrated Monitoring), EMEP/ECE (Co-operative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe), GAW/WMO (Global Atmosphere Watch), ACCENT (Atmospheric Composition Change–The European Network of Excellence) and EUSAAR (European Supersites for Atmospheric Aerosol Research). Monitoring programme of Kosetice observatory includes meteorology, solar radiation, air chemistry, precipitation chemistry, hydrology and surface water chemistry, soil and soil water chemistry and POPs monitoring in all compartments of the environment. More detailed information is available at www.chmi.cz/uoco/struct/odd/ook/indexe or in (Vana, Holoubek 2007).

The results of long-term monitoring in the period 1989–2008 show that:

- The reduction of sulphur emissions in the Czech Republic has resulted in decreasing of background sulphur deposition. The greatest difference is observed in throughfall. A distinct reduction of sulphates occurs in the basin. Sulphur input was decreasing continuously from 20–30 kg.ha^{-1}.year^{-1} in the first half of the nineties to 5–10 kg.ha^{-1}.year^{-1} after 2000. Reduction of sulphur input by almost constant output caused basic changes in sulphur balance in the catchment. In the beginning of 1990s retention predominated very rapidly, but since 2000 leaching was found.
- There is not considerable trend observed in nitrogen deposition. The nitrogen budget provides evidence of large consumption by vegetation. Nitrogen runoff displays a characteristic annual course, with its maximum in the spring when the vegetation is still unable to consume this element and water runoff is high, the minimum occur in the summer and autumn.
- The output of basic cations exceeds their input. The sources of these cations currently include ion exchange process in the soils, with the primary weathering of minerals accounting probably for their smaller part. Their output increases in last years while acidity of precipitation is decreasing.
- The level of pH in precipitation water increased continuously during the period under review. The most significant increase was registering in throughfall (from 3,8 in 1990 to 4,7 currently), the figure in free area is from 4,4 in 1990 to 5,0 at present. The highest pH is read in cases when air masses have their origin in the west (4,7) and the lowest values are measured when they come from the north (4,3).
- The annual mean surface ozone concentration stabilised in the nineties at a relatively high level (60 to 70 μg.m^{-3}) and has not increased further. Situations with rapid increase of ozone concentration, which then has a negative effect on human health, usually occur in longer periods of hot summer weather (extreme temperatures, high intensity of solar radiation). During such episodes extensive regions on a scale which goes beyond the borders of the Czech Republic are progressively affected.

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Monitoring of ecosystem patterns and processes in an artificial catchment in Lusatia, Germany

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Long-term formation of structures and processes during the initial phase of ecosystem development is investigated in an artificial catchment ´Chicken Creek´/´Hühnerwasser´ in the lignite-mining area of Lusatia, Germany. The catchment has an area of 6 ha and including a small lake.

A comprehensive monitoring program is carried out in the catchment including: meteorology, atmospheric bulk deposition, dust deposition, grid soil sampling, soil solution chemistry (ions, DOC, TOC, grain size, etc.), soil water (TDR, tensiometers), hydrology (stream flow, groundwater, water quality, etc.), erosion, vegetation development (species, cover), soil fauna (species, abundance), and limnology (water quality). A mini-drone system is used for monitoring the vegetation pattern and surface structures. The gathered data are the basis for the calculation of water and element fluxes in the ecosystem and their interactions with the formation of observed structures. The data will be integrated in a structure-processes-model and hydrological models for further analysis. First results will be presented and discussed.

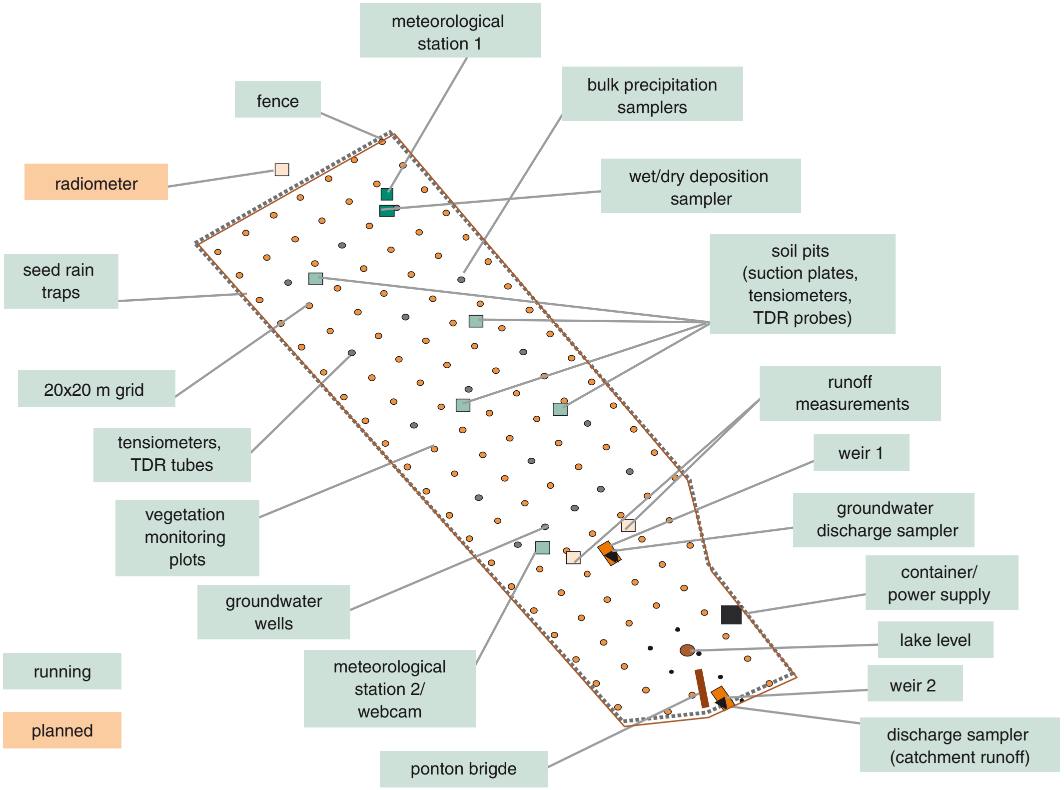

Fig. 1. Monitoring design at the artificial catchment ´Chicken Creek´/´Hühnerwasser´

Dynamic modelling of the potential impacts of climate change on water quality and ecology in six UK rivers

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A modelling study has been undertaken to assess the likely impacts of climate change on Water Quality across the UK. A range of climate change scenarios have been used to generate future precipitation, evaporation and temperature time series at a range of catchments across the UK. These time series have then been used to drive the Integrated Catchment (INCA) suite of flow, water quality and ecological models to simulate flow, nitrate, ammonia, total and soluble reactive phosphorus, sediments, macrophytes and epiphytes in the Rivers Tamar, Lugg, Tame, Kennet, Tweed and Lambourn. A wide range of responses have been obtained with impacts varying depending on river character, catchment location, flow regime, type of scenario and the time into the future. Essentially upland reaches of river will respond differently to lowland reaches of river and the responses will vary depending on the water quality parameter of interest.

Multiple approaches for modelling topographically planar peatland dominated catchments: response to acidic deposition

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Acid-sensitive catchments in the Athabasca Oil Sands Region of northern Alberta, Canada are presently under a perceived threat due to elevated levels of acid deposition. Increased S and N deposition originate from localized industrial emissions associated with the extraction and processing of bitumen from the world's second largest recoverable oil deposit. Industrialization of the region is a relatively recent (40 years) phenomenon, but rapid proliferation has occurred during the last decade and further expansion is anticipated for the first half of this century. Consequently, emissions of S and N in the region are expected to remain elevated indefinitely. Dynamic models are required to predict the future response of soil and surface water chemistry to acidic deposition to identify if and when critical chemical limits will be reached (i.e., the time-to-effects). The dynamic hydrogeochemical Model of Acidification of Groundwater in Catchments (MAGIC: Cosby et al. 1985) is being used in this assessment, and model output will be used in conjunction with monitoring data to guide emissions management policy.

This presentation will provide an overview of the methods used to apply MAGIC in the study region. Model application is a challenge in this complex environment and a novel approach is required owing to ill-defined hydrology, catchment heterogeneity, and extensive coverage of poorly understood fen complexes. Three approaches are used: a plot-scale application to forest soils, an interactive application to intensively studied catchments, and an automated application to regional lake catchments. The plot-scale application requires calibration to mineral soil chemistry (i.e. base saturation). The interactive application consists of a calibration to lake water chemistry at two well studied peatland dominated catchments receiving different levels of S deposition. Model parameterization at these catchments incorporates site-specific data from detailed physicochemical measurements of soils and surface waters. The techniques used for model calibration (e.g. flow routing, attribution of elemental sources and sinks) will be illustrated with reference to current understanding of the hydrologic behaviour of the two intensive catchments. The information gained from the interactive calibration is being extended to the regional application covering a large group of lake catchments (n = 48). It is anticipated that this exercise will enable assessment of the suitability of the approaches used in the site-specific calibration across a more diverse population. The regional application comprises lake catchments covering a range of data availability: those where mineral soil, fen and seasonal lake sampling took place to those where only annual lake chemistry was measured. This suite of approaches to MAGIC application enables prediction of time-to-effects under future emissions scenarios for the region.

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The Flux of Nitrate from Great Britain 1974–2005 in the context of the terrestrial nitrogen budget of Great Britain

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This study compiles long term records of the concentration of nitrogen species from British rivers in order to assess the temporal change in the total fluvial flux of nitrogen in comparison to the other inputs to and outputs from the UK terrestrial biosphere. The study considers the following nitrogen species: ammonia, nitrate, nitrite, dissolved organic nitrogen and particulate organic nitrogen. Concentration and flow records could be reconstructed from 1974 to 2005 for ammonia, nitrate, nitrate and dissolved organic nitrogen (DON) and from 1992 for particulate organic nitrogen (PON). The reconstructed fluvial nitrogen time series was compared to records for inorganic fertiliser, atmospheric. The results of the study show that:

- The total dissolved nitrogen flux over the study period when flow corrected varied from 470 to 980 ktonnes N, the average composition of that flux is: 69% nitrate-N; 26% dissolved organic-N; 4% ammonia-N; and 1% nitrite-N.
- The total nitrogen flux including PON varied from 504–1004 Ktonnes N yr^{-1}.
- The flux of ammonia-N shows a significant decline over the study period, but significant increases in both nitrate-N and dissolved organic-N mean that the total dissolved nitrogen flux shows a significant increase of 6.3 ktonnes N yr^{-1}.
- The dissolved nitrogen flux record shows both a steady increase and sharp discrete rises in response to severe droughts. The rise in response to severe droughts is not consistent with a storage effect of reduced flows but appears to represent new production in the year of the drought.

The long term rise of fluvial nitrogen flux from British rivers is in contrast to declines in inputs and other outputs, that although Great Britain is an overall sink of total nitrogen the size of this sink is diminishing. The nitrogen budget for the UK is then compared to historic land-use change within the UK since the 1930's and an export coefficient model is used to assess to what extent the present budget is still reposnding to historic releases of nitrogen and therefore, what might be expected into the future.

Continuous BVOC emission measurements from boreal forest floor

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Biogenic volatile organic compounds (BVOCs) constitute the largest part of volatile chemicals produced and emitted by the biosphere (Guenther et al. 2006). In troposphere BVOC compounds take part in chemical reactions which affect the formation and growth of aerosols (Kulmala et al. 2000). Aerosols themselves are important in the formation of clouds which increase the albedo of the atmosphere and thus slow down the warming of troposphere. Although the boreal zone is the largest forested region in the world, understanding on the dynamics of soil processes and the roles of different soil components such as roots, rhizosphere and decomposing organisms to BVOC formation and deposition is limited. In boreal forest soil, BVOC emissions have been observed to be the highest in spring and autumn (Hellén et al. 2006), but the processes behind seasonal fluctuation are still uncertain. Soil temperature and humidity conditions have a direct connection to many physical and biological processes of soil BVOC-formation (Asensio et al. 2007). Thus climate change and soil BVOC emissions may have a close interaction via feedback reactions, which raise an urgent need of soil process based studies of BVOCs.

We have conducted continuous BVOC emission measurements at SMEAR II station in Hyytiälä, in southern Finland, with an automated soil chamber connected to on-line PTR-MS (Proton Transfer Reaction-Mass Spectrometer). To determine spatial variation in soil BVOC emissions, we have measured also with manual chambers from ten collars installed at the site. Air samples are taken from the flow-through chambers into Tenax-adsorbent tubes and analysed by GC-MS (Gas Chromatography-Mass Spectrometer).

Preliminary results show, that BVOC emissions fluctuate greatly during the snow-free time between May and October when soil is unfrozen and microbial population is in the active stage. The emissions peak in the middle of the summer and in the autumn, when the soil function is at its highest due to high temperatures and high litter input. Emissions consist of mono- and sesquiterpenes and short-chained oxygenated compounds such as methanol. According to our results it is evident that manual measurements are needed to get an estimate of the spatial variation. Especially between forests of different tree species (Scots pine vs. Norway spruce) there are significant qualitative and quantitative differences in the amount of BVOC emissions.

Most of BVOCs from the soil are emitted by plant roots, but also microbes play a significant role in the production on of BVOCs. Chambers placed on the ground measure flux from the soil as well from all the plants inside the chamber. To measure fluxes from the bare soil, we have installed below ground BVOC profile collectors at the SMEAR II station. For measuring wintertime emissions, we have installed also snow cover BVOC profile collectors at the station. These collectors together with automatic and manual chamber measurements can give valuable information on the seasonal pattern of BVOC fluxes as well as on the BVOC formation and consumption processes in the soil. This data will be used in the future to build up a model for estimating the BVOC emissions from boreal forest soil and forest floor. The results of this study provide also quantitative information on BVOC emissions from boreal forest soil for climate modelling.

BVOC emissions of fungal species occurring in boreal forest soils

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Volatile organic compounds (VOCs) consist of a large group of volatile hydrocarbons originating from both natural and human activities (Guenther et al. 2006). In troposphere, the VOC compounds take part in chemical reactions which affect the formation and growth of aerosols (Kulmala et al. 2000). Aerosols themselves are important in the formation of clouds which increase the albedo of the atmosphere and thus slow down the warming of troposphere. Most of biogenic VOCs (BVOCs) emitted by flowers, fruits and green parts of plants can function as inter- and intraspecific messenger compounds, and as repellents or attractants for insects, but also decomposing processes, roots (Hayward et al. 2001) and micro-organisms (Leff & Fierer 2008) can produce and emit these compounds. Although fungi, as an important part of soil micro-organism pool, have a role on the decomposing process, the quantity and quality of their BVOC emissions is still poorly known. We decided to measure emissions from several fungal species from different functional groups (decomposer, ectomycorrhizal and endophytic fungi), originating from boreal forest soils.

Eight different fungal strains were grown as pure cultures in nitrogen poor liquid media for approximately one month in dark and in constant temperature (+28°C). We measured BVOC emissions from cultures with on-line PTR-MS (Proton Transfer Reaction-Mass Spectrometer) and collected samples to Tenax-adsorbent tubes for GC-MS (Gas Chromatography-Mass Spectrometer) analysis. In addition to the PTR-MS measurement of the calibrated compounds with quantitative results, we performed a run measuring all the compounds atomic masses between 29–248 g mol^{-1} in order to detect potential volatile compounds that have earlier not been connected to fungal processes. Two instruments were used to broaden the spectra of detectable compounds: PTR-MS can detect also short chained oxygenated BVOCs, while the GC-MS can separate compounds with same atomic mass (for example different monoterpenes, atomic mass 136 g mol^{-1}).

The biomass production in different cultures varied greatly, the highest production being 68-fold compared to the lowest. However, all studied fungal species emitted some BVOCs although the emitted quantities varied by two orders of magnitude between species, but the variation was more species-related than biomass-dependent. Among the most prominent short chained oxygenated compounds were acetone, methanol and acetaldehyde, also C-6 and C-8 carbohydrates were detected. We observed also isoprene, monoterpene and sesquiterpene emissions, but excluding a few fungi species emissions of those compounds were generally low. The summed emissions of monoterpenes were in the range of a few up to 800 ng g(DW)$^{-1}$ h^{-1}, and those of sesquiterpenes below 10 ng g(DW)$^{-1}$ h^{-1}, which are on average equal or lower than those measured e.g. from Scots pine needles (e.g. Hakola et al. 2006).

Methyl halide emissions from a SE Asian tropical rainforest

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Tropical rainforests have been implicated for a long time as major sources of both methyl bromide (MeBr) and methyl chloride (MeCl). This has been especially important as the known sources and sinks of these two ozone-depleting gases do not balance, leaving known sink terms about twice the size of known sources.[1] In recent years a few inverse modelling studies[2] as well as airborne and seaborne background measurements have suggested that the major missing source is to be found in the tropics. It has also been shown that detached foliage from some tropical plants emit large amounts of MeCl[3] but few direct studies on living tropical vegetation have been conducted.

In parallel with the OP3 biosphere-atmosphere field campaign that took place in a lowland tropical rainforest in Danum Valley, Borneo, Malaysia, between April and July 2008, fluxes of methyl halides were measured from live tropical plants and from leaf litter. The live species studied mainly comprised *Dipterocarps*, a family of pantropical trees, but also several other species. Both branch chamber and leaf litter enclosures were carried out, together with measurement of relevant environmental parameters such as air temperature, total solar radiation, photosynthetically active radiation and vegetation wet-to-dry mass ratio. Branch enclosures lasted 20 minutes and were conducted during both day and night, whilst leaf litter was generally enclosed for 24 hours.

Of the 18 species investigated, 7 had MeCl emissions greater than 10 ng g^{-1} h^{-1} and 10 had MeBr emissions greater than 0.25 ng g^{-1} h^{-1}, all values expressed per dry mass. Overall, emissions of MeCl and MeBr in branch enclosures varied between zero and 114 ng g^{-1} h^{-1} and 4.7 ng g^{-1} h^{-1}, respectively. Some plants such as *Shorea pilosa* and *Shorea agamii* had consistently high emissions, but in general no relationships between emissions and measured parameters have been discerned. There was also no prevalence of higher emissions during daytimes compared to night times. Diurnal cycles in emission were noted for some species but without a consistent pattern.

In general, much smaller fluxes were measured from leaf litter than from living vegetation. Individual MeCl and MeBr leaf litter fluxes ranged between -4.5×10^{-4} ng g^{-1} h^{-1} and -4.3×10^{-6} ng g^{-1} h^{-1} (uptake) to 1.6×10^{-1} ng g^{-1} h^{-1} and 1.5×10^{-4} ng g^{-1} h^{-1} (production), respectively (per dry mass). Fluxes of MeCl and MeBr were positively correlated with each other and both were negatively correlated with the leaf litter wet-to-dry ratio. Overall these findings are consistent with studies of temperate forests in Scotland which indicate that leaf litter is a minor source of methyl halides.[4]

Measurements of a single gradient profile in and above the forest canopy showed that MeCl concentrations decreased with height from 993 pptV just above ground level to 743 pptV at 60 m elevation. In contrast MeBr concentrations did not show any significant changes with elevation. Along with the measurements reported above, this suggests that the tropical rainforest studied is a strong source of MeCl to the atmosphere but only a moderate source for MeBr.

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Biosphere-atmosphere feedback processes within the climate system: Aerosol formation as potential stress result on boreal forests

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Coniferous forests cover approximately a sixth of the lands surface of the Earth. Any stress such as temperature, draught or ozone is supposed to cause volatile organic compound (VOC) emissions such as of terpenes. These terpenes not only buffer temperature effects on the cells but also react with the increased amount of oxidants with increasing temperature and produce a variety of reactive and low volatile organic compounds, which subsequently can contribute to new particle formation and the particles further growth. Detailed studies on the effect of ozone and water vapour on nucleation suggest a notable contribution of biogenic terpenes in Germany as well as in Finland. If so any predicted temperature change especially in the boreal regions as predicted by the 4th assessment report of the Intergovernmental Panel on Climate Change (IPCC) in 2007 will result in enhanced stress, thus enhanced emissions and aerosol formation. As proposed by Spracklen, Bonn and Carslaw (2008) this can be seen as a climate feedback process aiming to compensate the stress effects of the biosphere and resulting in a current cooling effect by -0.6 W m^{-2} of boreal forest surface. However, this currently remarkably cooling effect applies only if these ecosystems are maintained and the biodiversity is preserved. In this talk I will discuss the potential link between VOC emissions and new particle formation and try to exemplarily present potential consequences of temperature changes on aerosol formation at two different sites in Finland and Germany as shown by Bonn et al. (2008, 2009).

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Abiotic formation of volatile organic compounds from plant biomass and its dependence on temperature and UV radiation

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The emissions of volatile organic compounds (VOCs) from living vegetation are measured for many different plant species. However, almost no research has been performed on the VOC emissions from plant litter and senescent leaves. The few studies that are done on plant litter indicate that the VOC emissions from this material can be significant for atmospheric chemistry and the global budgets of those VOCs.

Recently a paper[1] was published which showed that methane is emitted from dead and senescent leaves, and that the emission rates are influenced by temperature and ultraviolet (UV) radiation. It is also observed that not only methane, but also ethane and ethylene were emitted from leaf material under the influence of UV radiation[2].

In this research, the emissions of ethane, ethylene, acetylene, propane, propylene, i-butane, n-butane and methyl chloride are measured with a gas chromatograph with a flame ionization detector. The effect of temperature and UV radiation on the emission rates of the different VOCs is measured for leaves of Sequoiadendron Giganteum. There are no emissions of acetylene and i-butane observed. The emission rates of the other VOCs increased exponentially with increasing temperature, while a linear increase of the emission rates was observed for increasing intensity of the UV radiation. In Fig. 1, the emissions of ethane as function of temperature and the intensity of UV radiation are shown as an example.

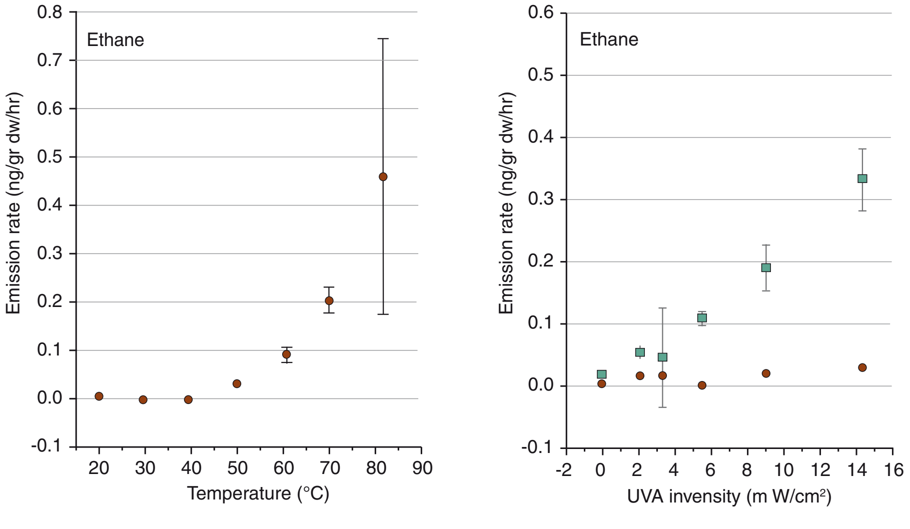

Fig. 1. Left: emissions of ethane as function of temperature. Right: ethane emissions as function of the intensity of UV radiation (grey), ethane emissions of the same leaves without UV radiation are shown in black.

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Fog and low clouds: chemistry and Liquid water content evaluation in mountainous sites of the Czech Republic

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The contribution deals with the evaluation of the long-term monitoring of the fog and low clouds chemistry and liquid water content of the clouds. Knowledge of the liquid water content (LWC) of clouds and fogs is important in order to evaluate the deposition of pollutants via cloud and fog water droplet deposition. The LWC values are also considered as a significant input parameter in calculation models of the fog precipitation deposits. Knowledge of LWC allows to define the concentration of the pollutants in the air from the analysis their concentration in the samples of fog water (Fuzzi et al., 1994, Tago et al., 2006). The LWC is not routinely measured and because the direct measurement of LWC is expensive, other methods are being applied for its estimation. The most commonly used calculation of LWC is the calculation through measured visibility. The LWC – visibility relation can be found for example in Kunkel (1984) or in Fisak et al. (2006).

The paper will summarize the resulte obtained at four mountainous headwater regions of the Czech Republic: (i) at the meteorological observatory situated at the top of Milesovka (50°33´17´´N, 13°55´57´´E, 837m a.s.l.); (ii) at the meteorological station Liz situated in the Sumava Mts. (49°03´53´´N, 13°41´34´´E, 830 m a.s.l.); (iii) at the meteorological station Labska bouda situated in the Giant Mts. (50°46´13´´N, 15°32´45´´E, 1325 m a.s.l.); and (iv) at the meteorological station Jizerka situated in the Jizerske hory Mts. (50°50´11´´N, 15°20´50´´E, 860 m a.s.l.). The observatories perform standard meteorological and climatological measurements. The measurement of visibility is performed by the PWD 11 and 21 (Vaisala, Finland). At the same time these devices serve for automatical operation of the active fog water collectors NES (Eigenbrodt, Germany).

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Improving regionalisation of CO_2 efflux with estimated root biomass distribution maps – failures and achievements

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Typically, measurements of soil respiration with portable Infrared-gas analyzers produce data of high variability and little spatial correlation. The present study aims on the one hand to clarify the influence of different sampling designs on the accuracy of spatial interpolations, on the other hand to investigate the role of different stand structural parameters, especially the types of forest species, their age, root distribution and allocation. The huge small-scale heterogeneity of soil respiration, caused by the intense variability of soil moisture, root biomass, thickness of litter layer, humid horizon and stand structure accounts for the low reliability of most kriging approaches. Therefore we implemented root biomass distribution maps to improve regionalisation results with regression kriging.

Two separate measurement campaigns (MC) were carried out in an investiagtion site of 4.6 ha that is located in an old growth forest in the core zone of the Hainich NP in Central Germany (50°14’ N, 10°00’ E). The CO_2 efflux was determined biweekly using sets of up to 79 closed chambers that have been arranged in a spatially nested design (first MC) and completely random (second MC). This allowed for the evaluation of scale dependency of the CO_2 efflux. CO_2 concentration in the chambers was determined by a PP EGM 4 infrared gas analyzer (PPM Systems, Hitchin, UK) in all cases. During the second measurement campaign, we additionally mapped all individual trees within the investigation area. For more than 3000 individual trees location, species, and diameter at breast height (dbh) were determined. Based on species and an empirical model (Ammer & Wagner 2002) their root distribution was estimated. The latter was used to create root distribution maps to deliver root biomass as input parameter for a regionalisation apporach.

The results underline the great within-site heterogeneity of soil respiration. The higher density of collars in the small scale level of the nested approach changed significantly the amount of the calculated annual efflux. Furthermore, only Ash (*Fraxinus excelsior*) showed a significant correlation between estimated fine root biomass and soil respiration especially in springtime whereas in general. This was neither the case for the general data set nor for other tree species. Our attempt to improve the regionalisation of soil respiration using estimated root distribution maps failed on total stand scale. However, it worked quite well for single tree species and might therefore be promising for more homogeneous forests.

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N_2O, CH_4 and CO_2 fluxes in Undisturbed and Burned Holm oak, Scots pine and Pyrenean oak forests in Central Spain

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Gas exchange between soils and the atmosphere is an important contributing factor to global change due to increasing release of greenhouse gas (GHG). The most important individual greenhouse gas is carbon dioxide, CO_2, but substantial contributions are also methane, CH_4, and nitrous oxide, N_2O. The forest soils represent a significant global atmospheric CH_4 sink (3–9%). Several studies have also demonstrated that N_2O is emitted in significant quantities from forest ecosystems. Among terrestrial ecosystems, forest constitute a major reservoir of the global soil carbon (C), in particular an average of 69–75% of the total forest C pool is below-ground in living biomass and soil organic matter pools. Soil respiration (SR) provides the main carbon efflux from terrestrial ecosystems to the atmosphere. In Europe, forest ecosystems cover about 28% of the total land area and may thus have importance for European scale GHG budgets.

Uncertainty is associated however with global soil sources and sinks and their spatial and temporal variability are poorly quantified, in particular from Mediterranean-type ecosystems. In this region every year forest are destroyed by forest fires. Moreover, projected climate change is expected to result in increment of forest fire regimens in this area. However few studies have investigated the effect of fire on the soil-atmosphere exchange of N_2O, CH_4 and CO_2 in this area.

Consequently, we started a study in *Pinus sylvestris*, *Quercus ilex* and *Quercus pyrenaica* stands located in the surrounding area of Madrid (Spain). The fluxes were measured for one year from both mature stands and post fire stands. N_2O and CH_4 fluxes were measured using the static chamber technique. Soil CO_2 fluxes were measured with a closed dynamic system (LI-COR 6400) using soil collars. Simultaneously with gas fluxes, soil temperature, soil water content, microbial biomass carbon (C-TMB), total organic carbon (TOC), total soil nitrogen content and other soil physico-chemical parameters were measured in the stands.

Key words: Greenhouse flux, fire, microbial biomass carbon, soil water content, soil temperature, *Quercus pyrenaica*, *Pinus sylvestris*, *Quercus ilex.*

Automated chamber measurements of VOC emission in boreal forest

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Volatile organic compounds (VOCs) contribute to the formation and growth of atmospheric particles which are an important factor in the climate system. In the ecosystem scale boreal forest is known to emit oxygenated VOCs but the emissions dynamics of individual trees is rather poorly known. We measured branch scale emissions of methanol, acetone, acetaldehyde and monoterpenes with automated chamber in summers 2007 and 2008. Measurements were conducted in SMEAR II measurement station in Hyytiälä Southern Finland. In our measurement system branches of Scots pine in the upper part of the canopy were enclosed into chambers. The chambers remained open most of the time and were closed periodically four times per hour. Sample air was drawn from the chamber to the PTR-MS (Proton Transfer Reaction Mass Spectrometer, Lindinger et al. 1998) which was used to determine VOC concentrations. As an example one week of measurements from June 2007 are presented in Fig 1. Emissions of three OVOCs (methanol, acetaldehyde and acetone) as well as monoterpenes have a clear diurnal cycle. The emission of OVOCs corresponds to over 80% of the total emission of these four compounds. Previously published results reported that in Hyytiälä the ecosystem scale monoterpene emissions correspond to about 50% of the total emission of these compounds (Rinne et al. 2007).

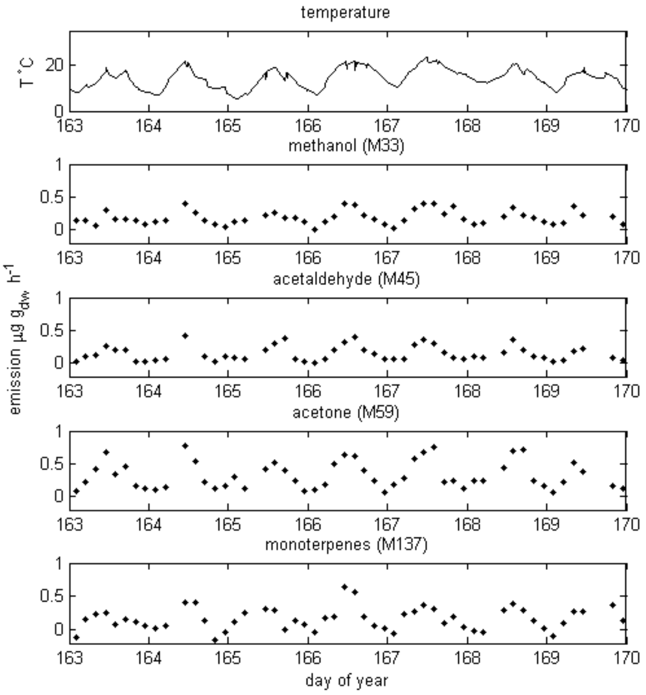

Fig. 1. Hourly mean temperature and hourly mean emissions of VOCs during one week in summer 2007.

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Extensive biomass burning in Russia during spring 2006 resulted in high deposition of ammonia in throughfall over northern Sweden

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Extensive biomass burning occurred during April and May 2006 over large areas in Russia and adjacent countries (Stohl et al., 2007). In total, 2 million hectares burnt during these two months. Due to an extensive highpressure weather situation over Russia, the polluted air massas were transported in a northwest direction across Fennoscandia and ended up at Svalbard and Iceland, were the snow was colored black and high concentrations of e.g. ammonia could be measured in the snow. A trajectory analysis demonstrated that much of the polluted air masses that ended up at Svalbard were transported over the northern part of Sweden (Stohl et al., 2007).

High air concentrations of ammonia, but also of calcium, were measured during May 2006 at many sites in northern Sweden, especially at high altitudes. Bulk deposition measured over the open field was high at one high atitude site (1100 m a.s.l.) during May and July in the county of Jämtland in the mid-part of Sweden. Very high throughfall deposition of ammonia was measured at one lowland Norway spruce site in the county of Jämtland (Fig. 1), while not at another site in the same county covered with Scots pine. Also at three sites at the tree-line border in the mountain area of Jämtland, record high levels of ammonia deposition were measured in throughfall, but during differents months during the summer 2006, depending on the frequency of precipitation at the different sites. The results show that ammonia can be transported long distances and the deposition takes place mainly as dry deposition.

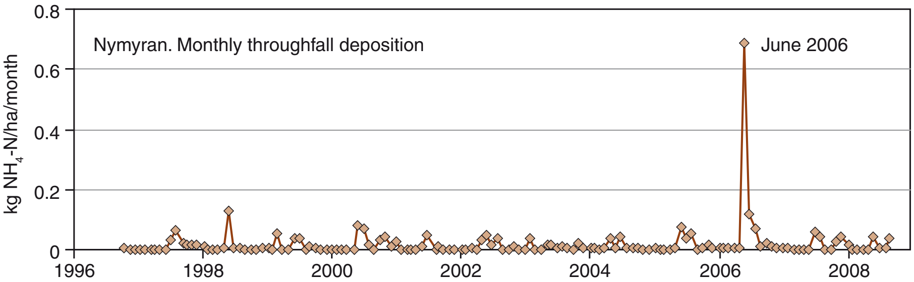

Fig. 1. Monthly values for throughfall ammonium deposition measured at one lowland Norway spruce site in the county of Jämtland. Measurements were performed within the Swedish Throughfall Monitoring Network where the methods are described (Pihl Karlsson et al., 2008).

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The Swedish Throughfall Monitoring Network for bulk- and throughfall deposition, soil water chemistry and air pollution concentration

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Deposition, soil water chemistry and air pollution concentrations have been monitored within the Swedish Throughfall Monitoring Network in forest ecosystems, during more that two decades. Monitoring is generally on a monthly basis, except soil water chemistry which is sampled three times per year. At present monitoring is performed on approximately 70 plots across the country. Bulk deposition is also measured over the open field in the vicinity of some of the throughfall (TF) sites. Soil water is sampled at all TF sites in the mineral soil at 50 cm depth. Deposition and soil water analysis include pH, SO_4, NO_3, NH_4, Kjeldahl N, cloride, aluminium, different base cations and TOC. Air pollution concentrations are measured with diffusive samplers on a monthly basis at 3 m above ground at some sites. Air pollution measurements include SO_2, NO_2, NH_4 and ozone. At many of the plots, different forest condition parameters are monitored every 5th year, such as basal area increment, crown condition etc. Also information of tree species, stand age etc is available. Information about soil conditions is also known for most plots. Meteorology is available from nearby official meteorology stations.

Sulphur deposition over the southern part of Sweden has gone through a dramatic change over the last 20 years which also has influenced the soil water chemistry. In Figure 1 we show an example of two dataseries from one site in southeast Sweden with sulphate deposition and sulphate concentrations in the soil water at 50 cm depth. Nitrogen deposition has decreased to a much less extent.

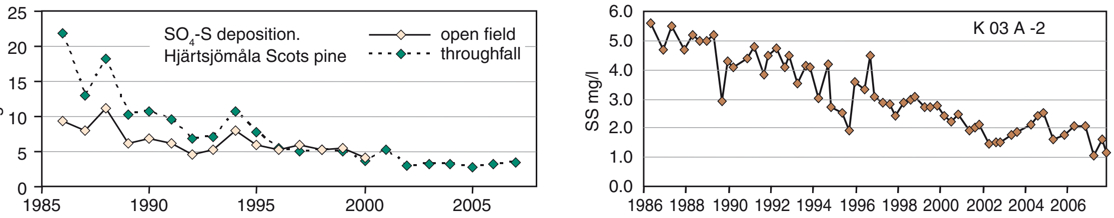

Fig. 1. An example of two dataseries from one site in southeast Sweden, covered by a mature Scots pine forest, with sulphate deposition (left) and sulphate concentrations in the soil water (right). SS, Sulphate sulphur.

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The estimate of canopy ion exchange in Czech spruce plots

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The czech forest ecosystems are under various stress factors from acidification, eutrophication, Al-phytotoxicity, deficiency of nutrients, biotic (insects attack) and abiotic (climatic) temperature, wind and precipitation perturbation. The aim of this paper is to provide the first and simple estimate of the impact of air pollution to coniferous forests. These cover about 77% of forest area (approximately 1/3 of the whole country). In 2007, the total deposition (wet and dry) was estimated to 52 043 tons of S and 70 611 tons of N (ox+red). Some dry, wet and total deposition maps will be presented. The acidic deposition to mountain forests are still slightly underestimated.

Intensive atmospheric and integrate monitoring programs have been provided by various research and academic institutions such as CGS, GI AS, FGMRI, HBAS, IH AS and the Czech Hydrometeorological Institute (see CHMI Annual Reports). All the measurements are in accord with the EMEP, ICP-Forest, or WMO-GAW recommendations. Various research programs have been also conducted to clarify cause-effect relationships between atmospheric pollution and forest damage. In consequence, huge and long-term data sets are available. Mainly the results from precipitation, wet-only, bulk, throughfall, stemflow have been measured at various localities of the Czech Republic.. These results and some research conclusions during last two decades (1986–2006) provide an opportunity to evaluate trends and interpret them. There are many hypotheses and references regarding the behaviour of pollutants in canopy.

In this paper, the cation leaching from spruce canopy (*Picea abies* (L.) Karst.) is applied as chemical indicator for direct or indirect impacts of acidic deposition. The canopy internal circulation of nutrients indicates and reflects the tree health and the ecological condition of a plot. For example, the increasing leakage of nutrient ions (K, Ca and Mg) from canopy shows its ability to resist stress. Determination of “real” deposition in forest stand is based on bulk deposition (BD) and throughfall (TF) determination and wet-only determination (WO). The calculation of total acidic deposition and tree canopy internal circulation of basic cations is applied in territory with higher contents of sulphur in deposition (heavy polluted area) Thus Basic assumption is minimal uptake of all sulphur compounds (dry and sulphate particles) by canopy and tree roots. Generally the throughfall was found more acidic than bulk precipitation. The neutralisation processes run on the wettable needle surface by passive diffusion and follows enhanced canopy leaching of basic cations. The rate of canopy exchange depends on tree species and ecological conditions of stand. The calculations for various mountain forest stands Beskydy Mts., Orlické Mts., and Giant Mts. and background highland plot Kosetice will be discussed. The sulphur enrichment canopy factor F_S is based on ratio $S\text{-}[SO_4]^{2-}$ (sulphur in sulphates) in total and real deposition of ions into forest canopy (Kubiznakova 1999 and 2000). The neutralization (protons and amonnia) from acidic deposition ions and exchange canopy of the cations like Mg, Ca, and K (leaching) is limited their supplies in the soil. Thus the incoming changes in canopy nutrient cycles of Ca, Mg, and K evaluated by this approach seem to be more important than the base saturation in the forest soils. This estimate makes it possible to predict the decline of canopy tree before visual changes, such as defoliation, appear.

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What causes differences in soil respiration in pole and mature spruce stands on Gleyic Podzol in south-east Estonia?

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Boreal coniferous forest soils play a significant role in the global carbon budget. One of the main C fluxes – soil respiration – was measured in a chronosequence of Norway spruce stands aged between 4–84 years on Gleyic Podzol in Järvselja in south-east Estonia in 2004–2006; this flux ranged between 534 and 1225 g C m^{-2}. Our aim was to account for the significantly higher soil respiration in the pole stand (aged 28 yr) than in the mature stand (aged 84 yr). Stand characteristics are shown in Table 1.

Table 1. Stand characteristics (forest survey data as of 2001).

Stand age (year)	Stand density (tree ha^{-1})	Diameter at breast height (cm)	Height (m)	Basal area (m^2 ha^{-1})
28	2315	8	8	15.5
84	698	26	24	29.0

Soil respiration (measured by infrared gas analyzer CIRAS-2 attached to a closed, dynamic SRC-1 soil respiration chamber) was monitored monthly from May to November, 2006 at ten random locations in each stand; soil temperature and soil moisture were measured at 5 cm depth at the same locations. Fine (D<2 mm) root biomass was measured both in soil cores and in 3rd year ingrowth cores. Additionaly, litterfall and soil organic carbon pool were collected and measured from 8–10 litter traps.

During the vegetation period in 2006 the total soil respiration measured in the pole stand was 827 g C m^{-2} and in the mature stand 670 g C m^{-2}. The temperature sensitivity seems to be greater in the younger stand, especially under drier soil conditions. Moreover, this effect is manifested by consistently moister soil conditions in the younger stand.

Soil organic carbon in O2+O3-horizon in the pole stand was 70% greater than in the mature stand, the respective C:N ratios were 26 and 30. The total litterfall was greater in the mature stand (349 g m^{-2} yr^{-1}) than in the pole stand (186 g m^{-2} yr^{-1}); however needle litter formed 122 and 161 g m^{-2} yr^{-1}, respectively. Fine root biomass in soil cores was similar; 930 g m^{-2} in the pole stand and 870 g m^{-2} in the mature stand. However, the biomass in ingrowth cores was 70% higher in the pole stand (1220 g m^{-2} and 720 g m^{-2}, respectively) indicating increased fine root production in the younger stand.

Hence, factors resulting in higher soil respiration in the younger stand are likely the combined effects of greater carbon pool and decomposability of O2+O3-horizon, better litter quality for decomposers, better water availability and higher root+rhizosphere respiration.

Photosynthetic production of ground vegetation in early succession

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Until recently, research of CO_2 fixation has mainly been aimed on photosynthetic production of trees. However, 282 000 ha (1.4%) of forests in Finland are completely treeless and 3264 000 ha (16.1%) of forests are younger than 20 years (Metla, 2004). Therefore a significant part of Finnish forests is in the phase of early succession. In this study, we measured net CO_2 exchange and its components of most common species separately, relationships between the activities and environmental factors and the species composition of ground vegetation on two 5-year-old clear cut sites in southern Finland. One of the studied sites is very fertile with fast-growing and opportunist dominant species having rapidly reproducing new tissues. The other site is nutrient-poor, and the dominated species are evergreen and grow slowly. In the end, we upscaled fixing and respirating rates of ground vegetation for a whole growing season to estimate the potential present range of yearly CO_2 production on different young sites.

Heather, fireweed, wavy hair-grass and raspberry have clear, species-specific annual cycle in their photosynthetic activities. The maximum of heather and fireweed is around June and July while raspberry has maximum as late as in August. It appears that photosynthetic activities of heather and wavy hair-grass follow the temperature history nicely when the soil moisture conditions are normal.

There are individual differences in reaction to the drought. One heather shoot and one raspberry shoot decreased their photosynthetic activity during a drought while the low soil moisture had no effect on the others. Also fireweed showed differences in the individual reactions. One shoot at infertile site decreased permanently its photosynthetic activity while one shoot at the fertile site decreased its activity only for the drought period. In addition, one of the shoots did not show a visible decrease in its activity during drought but after an increase in soil moisture, the shoot had a second growth that doubled the rate of photosynthesis of the whole plant.

Heather is a small shrub that has a lot of wooden biomass and perennial leaves. As a result, heather has the lowest mass-specific level of the respiration. However, the temperature response of respiration was of the same range with the other species. Whole-plant respiration of raspberry and specially fireweed did not have a clear sensitivity to temperature.

By species composition, we upscaled the species-specific process rates and by continuous temperature and radiation measurements we integrated fixed and respirated CO_2 of ground vegetation during a whole growing season 2005. The photosynthetic production was 1120 g C m^{-2} a^{-1} on the fertile site and 440 g C m^{-2} a^{-1} on the infertile site.

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Free air humidity manipulation (FAHM) in a deciduous tree canopy – experimental set-up and some preliminary results

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The rise in CO_2 concentration and its influence on forest ecosystems has been addressed in different "FACE" experiments. Water vapour is also one of the most important "greenhouse gases", absorbing infrared radiation and affecting the energy-balance of ecosystems. The average concentration of atmospheric water vapour is about 2% (compared to 0.037% for CO_2). There exists a network of free air carbon enrichment (FACE) experiments to investigate CO_2 effects, but no experiments to investigate effects of changes in air humidity. Nevertheless, this basic knowledge is essential for predicting reactions of forest ecosystems to climate change.

To fill this gap in our knowledge, the infrastructure at the Rõka experimental area (58º 22' N, 26º 44' E, Estonia) was established in the summers of 2006 and 2007. Altogether 9 experimental rings (diameter 12 m) were built into plantation (fenced area, 2.7 hectare in size) of hybrid aspen (Populus tremula L. × P. tremuloides Michx.) trees. One-year-old hybrid aspen clones from micropropagation and seedlings of silver birch (Betula pendula Roth.) were planted to the experimental rings. The stand density of the plantation surrounding the experimental rings is 2500 trees per hectare, whereas the density inside of experimental rings is 10000 trees per hectare.

To raise the air humidity inside of humidification (H) rings, liquid water (from the pond) was atomised by moving it through thin jets (0.15 mm) under high pressure (0.8 MPa). The size of the generated water particles is about 20 µm and can sometimes be observed as a mist. Thereafter the vaporised water was carried into experimental plots by the wind and/or by the airflow, generated by a ventilator through the pipe system. Jets and airflow usually work only on the up-wind side but all directions are covered in still air. Humidification was switched "on" when the relative humidity dropped below 75% and this was the case 56, 42 and 51% of time in June, July and August 2008, respectively.

Relative air humidity was on average 9% higher and air temperature 0.4 degrees lower in H-rings than in control (C) rings. Also, the difference in water vapour concentration between leaves and air was about 40% lower in H-rings. Xylem sap flux per unit leaf area was about 40% less in H-rings, compared to C-rings, whereas the canopy conductance to water vapour did not vary considerably between the treatment and control. Leaf temperature was up to two degrees lower in H-rings than in C-rings – possibly due to evaporation from (sometimes invisibly) wet leaves. Our preliminary results suggest that the increased air humidity and wetness of the leaf surface impacts trees water relations and leaves temperature, thus providing possible information about trees and forest functioning in humid climate conditions.

Long-term monitoring of soil CO_2-fluxes in two temperate forest ecosystems

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Soil CO_2 fluxes in terrestrial ecosystems are characterized by the high temporal (monthly, seasonal, annual) and spatial variability. The real estimates of CO_2-fluxes can be obtained on basis of the long-term measurements in different ecosystems. This study was aimed to estimate: (1) the soil CO_2 fluxes in two forest ecosystems of Russian temperate zone and (2) the effect of climatic conditions on CO_2 emission from soils.

Our investigations were carried out in the temperate forest ecosystems (Russia, Moscow region, 54o50'N, 37o35'E) located on sandy Albeluvisols (mature mixed forest, MMF, appr. 100 years) and loamy Phaeozems (secondary deciduous forest, SDF, appr. 50 years). The rate of CO_2 flux from soil surface was measured in situ by closed chamber method through 10 yrs (from November 1997 to October 2007) at 7–10 days intervals. Climatic conditions and annual fluxes of CO_2 (AFCO2) widely varied during the investigation period (Table 1). It was found that the mean $AFCO_2$ in ecosystem studied were not significantly different and averaged 646+39 g C m^{-2} yr^{-1} and 583+41 g C m^{-2} yr^{-1} from sandy Albeluvisols and loamy Phaeozems, respectively. Its interannual variability was 19-22%. The soil CO2 flux for the warm season (May-October) was the main part of $AFCO_2$. The cold CO_2emission (from November to April) was an essential part of total annual CO_2 flux. It varied from 14 to 41% and average 25%. It was showed that the main factor controlling the annual CO_2 emission from soils in Russian temperate zone was precipitation sum for the spring-summer period (Pss). The correlation coefficients between $AFCO_2$ and Pss amounted to 0.85-0.87 (F<0.002). A relationship between $AFCO_2$ and mean annual air temperature was not observed. Temperature coefficient Q10 for different time, moisture and temperature intervals were estimated on basis of the long-term soil CO_2 fluxes monitoring.

Table 1. Precipitation sum during the year (Pan, mm) and spring-summer period (Pss, mm), mean annual air temperature (Tair, °C), annual, and seasonal soil C-CO_2 fluxes (gC/m^2yr) in two forest ecosystems

Year	Pa	Pss	Tair	Annual and seasonal C-CO2 fluxes					
				MMF (sandy Albeluvisols)			SDF (loamy Phaeozems)		
				annual	warm	cold	annual	warm	cold
1997/98	770	471	5.0	892	673	219	784	590	194
1998/99	726	437	5.2	657	514	143	588	451	136
1999/00	618	326	5.7	561	472	89	573	494	79
2000/01	653	329	6.3	589	350	238	535	346	189
2001/02	571	176	5.8	425	339	86	298	204	94
2002/03	668	421	3.8	685	501	184	593	428	165
2003/04	713	398	5.9	636	482	153	623	442	181
2004/05	690	381	5.5	693	539	153	540	383	156
2005/06	703	480	4.5	744	547	197	733	561	172
2006/07	599	241	7.1	576	351	225	570	351	216
Mean	640	366	5.4	646±39	477±33	169±17	583±41	425±36	158±14

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Mercury fluxes in southern boreal forest and wetland

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Total gaseous mercury (TGM) fluxes between forest floor/wetland and atmosphere were studied with the static flux chamber technique previously used for hydrocarbon emissions (Hellén et al., 2006). The study was conducted in the southern boreal zone in Finland (61º 14' N, 25º 04' E). There were five study plots in total of which two were forest floor about 20 m apart and three were in wetland right next to each other. The experiments were carried out between April and September in 2007. In total, there were eight different experiment days with 1–6 measurement events. The sampling system consisted of a Teflon flux chamber connected to Tekran 2537A Mercury Vapour Analyzer. The dimensions of the flux chamber were 60 × 60 × 25 cm (l × w × d). Hg chamber blanks were performed in the laboratory and found to be negligible.

The results show that the Hg fluxes were relatively low with average values of 1.2 ng m^{-2} h^{-1} at forest floor plot and 0.2 ng m^{-2} h^{-1} at the wetland plots during the daytime. Maximum flux (3.0 ng m^{-2} h^{-1}) was detected on a sunny warm day with air temperature of 26 ºC. In late August, flux measurements were carried out every 3 h for one full day to study diurnal variation. The emission pattern followed the air temperature changes with somewhat increasing emission from the morning towards the afternoon and then decreasing again towards the night except just before sunrise at 5 a.m. (see Fig.1). At 2 and 8 am, the emissions were insignificant. A monthly Hg emission rate during the summer months was estimated and compared with the Hg bulk deposition at the site (data from Finnish Environment Institute). The results indicate that during summertime, the monthly TGM emission may equal to the amount of deposited Hg.

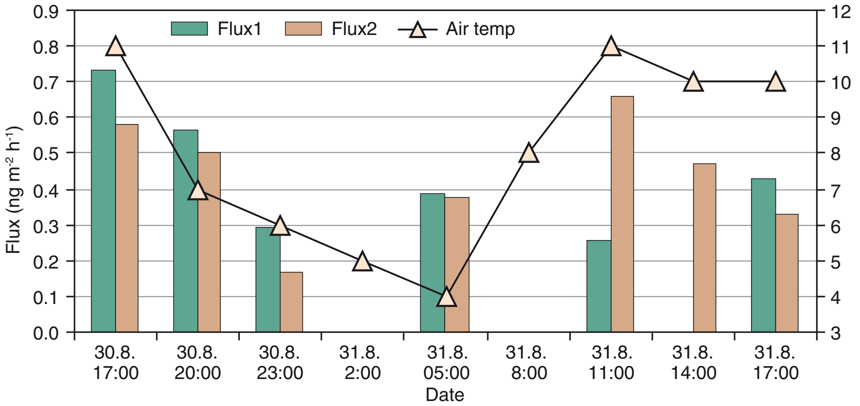

Fig. 1. TGM flux and air temperature during a 24 h experiment

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Atmospheric Exchanges of N_2O and CH_4 with Deciduous and Boreal Forest Soils in Eastern Canada

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In Canada, about 45% of the land surface is covered by forests, which plays a significant role in atmospheric CO_2 sequestration; however, very little is known about the fluxes of CH_4 and N_2O and their controllers at the ecosystem scale. The fluxes of these gases may be small, but given the large area of forested land in Canada, the net global warming potential may be significantly influenced, when fluxes of CH_4 and N_2O are considered in the quantification of greenhouse gas fluxes from Canadian forest soils.

We investigated the fluxes of CH_4 and N_2O from deciduous and boreal forest soils in eastern Canada in 20 forest plots representative of different soil drainage classes, management schemes and natural disturbance, from 2006 to 2008. Well-drained soils in the deciduous forests consume 13 ± 1 while poorly-drained soils emit 92 ± 22 g CH4 m^{-2} y^{-1}. In contrast, well-drained soils in the boreal forests were minor sinks of atmospheric CH4 [0.05 ± 0.02 g CH4 m^{-2} y^{-1}], while boreal forested wetlands were minor sources [0.07 ± 0.02 g CH_4 m^{-2} y^{-1}]. CH_4 fluxes from cut-over boreal forested wetlands increased by a factor of 10 compared to mature forested wetlands. Soil drainage classes, forest type, moisture and temperature exerted significant control on seasonal CH_4 flux patterns from all the sites. Deciduous well-drained soils emitted 37 ± 8 and poorly-drained soils emitted 115 ± 35 mg N_2O-N m^{-2} y^{-1}. On certain sampling dates, atmospheric N_2O was consumed ranging from -237 to -9 mg N_2O-N m^{-2} y^{-1}. N_2O consumption was mainly driven by higher soil organic C substrate and low soil NO_3 contents under anoxic conditions. Well-drained boreal forests emitted 5 ± 4 while poorly-drained sites 4 ± 6 mg N_2O-N m^{-2} y^{-1}. Background and event-based N_2O fluxes were apparent from these sites. Hourly N_2O flux rates at the plot scale were highly variable and did not correlate with any environmental variable; however, averaged annual emission rates were markedly controlled by soil C:N ratios (Fig. 1) and mean annual N mineralization rates.

Our results show that CH_4 and N_2O fluxes from forest soils in eastern Canada could be estimated using ecosystem scale variables (Groffman et al. 2000) such as soil drainage classes, forest type, moisture, temperature and C:N ratios as scalar parameters. Using this approach, a range of CH_4 and N_2O fluxes from well and poorly-drained forest soils in Canada could be estimated for input into models such as the Carbon Budget Model of the Canadian Forest Sector.

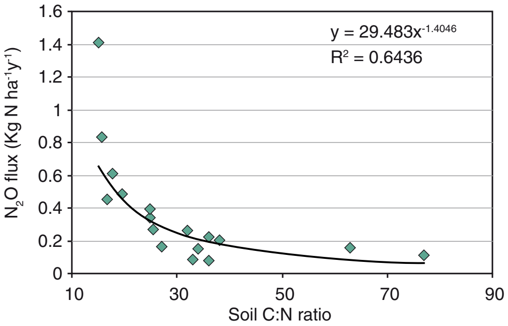

Fig. 1. Relationship of annual N_2O fluxes and soil C:N ratio in deciduous and boreal forest soils, eastern Canada.

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Biosphere-Atmosphere exchange of a mixed forest stand in a hemiboreal ecosystem at Järvselja, Estonia

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A field campaign to study biosphere-atmosphere exchange of trace gases in a northern temperate (hemiboreal) ecosystem was conducted in August 2008, at the Järvselja experimental forestry station in south-east Estonia. The plant cover at the location of the campaign is a mixed forest stand with predominantly birch (Betula pendula and Betula pubescens) and spruce (Picea abies) trees. Within the footprint area of the Eddy covariance tower, also occurrences of poplar (Populus sp.), oak (Quercus robur) and lime (Tilia cordata) trees are found as deciduous species. A coniferous species in the surrounding is as well scots pine (Pinus sylvestris). Integrated ecosystem flux measurements in connection with measuremetns of aerosol formation, leaf level measurements, and sampling of biogenic volatile organic compounds (BVOC) such as isoprene and monoterpenes have been conducted the first time in Estonia.

Here, we present results of the Eddy-covariance measurements which have been conducted to asses the net ecosystem fluxes of the hemiboreal ecosystem at the location. In comparison with boreal ecosystems, the canopy is much more closed which gives the opportunity to compare Eddy fluxes within and above the canopy. One system was installed in the understorey at a height of 1.5 m and the second system on top of the measurement tower at a height of 20 m, reaching above the canopy. The Eddy covariance system on top also included isoprene measurements using the Fast Isoprene Sensor (FIS, Hills Scientific, Boulder Colorado, USA). Average diurnal courses of the Eddy fluxes above the canopy are ranged between 10 µmol m^{-2} s^{-1} during the night and about -25 µmol m^{-2} s^{-1} during the day including the standard deviations. In the understorey system, is no difference between night and day visible, the range is between 5µmol m^{-2} s^{-1} and -5 µmol m^{-2} s^{-1} over the course of the day as well including the standard deviations.

Air concentrations of nitrogen oxides (NO, NO_2, NO_x), ammonia, sulphuric compounds, and ozone, have been measured on several heights throughout the campaign. Nitrogen oxides have been measured on top of the tower (20 m) and at a height of 5 m. Ozone was measured on top of the tower, ammonia and sulphuric compounds at a height of 5 m. Additionally, fine dust particles (PM1, PM2.5 and PM10) have been measured at the 5 m height. During the campaign, ozone concentrations have been found to range between 0 to 50 ppbv and nitrogenous compounds between 0 and 2 ppbv in average.

Greenhouse gas balance of forestry-drained peatland soils in Finland

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Soil greenhouse gas balance is being studied on 69 forestry-drained peatland sites in Finland. The sites were chosen among the Finnish National Forest Inventory (NFI) sample plots to enable the use of tree stand and site variables measured in NFI. Sites were chosen so that all the site types from fertile to poor are evenly represented in different parts of the country. CO_2 measurements were done and CH_4 and N_2O samples were taken during the frost free period of years 2007–2008. The data is currently being analyzed to calculate the annual values of gas fluxes between the soil and the atmosphere.

CO_2 measurements were done both on five total soil respiration and five heterotrophic respiration sample plots on each site. During summer and autumn of 2006, litter layer and ground vegetation were removed from the heterotrophic respiration plots and a 30 cm deep metal cylinder was inserted into soil to cut the incoming roots. Litter and germinated plants were removed each time before measuring. On the total soil respiration plots litter layer, ground vegetation and roots where left untouched. Measuring interval was 2–3 weeks. Measurements were done with static chambers (modified SRC-1, PP-Systems, Ø 30 cm) and portable IRGA analyzers (EGM-4, PP-Systems). For laboratory analyses of CH_4 and N_2O, gas samples were collected with static chambers (Ø 30 cm, h 30 cm) 3–4 times each year. Samples were collected from four of the total soil respiration plots.

To get to the annual values of CO_2 fluxes, an regression model by Lloyd & Taylor (1994) between soil temperature at 5 cm depth and measured CO_2 fluxes has been built up individually for each site. Using peat and air temperature data measured with temperature loggers on study sites and air temperature data from the Finnish Meteorological Institute, a 30-year data set of soil temperature will be simulated for each site. Using these data sets and the regression models, annual fluxes will then be calculated. Annual fluxes of CH_4 and N_2O will be interpolated from the measured fluxes.

Annual values of gas fluxes will be modelled using groundwater table level, site type, carbon-nitrogen ratio (CN) of soil and tree stand characteristics as driving variables. Fluxes are then up-scaled for the whole Finland using site type area estimates and tree stand characteristics obtained from NFI and CN data previously measured for the peatland sample plots of NFI. To estimate the carbon input to soil, litter fall and decomposition will be estimated using biomass and decomposition simulation models and tree stand characteristics. Finally, uncertainties in different models and data sets used will be evaluated to assess the reliability of the greenhouse gas balance estimate.

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Evaluation of a process-based model for biogenic isoprene emissions

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Terrestrial vegetation plays a crucial role in the regulation of atmospheric composition and climate that goes beyond that of carbon dioxide and surface energy fluxes (Arheth et al., 2008). In particular biogenic volatile organic compounds (BVOCs) affect the lifetime of some greenhouse gases (e.g. methane, Monson & Holland, 2001), are precursors of others (e.g. ozone, Sanderson et al., 2003) and are a source of secondary organic aerosol (SOA) (Claeys et al., 2004).

Isoprene emissions represent approximately one half of the total BVOCs emissions (c.a. 1000 TgC/y, Guenther et al., 2006).

In order to identify and quantify the key feedbacks between biogenic isoprene emissions, atmospheric chemistry and climate a process-based scheme for isoprene emission (Arneth et al., 2007) will be implemented into the Met Office's earth system model HadGEM2-ES.

As a first step offline simulations of isoprene emissions have been made to evaluate the model and test its sensitivity. Local isoprene flux measurements have been used to test diurnal, seasonal and inter-annual variability of modelled isoprene emissions for different biomes. Satellite-derived isoprene emission estimates have been used to test spatial variability in modelled isoprene emission.

Regional and global isoprene emission estimates will be also presented.

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Reactivity of VOCs in boreal forest area

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In the rural boreal regions the summertime volatile organic compounds (VOCs) concentrations are typically dominated by biogenic compounds. However, information on the contribution of oxidised VOC on the reactivity and on the diurnal cycle of oxidation rates is limited (Hakola et al. 2000)

Ambient air concentrations of volatile organic compounds were measured online during summer 2006 and autumn 2007 continuously in SMEAR II station (Station for Measuring Ecosystem-Atmosphere Relations) which is a high latitude boreal measurement site in Hyytiälä, Finland (Taipale et. al. 2008). Ambient air was measured with PTR-MS (proton transfer reaction mass spectrometer, Lindinger et. al. 1998) at several measurement heights both inside and outside of the canopy. Additional measurements were used for compound identification.

Of the biogenic VOCs, methanol and acetone had higher concentrations than terpenoids during summertime. However, the total VOC reactivities against OH and ozone during the summertime were dominated by terpenoids. By combining VOC concentrations with measured ozone concentrations and measured and modelled OH levels we calculated total VOC oxidation rates. In this study we are interested in OH and O_3 reactivity in long-term VOC measurements. We will present the diurnal and seasonal cycles of reactivities and oxidation rates in relation to aerosol growth rates.

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Dust-derived phosphorus in tropical forests of the Luquillo Mountains, Puerto Rico

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Understanding ecosystem nutrient dynamics and response to environmental change is limited by the lack of long-term estimates of nutrient fluxes. In particular, the importance of mineral aerosol (dust) inputs to phosphorus (P) cycling in tropical forest ecosystems is not well known. A new dust deposition calculation is used to construct a broad analysis of the importance of dust-derived P to the P budget of a montane wet tropical forest in the Luquillo Mountains of Puerto Rico. The dust deposition calculation used here takes advantage of an internal geochemical signal (Sr isotope mass balance) to provide a spatially integrated longer-term average dust deposition flux. Dust inputs of P (0.23 ± 0.08 kg ha^{-1} yr^{-1}) are compared with watershed-average inputs of P to the soil through the conversion of underlying saprolite into soil (between 0.07 and 0.19 kg ha^{-1} yr^{-1}), and with watershed-average losses of soil P through leaching (between 0.02 and 0.14 kg ha^{-1} yr^{-1}) and erosion (between 0.04 and 1.38 kg ha^{-1} yr^{-1}). The similar magnitude of dust-derived P inputs to that of other fluxes indicates that dust is an important component of the soil and biomass P budget in this ecosystem. Dust-derived inputs of P alone are capable of completely replacing the total soil and biomass P pool on a timescale of between 2.8 ka and 7.0 ka, less than both the average soil residence time (15 ka) and the average landslide recurrence interval (10 ka). On smaller spatial scales, the importance of dust-derived P is likely to be quite variable. This example illustrates that geochemical mass balance approaches allow for larger scale analyses of nutrient cycling that are critical to characterizing ecosystem responses to human, climatic, and tectonic perturbations.

Carbon balance of a boreal lake and its catchment area – CO_2 concentration in the riparian zone

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Although carbon cycle is one of most important cycles of ecosystems, terrestrial and aquatic parts are often studied separately. Carbon enters terrestrial ecosystems in photosynthesis. Part of this assimilated carbon is transferred to the soil in litter fall, root turnover and dead plants. Carbon is also leached from the vegetation to the soil in rain water passing through the canopy. A substantial amount of the carbon entering the soil is released back into the atmosphere as CO_2 in different biological processes such in the respiration of roots and mycorrhizal fungi and in the decomposition of organic material. A fraction of the carbon finds its way to water bodies as dissolved organic carbon (DOC), as dissolved inorganic carbon (DIC) or as particular organic matter (POM), and is thereafter either released into the atmosphere, sedimented to the bottom or carried along with rivers. The aim of this study is to increase the knowledge of boreal carbon cycling and especially to study the connection between terrestrial and aquatic parts. We will study the carbon and water balance of a small boreal headwater lake Valkea-Kotinen and its catchment area belonging to the ICP integrated monitoring programme.

The CO_2 concentration at different depths in the lake and in its riparian zone soil matrix is followed by continuous measurements with Vaisala CO_2 probes (GMP343, GMM221, Vaisala Oyj, Finland). We will study the seasonal variation in the DOC and DIC concentrations in the different components of the water balance and pay special attention to time periods following rain events. Also the amount of precipitation and throughfall as well as the amount of water leaving the catchment area in the brook is measured. The carbon exchange between the lake and the atmosphere is monitored with continuous eddy covariance measurements conducted above the lake surface. The carbon exchange between the catchment area and the atmosphere will be modelled based on biomass measurements, manual soil CO_2 flux measurements and automatic measurements.

There is a clear seasonal variation in the CO_2 concentration of the soil. At 2 and 10 cm depth concentration started to rise in the end of April, was highest in July and started to decrease in the end of October. The concentration was more or less constant from December to April. Deeper in the soil the CO_2 concentration was constantly higher and changes were slower than those measured closer to the soil surface. Preliminary results show that the effect of rain could be seen in the CO_2 concentration both in the lake and in the soil. After a rain event the CO_2 concentration increased both at 2 cm and at 10 cm depth in the soil, probably as a result of water filling the soil pores and decreasing diffusivity of CO_2 especially deeper in the soil. More favourable moisture conditions for the microbial decomposition as a result of rain could also increase the respiration in the soil. There seemed to be also daily variation in the CO_2 concentration of the soil. The activity of roots and microbes in the soil varies with environmental factors such as soil temperature and soil moisture. The root activity may also vary as a result of variation in the activity of vegetation, because substantial part of CO_2 fixed by plants is recycled quickly back to the atmosphere in root and rhizosphere respiration.

Trends in stream water nitrogen concentrations and export from forested catchments in Eastern Finland

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Exports of nitrogen (N) from terrestrial to aquatic ecosystems significantly contribute to water quality. Nitrogen leaching is controlled locally by soil nitrogen pools and land-use and land-use management, and regionally by atmospheric acidifying deposition and climatic conditions. Climate change can be expected to increase N leaching, which would be particularly detrimental to boreal aquatic habitats. Changes in N concentrations and exports of streams and rivers over the last few decades have been observed in Europe, but the overall role of climate is confounded by differences and changes in land-use, relatively high levels of N-deposition or shortness of the time series of these studies. In order to better ascertain the specific impact of climate change on N leaching to water courses long-term biogeochemistry studies of small forested catchments, particularly when forest management is excluded, are invaluable.

In this study we analyzed long term data sets of stream water total organic nitrogen (TON), nitrate (NO_3-N), and ammonium (NH_4-N) concentrations and exports, as well as the ratio of total organic carbon (TOC) and TON concentrations from 8 boreal forested catchments in eastern Finland for significant temporal trends. The catchments varied in area from 29 to 494 ha with a varying proportion of peatland cover (9% to 70%). The catchments were fitted with a V-notch weir and runoff recorded continuously. Water samples for chemical analysis taken monthly or biweekly throughout the monitoring period (15 to 28 years). Three of the catchments have been managed by clear cuttings and drainage of peatlands, but the period of the treatment effects was removed from the data. Linear trends in annual and seasonal data were identified using Seasonal Kendall trend analysis. Correlation analysis was conducted to detect interdependencies between catchment characteristics and N concentrations and exports.

The export of NH_4 -N averaged across all the studied catchments and monitoring periods was 0.02 kg ha^{-1} a^{-1}, that of NO_3 -N 0.03 kg ha^{-1} a^{-1}, and that of TON 1.4 kg ha^{-1} a^{-1}. Exports of all three N fractions were positively correlated with catchment size and those of NO_3 -N and NH_4 -N also with the percentage of peatland coverage. For half of the number of the catchments, annual concentrations and export of inorganic N fractions significantly ($p<0.05$) decreased during the monitoring period. Significant changes mostly occurred in autumn (September-November) and the decrease paralleled a regional decrease in N-deposition from c. 8 kg ha^{-1} a^{-1} to c. 3 kg ha^{-1} a^{-1}. Significant increases in TON concentrations during spring (March-May) occurred at two of the catchments, but because of large inter-annual variability in runoff, annual TON exports remained unaffected. The catchment mean annual TOC/TON ratio varied from 51 to 85 and it significantly increased at three catchments, indicating a change in the quality of the dissolved organic matter.

Over the period 1979–2006, while the annual precipitation amount had not changed, for example mean annual air temperature had increased significantly (1.2 °C). Trends in temperatures, however, did not appear to result in increased exports of N from the catchments. Boreal forest ecosystems, especially those receiving low levels of N deposition, are well known to be N limited. The observed decline in N deposition at our sites would accentuate this situation further. However, if the increase in mineralization were eventually to result in N saturation of the forests, then leaching of N to surface waters related to climate change would be expected.

Influence of atmospheric deposition on acid neutralization capacities and sulfate pools of acidic forest soils

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Deposition of acidifying compounds like SO_2 and NO_x caused acidification of soils all over Europe. The decline in pH was monitored very closely at many sites. A parameter which was very rarely determined in this context is the acid neutralization capacity or buffering capacity of the soils. This property reflects the potential of the soils to withstand further acidic inputs. Also sulfate fixed in the soils can cause further acidification despite declining atmospheric deposition of acidifying compounds, which can also lead to loss of nutrients and release of heavy metals. Knowledge about the stored amounts of sulfate in the soil horizons is also very sparse.

Therefore the Bavarian Environment Agency determined in an EU-funded project , in cooperation with the Czech Republic, buffer capacities and sulfate pools of forest soils along the Bavarian-Czech border region. Soils of the mountainous region were heavily affected by deposition of acidifying compounds emitted by brown coal combustion around the 1980'ies. From 519 samples of 91 sites the acid neutralization capacity and the acid induced release of nutrients and heavy metals were determined. Additionally the water soluble and total pool of sulfate was measured.

In the organic layer and the topsoil the remaining acid neutralization capacities (0.5–2.0 keq ha^{-1} cm^{-1}) were much smaller than in the subsoil (3–10 keq ha^{-1} cm^{-1}) and the underlying bedrock (5–50 keq ha^{-1} cm^{-1}). It could be further recognized that basin areas had mostly larger acid neutralization capacities in comparison to mountainous regions, which also received a larger deposition load. This effect is also reflected in the stored total amount of sulfate, especially in the subsoil. Whereas water soluble content of sulfate is mostly homogenous in the region (25–100 mg SO4 kg^{-1}), the total content of sulfate is in the mountainous regions about 200–400 mg SO4 kg^{-1} larger.

This results show how strongly atmospheric depositions affected and still affect the forest ecosystem in the Bavarian-Czech border region. The obtained data base gives valuable information for appropriate land use strategies and helps to protect very sensitive soils from further removal of nutrients.

Direct ecosystem scale measurements of volatile organic compound emissions from a boreal forest in 2006–2008

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Volatile organic compounds (VOCs) are involved in the formation and growth of atmospheric aerosol particles (e.g., Tunved et al., 2006), which are an important factor in the climate system. Boreal forests emit large quantities of terpenoids (isoprene, monoterpenes, and sesquiterpenes) and oxygenated VOCs into the atmosphere. To quantify oxygenated VOC emissions in the ecosystem scale and to assess their importance in comparison with monoterpene emissions, we carried out micrometeorological flux measurements above a boreal Scots pine forest in southern Finland in June–September 2006, March–September 2007, and May–August 2008. These direct flux measurements were conducted using the disjunct eddy covariance method (Rinne et al., 2001) and a proton transfer reaction mass spectrometer (PTR-MS; e.g., de Gouw and Warneke, 2007) was used for the associated VOC concentration measurements. The emissions of oxygenated VOCs, consisting of methanol, acetaldehyde, and acetone, were of the same order of magnitude as the monoterpene emissions. The compatibility of the measured monoterpene emissions with the traditional temperature dependent emission algorithm was reasonable (Fig. 1).

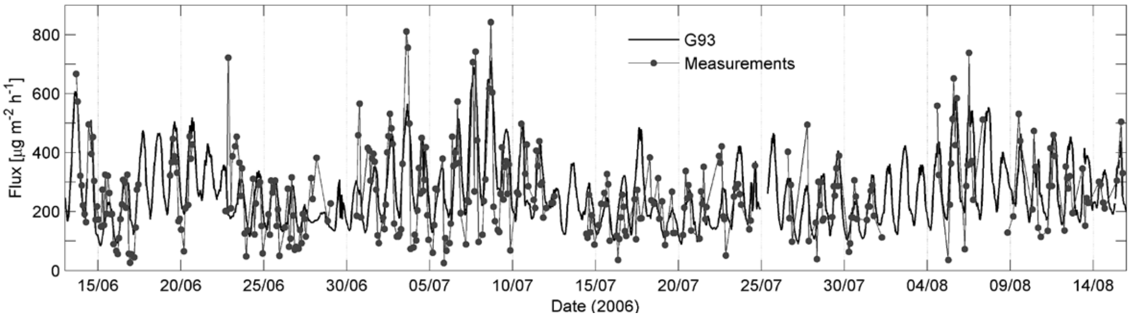

Figure 1. Monoterpene emissions in the summer 2006. The black line shows the emissions derived from the temperature (T) dependent emission algorithm $E = E_{30}\exp[\beta(T - 30\ °\mathrm{C})]$ (G93; Guenther et al., 1993) using an emission potential $E_{30} = 744\ \mu\mathrm{g\ m^{-2}\ h^{-1}}$ and a fixed temperature coefficient $\beta = 0.09\ °\mathrm{C}^{-1}$.

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Impact of forest type and edge structure on patterns of throughfall deposition in forest edges

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Forest edges are subject to significant edge effects on deposition of aerosols and gases due to a higher level of atmosphere-forest interaction caused by enhanced wind speed and turbulence at edges (Irvine et al. 1997). In Europe, temperate forests have suffered high rates of fragmentation due to centuries of human activities (Wade et al. 2003). With forest fragmentation, forest edges become dominant features in the landscape matrix. In northern Belgium, for example, almost 60% of the total forested area consists of forest edge area (De Schrijver et al. 2007). Despite the high proportion of forest edges in European temperate forests, there is little knowledge on the impact of edge-related changes in atmosphere-forest interaction on the fluxes of pollutants or nutrients, particularly N, and on the impact of forest structure characteristics on this change in atmosphere-forest interaction. This presentation merges the results of a four-year study on the impact of forest type and edge structure on throughfall deposition of nitrogen (N) and potentially acidifying ions (NO_3^-, NH_4^+, and SO_4^{2-}) in edges of forests under high deposition loads. By contrasting eight homogeneous forest stands, we found that stands of *Pinus nigra* ssp. *laricio* Arnold are subject to more pronounced edge effects on throughfall deposition than stands of *Betula pendula* Roth. and *Quercus robur* L. (Wuyts et al. 2008a,b). As a result, the extra input of N and potentially acidifying deposition was 85–90% lower in the latter stands. Next, the impact of leaf area index (LAI), tree crown depth, and edge transition type (i.e., steep versus more gradual transitions) was evaluated by a wind tunnel study and two field studies. The wind tunnel study demonstrated that gradual edges and higher LAI values decreased dry deposition in the forest edge by 66 and 40%, respectively (Wuyts et al. 2008c). Wind speed and turbulence measurements pointed to deflection and deceleration of wind flow by the gradual edge and to a fast deceleration of in-canopy wind speeds in forests with high LAI. The crown depth had a minor influence on the edge patterns of the simulated deposition. Field studies on edge patters of throughfall deposition at adjacent steep and gradual edges and at *P. nigra* and *P. sylvestris* L. stands with differing LAI confirmed the wind tunnel study results on the impact of edge transition type and LAI (Wuyts et al. in press). In addition, the field study on transition type demonstrated the importance of the shape and size of the gradual edge vegetation in the impact of gradual transitions on edge patterns of deposition.

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Behavior of ethylene and inhibition on atmospheric methane consumption in forest soil

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Forest has many ecosystem services, such as CO_2 fixation, anti-soil erosion, biodiversity and water preservation. Consumption of atmospheric methane (CH_4) by terrestrial soil, globally 30 Tg CH_4 in each year, is also important in regarding to climate change. Many studies have shown that NH_4^+, water stress and release of monoterpenes and ethylene (C_2H_4) in forest surface soils are the main driving factors which may influence net flux of CH_4 between soil and the atmosphere. We have conducted a series of field experiments and laboratory studies in Chiba University's Environmental Horticulture and Forestry Farm, Japan and in Changbai mountain, China to study ethylene production in forest soils and the associated key microbial driving mechanisms, *in situ* measurements for ethylene and methane production in forest soils and the effects of N fertilizers, and also consumption of ethylene and methane by forest soils and their responses to nitrogen and carbon additions. We also investigated the vertical distribution and interaction of ethylene and methane in forest soils. As results, ethylene production in forest soils was carried out mainly by streptomycin-insensitive microbial mechanisms. Laboratory studies and *in situ* measurements revealed that methane production in forest soils was much larger than ethylene production under oxic conditions and addition of N sources enhanced both productions. Ethylene and methane were consumed in forest soils and their responses to nitrogen and carbon additions were variable with kinds of soils and forest types. The vertical distribution and interaction of ethylene and methane were also observed in temperate forest soils. Hence, *in situ* measurement of C_2H_4 production in N-fertilized forest soil should be useful to further explaining the effects of N inputs on the net CH_4 flux from forest soils.

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The effect of stratification on the roughness length and displacement height of vegetation canopies

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The roughness length, Z_{0u}, and displacement height, d_{0u}, characterise the resistance exerted by the roughness elements on turbulent flows and provide a conventional boundary condition for a wide range of turbulent-flow problems. Classical laboratory experiments and theories treat Z_{0u} and d_{0u} as geometric parameters independent of the characteristics of the flow. In this paper, we consider very rough earth's surfaces, such as boreal forests, and demonstrate essential stability dependences – stronger for the roughness length (especially in stable stratification) and weaker but still pronounced for the displacement height. We develop a scaling-analysis model for these dependences and verify it against experimental data. The model could be of use in the field of terrestrial ecosystem meteorology, because the roughness length controls the downward momentum flux and therefore the turbulent mixing and the exchange of gases and aerosols at the upper boundary of the vegetation canopy; whereas the displacement height serves as the depth scale for the lower, stagnation sub-layer within the canopy.

Key words:Air pollution, Convection, Displacement height, Logarithmic boundary layer, Roughness length Stable stratification, Terrestrial ecosystem meteorology, Vegetation canopies

The decomposition of riverine dissolved organic matter in the coastal ocean

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Riveine input provides a remarkable source of organic matter, nutrients and metals for the coastal ocean. Although rivers export globally about 0.25 Gt C per year to the ocean (Cauwet 2002) apparently little dissolved organic matter (DOM) in the open ocean originates from the continents. This implies an efficient transformation and coupling of riverine DOM to biological communities in the coastal ocean.

Our interest is in how riverine DOM decomposes in the ocean and which proportion of DOM is eventually photochemically or biologically degradable. Additionally, we will examine how much riverine dissolved organic carbon (DOC) contributes to the heterotrophic production in the coastal ocean. We address these questions by sampling the biggest rivers (Fig. 1) exporting >1/5 of DOM to the ocean (Cauwet 2002). We hypothesize that photochemistry plays a major role in the decomposition of riverine DOM in the ocean. The photochemical and biological reactivity of riverine DOM in an oceanic matrix is assessed in laboratory in order to obtain modeling parameters for the photochemical and biological decomposition of DOM. These model parameters are applied to the environmental conditions of each river plume to quantify the rates of photochemical and biological decomposition in the coastal ocean. With this approach we determine the utilization rates of carbon and nutrients (e.g., N, P, iron) bound in the continental DOM. Our study will benefit from collaboration and allows opportunities for assessing global fluxes between the continents and the ocean. We warmly invite researchers interested in the export of matter from the continents to the ocean to join our effort.

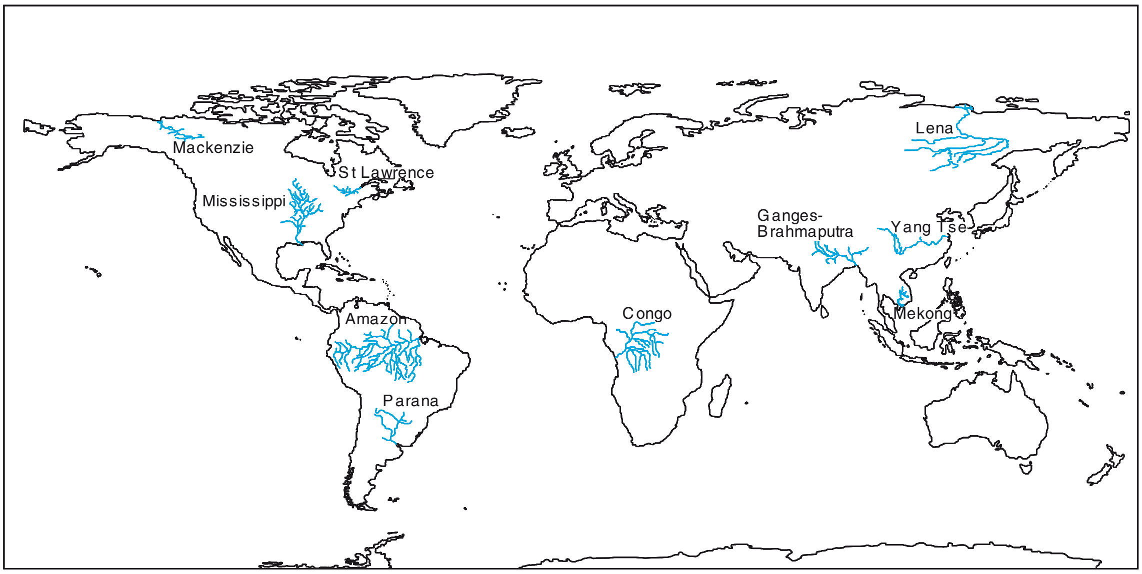

Figure 1. Map of the rivers in the study.

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Eroding blanket peat systems as analogues for long-term water table lowering: impacts on dissolved organic carbon

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Water table is a fundamental control on peatland functions and there is significant research focus on the impacts of water table lowering on the biogeochemistry of peatland systems. Most experimental and field studies of water table lowering are constrained by the timescales of investigation (typically <5 years). Such studies may be dominated by short-term adjustment effects rather than long-term responses to changes in water table conditions. Many areas of blanket peatland in the UK are severely eroded by gullies. Gully erosion alters peatland hydrology, lowering water tables through topographic changes including gully-edge drawdown effects and reduced hydrological contributing areas. Eroded blanket peatlands therefore offer potential analogues for long-term (decadal to centennial) changes in water table conditions anticipated under scenarios of future climate change.

This study focuses on the relationships between water tables and dissolved organic carbon in eroded blanket peats of the South Pennines, UK. There are three aims: (1) to quantify the relationship between gully erosion and water table conditions; (2) to map water table conditions across the peatland landscape; (3); to assess stormflow dissolved organic carbon (DOC) across a set of sub-catchments with high to low water table conditions. Water tables were routinely measured over a nine month period in 500 dipwells at 19 sites with varying erosion status and gully density. Spatial variations in water table could be effectively explained using a simple topographic model based on site slope and hydrological contributing area (see Beven 1997). Sites with dense gullying were associated with low mean water table conditions and high water table variability. Intact sites were characterised by high mean water tables with low water table variability. Water table conditions across the peat landscape were mapped by combining the water table model with a high spatial resolution (2m) digital elevation model (DEM) derived from laser altimetry (LiDAR). A series of sub-catchments along a high-low gradient of water table conditions were identified for stormflow sampling. Mean stormflow DOC concentrations are positively correlated with mean sub-catchment water table depth and variability. This suggests that long-term water table lowering results in increased stormflow DOC concentrations. However, the dynamics of the DOC-water table relationship are dependant on antecedent conditions, and within individual sub-catchments there is strong coupling between sulphate and DOC concentrations. After dry antecedent conditions sulphate concentrations in runoff are high and DOC concentrations relatively low. The inverse relationship occurs in stormflow after wet antecedent conditions. These observations are consistent with the hypothesis that high concentrations of sulphur released from atmospherically contaminated peat after dry antecedent conditions can suppress the solubility of DOC (see Evans *et al.* 2006). The study exemplifies the potential of eroded blanket peats for evaluating the impacts of long-term water table lowering on runoff chemistry.

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Do long-term patterns in pH and water colour in small boreal lakes differ between lakes of varying hydrological and landscape settings?

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Water chemistry data of 23 small boreal lakes since 1977 were analyzed from the Evo Forest Area, southern Finland, in order to investigate whether lakes of varying hydrological and landscape settings have different patterns in pH and colour. The results clearly indicate that in groundwater lakes patterns in pH and colour differ from those lakes dominated by surface-runoff. In long run pH has remained more stable in groundwater lakes compared to other lakes, and in spite of remarkable reduction in sulphate deposition pH have remained at low level in some groundwater as well as in majority of other lakes. Water colour has increased in many of the lakes, and the increase has been distinct especially in those dominated by surface-runoff. Also in lakes impacted by beavers water colour has typically increased substantially. Besides beavers and human induced changes in the catchments due to forestry practices climatic variability seems to be the main driver controlling water colour in the study lakes. The results imply that the hydrological conditions may have been changed since the middle of 1990´s compared to the late 1970´s and 1980´s, and that this change may have caused important changes in water chemistry in many of the small lakes in the area.

Effects of storm events on mobilisation and in-stream processing of dissolved organic matter (DOM) in a Welsh peatland catchment

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Peatlands are important contributors of dissolved organic matter (DOM) to downstream aquatic systems (Aitkenhead and McDowell, 2000). We investigated the effects of storm events on dissolved organic carbon (DOC) concentrations and DOM quality in a stream draining a Welsh peatland catchment. Intensive stream samples were collected and analysed for pH, DOC, DOC/DON ratio, absorbance and fluorescence. Soil water samples and samples of sphagnum pore water were also collected, and a simple end-member mixing model was applied to account for changes occurring during the events. Fluorescence data were interpreted using parallel factor analysis (PARAFAC) (Stedmon *et al.*, 2003). DOC concentrations increased and pH decreased during the storm events. The soil water data and the mixing model indicated that this was due to a change of flow paths and draining of the DOC-rich acrotelm. Absorbance indices (sUVa and E2/E3) and the DOC/DON ratio suggested that the DOM released during events was less degraded (Peuravuori and Pihlaja, 1997; Saadi *et al.*, 2006). There was a striking, inversely related diurnal pattern in absorbance and fluorescence after the discharge peak. The diurnal pattern in fluorescence, the lack of fit of fluorescence intensities with the mixing model, and the indication from the PARAFAC results that the fluorescing material was less degraded in the stream at base flow than in the acrotelm (peak at higher wavelengths in the acrotelm, cf. Senesi, 1990; Sharma and Schulman, 1999), suggested that fluorescing DOM was mainly produced in-stream. Fluorescence has been found to peak in the morning and decline during day-time due to photo-bleaching (Spencer *et al.*, 2007). We hypothesise that the input of additional DOM during events causes a change in the diurnal pattern, giving a peak at mid-day, when the processing of the additional DOM is highest. This seems to be supported by in situ fluorescence measurements during a storm event in a nearby stream on the same area of blanket peat.

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Impact of drought on transport of matter in large rivers, the example of the Elbe River, Germany

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Hydrological extremes can adversely affect the ecological function of river systems by relocation of pollutants. In the River Elbe, one of the large German rivers, the annual stream flow is characterized by considerable seasonal variations between floods and droughts. Both, the intensity and the frequency of floods and droughts are likely to increase due to climate change. Therefore, the investigation of the impact of these hydrological key situations on the river water quality is highly recommended to predict the future development of the river system.

In this paper, we present results of water quality measurements in the German part of the Elbe in 2007 and 2008 during long lasting low discharge periods. To consider as much morphological features as possible, the investigations were performed along a 545 km long profile (from river km 4 to river km 549). The observed relationships between concentration, composition (particle numbers, size distribution, loss on ignition, C/N/S, chlorophyll-a) of suspended particulate matter (SPM) and nutrients, organic sum parameters, heavy metals and arsenic are discussed.

In detail, the SPM values showed a strong correlation with temperature and phytoplankton development. Dissolved silicate, ammonium and phosphate are temporarily depleted due to consumption during biomass growth. The impact of polluted tributary river systems and the re-dissolution of pollutants from sediments locally increased dissolved and particulate concentrations of some potentially highly eco-toxic trace elements (e.g. Hg, As, Pb). This was particularly true for the middle reaches of the Elbe River, where inputs from the tributaries Mulde and Saale as well as from the groyne field sediments clearly compromise water quality.

The results suggest that several processes control the longitudinal matter transport and water quality in the Elbe River during droughts:

a. Increasing impact of polluted tributaries on the mainstream, due to changes in mixing processes and -proportions
b. Interactions between phytoplankton and dissolved compounds
c. Re-dissolution of trace elements from sediments during the vegetation period, due to changes in their redox state induced by increasing water temperatures and phytoplankton activity
d. Higher sedimentation rates of suspended particulate matter (SPM) in still water areas, due to lower flow rates and current velocities

For many rivers, precise knowledge on the existing water quality is crucial for the development of efficient management strategies and for the achievement of the good ecological status. In polluted rivers, results obtained during droughts may help assessing the success of recent remediation measures and identifying remaining pollution sources within the watershed. Drought periods are key situations for both (i) the assessment of global change-induced evolutions of river systems and (ii) ecological status that may be seriously compromised by low discharge and high water temperatures.

Effects of summer flooding on floodplain biogeochemistry in Poland; implications for increased flooding frequency and water storage

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The frequency of summer flood events has strongly increased in Eastern Europe during the last decades, which is most probably related to climate change. This urges the need to understand the consequences of summer inundation, when microbial activity is significantly higher than during winter inundation, for floodplain biogeochemistry. In addition, information on the interactions between flooding, water quality and soil quality is important because the creation of water storage areas in the floodplains is often combined with the aim to re-create more natural and biodiverse riverine systems.

In order to test the interacting effects of temporal flooding, water quality (nitrate and sulphate pollution) and agricultural use (hay- making or pasture), we used a mesocosm design with sods including vegetation from two meadows (a fertilized hayland and a pasture) along a tributary of the Vistula River (Poland), where water storage compartments have been planned.

Concentrations of nitrate and sulphate in the flood water, expected to interfere with soil redox processes, were varied at environmentally relevant concentrations (1000 μmol l^{-1}). Inundation led to increased nutrient mobilization in all treatments, particularly for phosphate (SRP; Fig. 1) which reached extremely high concentrations in both soil pore water (200-300 μmol l^{-1}) and overlaying surface water (25-35 μmol l^{-1}), leading to algae blooms, as a result of increased iron reduction. The response was clearly linked to the phosphate saturation of the soils, which was related to the level of fertilization. Unexpectedly, the water quality did not play an important role in the response to short-term flooding.

The observed interacting effects of water quality and agricultural use are important in order to understand and predict the biogeochemical effects of (more frequent) summer flooding of Eastern European rivers. It also proves that it is necessary to take into account the soil quality in assessing the consequences of planned measures to combine water storage, high biodiversity and ecosystem functioning.

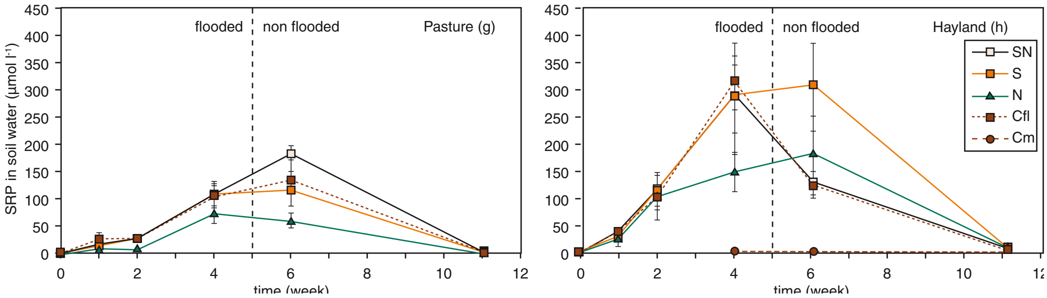

Fig. 1. Phosphate mobilization into soil water in tested meadows at different treatments. Cm – non flooded, Cfl – flooded with local water quality; N, S and SN – addition of NO_3, SO_4 and their combination.

Spring flush of soil nutrients in low arctic tundra and the influence of snow depth

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The availability of nitrogen (N) and phosphorus (P) determines plant communities and ecosystem carbon (C) storage in arctic tundra (Shaver *et al.* 1992). Although plant growth is limited in the growing season by low soil nutrient pools, N and P may accumulate in frozen soils and soil microbes over winter (Schimel et al 2004, Buckeridge and Grogan 2008). These nutrients could be an important part of the annual vegetation budget if they are released to the soil solution during spring thaw. Despite the importance of the vernal nutrient flush for spring plant growth in many ecosystems, and although a substantial increase in nutrient concentrations has been characterized in arctic lakes during nival melt, a spring flush has seldom been reported in arctic tundra soils. Furthermore, the timing, the magnitude and the drivers of this flush, and the sensitivity to winter conditions, have not been previously described.

Soil biogeochemistry and soil microbial biomass were sampled every three days for over two months, from late winter frozen soils to mid-spring thawed soils, under ambient (0.3 m) and experimentally deepened (1 m) snow in a Canadian low arctic site (Daring Lake, NWT). This was a much earlier and much higher sampling frequency than previously reported in tundra soils, and two important soil temperature periods of approximately 3 weeks each were identified. Deepened snow stabilized winter soil temperature and increased average diel minima from -16 °C to -8 °C, but did not alter the timing of initial soil warming from deep cold. When all soils hovered near -5 °C and the ambient snow pack thawed, there were large peaks and troughs in soil solution and microbial C and P under ambient and deep snow. When soil temperatures hovered near 0 °C (i.e. before soil thaw), and the deep snow was melting, ambient C, N and P pools stayed low and relatively consistent, but soils under deepened snow had very large fluctuations in soil solution and microbial C, N and P. In this second period, attributable to the larger snow pack, the thaw peak in microbial nutrient content was 25 g MBN m^{-2} and 13 g MBP m^{-2}, 2 and 5 times the background microbial N and P, respectively, and 4 and 45 times the estimated annual N and P uptake requirement for plant growth in this ecosystem[1]. Overall, large changes in microbial C:N:P ratios were common during the study period under ambient and deepened snow, and suggest rapid community succession over spring thaw. Fluctuations in microbial biomass pools were an order of magnitude larger than changes in soil solution pools, suggesting that any microbial biomass-related flush was rapidly lost from the system or acquired by plants. In summary, we observed flushes of nutrients that released large pools of C, N and P from microbes and soils before soil thaw, and that were substantially enhanced by deepened snow.

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Repeated drying and rewetting of soils with different microbial biomass: effect on phosphorus and carbon dynamics

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Drying and rewetting cycles are known to be important for the turnover of carbon (C) in soil, but less is known about the turnover of phosphorus (P) and its relation to C turnover. In this study, the effects of repeated drying-rewetting (DRW) cycles on P and C flushes and microbial biomass were investigated. Soil (Chromic Luvisol) was amended with different C substrates (glucose, cellulose, starch; 2.5 g C kg^{-1}) five times over a 25 week period or non-amended to manipulate forms and availability of P as well as size and community composition of the microbial biomass. Subsequently, soils were either subjected to three DRW cycles (1 week dry / 1 week moist) or incubated at constant water content (70% water filled pore space). Rewetting dry soil always produced an immediate flush in respiration, between 2-10 times the basal rates of the moist incubated controls, but respiration flushes decreased with each DRW cycle. DRW increased total CO_2 production in glucose and starch amended and non-amended soils but decreased it in cellulose amended soil. Large differences between the soils persisted when respiration was expressed per unit of microbial biomass. In all soils, a large reduction in microbial biomass (C and P) occurred after the first DRW event and microbial C and P remained lower than in the moist control. Flushes in extractable organic C (EOC) after rewetting were related to changes in microbial C only during the first DRW cycle, and EOC concentrations were similar in all soils despite large differences in microbial C and respiration rates. Up to 7 mg kg^{-1} of resin extractable P (P_{resin}) was released after rewetting, representing a 35-40% increase in P availability. Unlike respiration and reductions in microbial P due to DRW, flushes in P_{resin} increased during subsequent DRW cycles, indicating that the source of the P flush was probably not the microbial biomass. Microbial community composition as indicated by fatty acid methyl ester (FAME) analysis showed that in amended soils, DRW resulted in a reduction in fungi and an increase in Gram positive bacteria. In contrast, the microbial community in the non-amended soil was not altered by DRW. The non-selective reduction in the microbial community in the non-amended soil suggests that indigenous microbial communities may be more resilient to DRW. In conclusion, DRW cycles alter not only nutrient dynamics but also microbial community composition, particularly in soils with an active microbial biomass. The transient flushes in available P could be important for P availability in soils under Mediterranean climates.

Reconstruction of nitrate pollution of water resources using ^{15}N and ^{18}O data – case studies

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Stable isotopes of O ($\delta^{18}O$) and N ($\delta^{15}N$) in water have been used as natural groundwater tracers. Understanding the dynamics in the hydrological structure, including hydrological pathways, recharge mechanism and water transport is required for tracing of nitrogen pollution sources and for better groundwater management. The $\delta^{18}O$ data are used for development of a conceptual model of recharge system specifying recharge rates and size (mean residence time) of subsystem models. The $\delta^{15}N$ data are used for identification NO_3^- of sources (e.g. point sources as sewerage systems, landfills, etc., or diffusive sources as seasonal application of manure and inorganic fertilizers).

The Lita site represents a partly karstic Turonian aquifer with the fissure type of groundwater flow. Wells are located in depth between 31 and 129 m. Mean groundwater residence time estimated from freons (CFC_S), SF6 and tritium concentrations varies from tens to hundred years. In spite of it monthly fluctuations in nitrate content and its $\delta^{15}N$ were observed. Two types of recharge were identified by recharge rate: rapid transfer of abundant precipitation to wells through the main drain system and slow, diffusive infiltration into aquifer matrix. Proportional separation of recharge component from $\delta^{18}O$ data was used to separate nitrate content and $\delta^{15}N$ and specify possible nitrate sources.

Tile drained agricultural catchment is a special case of nitrate contamination. Draining changes natural water and nutrient regime of catchment what frequently results in increased nitrate discharge and consequently in contamination of groundwater in the area. To evaluate the effect of agriculture practice on nitrate discharge differentiation of nitrate inputs is essential. A conceptual model of drainage discharge comprises the infiltrated precipitation and the local groundwater, both discharging into the drainage system. The movement of the water via the unsaturated zone was described as a piston-like flow with a varying amount contributing to the total drainage.

Two tile drainage systems were studied for nitrate loss. The transit time in between the rainfall infiltration and the drainage into the tile system is estimated to be approximately one year. This process is strongly dependent on the duration of the infiltration and its magnitude, and thus on the discharge dynamics in general. The local groundwater contribution to the system formed a significant part of the drainage discharge (varying as 65–98% of the whole drained amount). Nitrate content and $\delta^{15}N$ data were used for the specification of the nitrate flux and nitrate origin in the drainage discharge.

Understanding trace element transport during a major flood event: dam management, geochemical signals and flood scenario

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Dissolved and particulate trace metals in fluvial systems are derived from natural and anthropogenic sources. Source identification and quantitative understanding of processes, temporal variability and interactions controlling trace element transport in rivers require (i) adequate sampling for extreme events inducing high variability of geochemical composition and properties of the transported material, and (ii) knowledge on watershed features such as potential source zones and/or reliable geochemical tracers and signatures.

The Lot River is a major tributary of the downstream Garonne-Gironde fluvio-estuarine system, South West France and drains a heterogeneous medium scale watershed (A=10,700 km^2; Qaverage =150 m3/s). The 2003-December flood, caused by heavy rainfalls, mainly in the upper Lot River Watershed, had a “return period” of once every 50 years. During this extreme event, high-resolution sampling (every 3 hours) of river water and suspended particulate matter (SPM) was performed at the outlet of the Lot River (permanent observation site). Dissolved and particulate metal concentrations were analyzed and compared with monthly data of the same site obtained for the 1999-2007 period. Based on the respective temporal resolution of available data on water discharge and concentrations of SPM and metals/metalloids, annual and flood-event fluxes were established and compared.

Suspended particulate matter (SPM) concentrations closely followed river discharge during the flood event with a maximum value (1,530 mg/l) coinciding with the discharge peak (2970 m3/s). However, for a same discharge value, SPM concentrations were higher during the recession limb of the hydrograph. Trace metal concentrations showed significant temporal variations and responses of the considered elements were contrasting. Dissolved and particulate concentrations (except for dissolved Cr and Pb, particulate Th) were in the range of baseline values at the beginning of the flood and increased during the event, yielding anticlockwise and complex shape hysteresis. Metal inputs by rain water cannot explain the observed dissolved metal concentration during the flood. The contrasting responses of dissolved concentrations may be due to superposition of different sources, different dissolution/desorption kinetics in the upper soil and different kinetics of equilibration (sorption) effects between both phases in the river. Metal partitioning strongly depended on the element and discharge with partition coefficients Kd (= ratio of particulate over dissolved metal concentrations) following the sequence U<Mo<As<Sb<Ni<Zn<Cd<V<Co<Cr<Pb. Comparison of the SPM (440,000 t) and trace metal fluxes (~80% transported in the particulate phase) during the flood with annual fluxes (1999–2007) highlights the importance of major flood events in fluvial transport. Moreover, the use of geochemical signatures for quantitative understanding of fluvial transport processes is demonstrated in this study. Transport processes during the flood were characterized combining the variations of Zn, Cd and Sb concentrations, concentration ratios (e.g. Zn/Cd, As/Th, Cd/Th) and hysteresis loops. By this, SPM and metal transport were attributed to successive dominance of different water masses transporting material from different sources (e.g. industrial point source, bed sediment from reservoirs, plain erosion). The remobilization of >25 years-old polluted sediment from reservoir lakes, mainly due to flood management (dam opening), accounted for ~185,000 t of SPM (i.e. 42% of the total SPM fluxes during the flood) and strongly contributed to particulate metal transport for Cd (90%), Zn (83%) and Pb (61%).

It appears important to note that dam lake reservoirs do not represent “final” traps for contaminated sediments and that sediment remobilisation during floods may be important, sometimes enhanced by flood management. Therefore, natural and/or manmade riverbed erosion during floods needs to be taken into consideration in future models for erosion and fluvial pollutant transport.

Impact of climatic variations and deposition on the runoff water of Lake Saare (ICP IM area: EE02) in 1995-2008

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I subcatchment, situated in North-West of Lake Saare (58°39'N, 26°45'F), is the largest (109.2 ha) out of 4 subcatchments and its runoff is richest in water (100 mm annually). Daily discharge of runoff was recorded using a calibrated V- shaped metal barrier. Runoff water samples were collected twice a month. Major anions (Cl^-, NO_3-, and SO_4^{2-}) and cations (Na^+, K^+, Ca^{2+}, and Mg^{2+}) in the water were analyzed by ion chromatography. NH_4^+ was analysed by spectrophotometry, while alkalinity (HCO_3^-) and pH were measured potentiometrically. SiO_2 was determined using atomic absorption spectroscopy.

Concentrations of major ions (mostly calcium and bicarbonate, but also magnesium) were higher in the runoff water than in bulk precipitation and throughfall. Weathering of carbonate minerals is a major source for content increase of these ions. The share of anthropogenic anions (SO_4^{2-} , Cl- and NO_3) was low, only 16% of all anions on an equivalent bases. Such proportion of ions is characteristic to well buffered surface water that is not sensitive to acidifying deposition. High buffering capacity is characterized also by pH, which varied between 7.2–7.8.

Monitoring of the runoff waters showed significantly ($p < 0.001$) increased concentration of SiO_2 during 1995–2008. A Similar trend in soil water (measured in depths of 40 cm in pine and spruce stands at the catchment area) indicates increased weathering of silicate minerals due to increased acidification (podzolisation) in soil and, also, shortening of the soil freezing period related to changes in climatic conditions.

During the mild winter of 2007/2008 high concentrations of NO_3-N, Ntot and Ptot were recorded in the runoff water, resulting in the highest outputs of leached eutrophicating nutrients for the whole monitoring period. Nutrients originating both from mineralization and deposition reach the lake during mild winter months in considerable amounts due to lack of consumption by vegetation in dormant period, and this will cause some extra eutrophication of the lake.

The summers of 2002 and 2006 were exceptional cases of dry weather with high temperatures, so that consumption of nitrogen by plants was inhibited and, as a result, concentration of NO_3-N in runoff water increased sharply, exceeding NO_3-N concentrations in throughfall and bulk precipitation. In this case the increased NO_3-N derived from internal N fluxes.

Annual mean concentration of SO_4-S in the runoff water decreased during the monitoring period, but the decline was not statistically significant. From the data of S input–output calculation it appeared that during years that were rich in precipitation, (2000, 2003, 2004, 2007, 2008) net release of S occurred from catchment: output of S was higher than input by current annual airborne deposition (4–5 kg SO_4-S per ha). Data from ICP IM network (1997–1999) showed net release of previously retained S from 17 catchments with different sulphur deposition loads (2.2–17. 3 kg S per ha) (Forsius, 2005).

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Hydrologic variability, critical loads and relationship to wetland characteristics and permafrost melt in Western Canada: an isotopic perspective

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Runoff is a highly variable process in low-relief, lake- and wetland-rich regions of western Canada where it can often be difficult to reliably interpolate site-specific hydrology from sparse regional gauging networks. Here we describe a stable isotope mass balance approach for estimating lake water balance and demonstrate its application to estimate landscape water yields and critical loads of acidity for a series of lake basin networks across Alberta, Saskatchewan and Manitoba spanning Boreal Plains and Boreal Shield environments. Systematic evaporative isotope enrichment in lakes is used to define the unit water balance of a lake, i.e. to determine the fraction of water losses by evaporation and fraction of liquid outflow. Interpolated climate data is then used to scale the water balance, to resolve the vertical fluxes of precipitation and evaporation, and to solve for residual lateral inflow to the lake. While there are assumptions and uncertainties which may limit application of the method in some circumstances, the approach is shown to be readily incorporated within standard lake geochemistry surveys and is particularly well-suited to incorporation in critical loads assessments of surface waters. Observed correlation between bog occurrence, permafrost collapse-scar features and water yield variability across the region suggests that melting of permafrost may be an important source of water to regional runoff. Implications for acidification of lakes and mapping of acidification risk in the region are also discussed.

Rapid ecosystem shifts in peatlands: linking plant physiology and succession

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Changes in environmental conditions can sometimes cause abrupt changes in ecosystems. In peatlands, stratigraphic records indicate that the shift from rich fens (i.e. species rich calcareous fens), to species poor bogs is a rapid switch (occurring within hundred years). In this process, invasion of acidifying *Sphagnum* bog species, not normally found in rich fens, play a key role. To test under what conditions an acidifying bog species could invade a rich fen, we contrasted the bog species *S. fucsum* with two other *Sphagnum* species (*S. warnstorfii, S. teres*) normally growing in rich fens. The effect of calcareous water was tested by growing the three species at different distances (constant) above the water table (DWT; 2–7–14 cm) in a rich fen pool, and measuring maximum photosynthetic rate and biomass growth as response variables. None of the species showed indications of being negatively affected physiologically when placed at low DWT, but *S. fuscum* was a weaker competitor at low DWT compared to high DWT. The three species were also transplanted into habitats with different DWT in a rich fen to test performance under naturally varying DWT. Here *S. fuscum* nearly ceased to photosynthesise when transplanted to low DWT (brown moss carpet), while it performed similar as the two rich fen species at the intermediate level (at *S. warnstorfii* hummock level). In contrast to *S. fuscum*, the rich-fen *Sphagna* performed equally well in both habitats. In a third experiment we investigated why *S. fuscum* and not the rich fen species suffered in the brown moss carpet. Now, *S. fuscum* and *S. teres* were exposed to drought and submerged (distilled or calcareous rich fen water) in a factorial common garden experiment. In contrast to *S. teres*, we found that *S. fuscum* was severely damaged when submerged in rich fen water. Our results showed that allogenic events – flooding, and low DWT, are two factors that can prevent the establishment and growth of *S. fuscum* in rich fens. Threshold effects of these two factors might be the mechanism behind the rapid rich fen to bog ecosystem shift. Consequently, extended periods without flooding, or an increase in DWT, may trigger this abrupt ecosystem shift.

Human management and ecosystem service in small watersheds: A case study in mountainous Southwestern China

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Various and serious climate and consequences saw China wounded from meteorological disasters and became a first country beginning research in integrated small watersheds (SWs) management. In 1970s, some integrated projects, applying biological and engineering methods, were launched in Southwestern mountains. Heisha (which in Chinese means ”black sand”) River in Southwestern Sichuan is a good example. The river, which aged aborigines call “Disaster River”, kept flowing quietly for some 30 years after a series of hydrological and ecological projects between 1966–74. However, recently the ecosystem of its watershed seems to have degraded, which may have resulted from decades of monitoring lacking.

Ecosystem service (ES) is a relatively new term in ecosystem ecology. It does not only include evaluating traditional wealth of an ecosystem such as forestry production or food supply, but also macro aspects of flood controlling and atmospheric regulation. Although studies in ES is increasing, studies in SW scale is remote. As cells of larger ecosystems, decent functioned SWs can work as integral parts of higher hierarchies in ecosystem metabolism. In massive coarse mountainous regions as Heisha River basin, where climate brings local vegetation’s awful capability of water and soil, soil erosion is very popular. In first years after the projects’ completion in 1974, soil erosion and mud flow declined remarkably, also rewarded good social feedbacks. Unfortunately in the absence of human management, climax effect lead to the regression of the ecosystem. By comparing and analyzing relative climate, vegetation, soil, hydrological and social figures before, in and after the period of 1974-2004 when the projects operates well, we aim to find illustrative repeated patterns of positive human impacts on ES of SWs, and to conclude a model for alike regions in Ecosystem Service.

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Wet summers induce high nitrogen loading from southern boreal catchments

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We studied the disharge and nitrate (N/NO_3) concentrations in four small boreal rivers in southern Finland during contrasting summer weather conditions. We focused on a very dry summer 2003 and the following extremely wet summer 2004 and compared the results with another pair of summers 1997 and 1998 when a dry summer was also followed by a wet one.

The 30-year (1978–2007) average precipitation during summer (June-August) was 224 mm. In summer 2003 the precipitation was 16% lower and in summer 2004 84 % higher than the average and in summers 1997 and 1998 the corresponding values were 11% and 64%, respectively. In 2003 and 1997 the summer precipitation contributed less than one third of the annual precipitation but in 2004 and 1998 the proportion was about one half.

Due to high evapotranspiration in dry summers the proportion of runoff from precipitation was lower than in wet summers. In summer 2003 the cumulative runoff (m^3 km^{-2}) in the catchments of the two largest rivers was about 60% lower than 30-year average. Runoff responded strongly to increased precipitation in summer 2004: the cumulative runoff was more than twice the amount of 30-year average. The difference in runoff between dry and wet summer in 1997 and 1998 was not as noticeable.

Increased concentrations of N/NO_3 were found with high summer runoff. The highest concentrations were observed in two small rivers in wet summer 2004. In two larger rivers higher N/NO_3 concentrations were found in summer 1998 than 2004 (Fig.1). Peaks in concentrations were not observed in dry summers 1997 and 2003, but there was some variation in response of rivers: in River Haarajoki the concentrations were extremely low during the dry summer while in River Mustajoki the median of concentrations was almost the same in dry and wet summer in both observed pairs of summers.

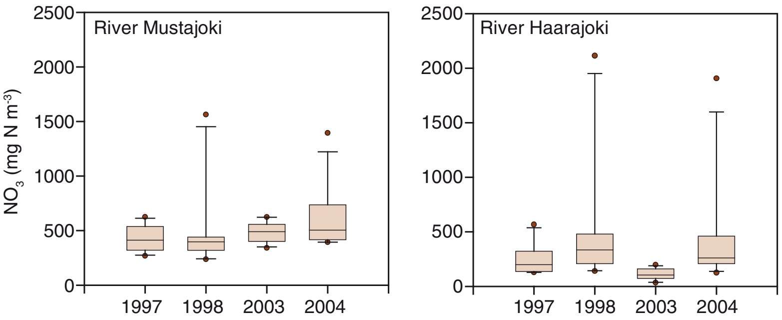

Fig. 1. The median and quartiles of NO_3/N concentrations in weekly sampling from the two larger study rivers during the dry (1997 and 2003) and wet (1998 and 2004) summers. The whiskers show the 90th and 10th percentiles.

The results show that intensive precipitation strongly modifies the hydrology and NO_3/Nconcentrations. The load of NO_3 transported by rivers can be remarkably high during summers of high precipitation, thus adding nutrients to recipient lakes during the growing season.

Studying of metalorganic complexes of the river flow with use of the method of the step filtration

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This work is aimed to the study of speciation and colloidal forms of chemical elements, in particularly heavy metals, during their transformation and migration in natural waters. The object of this study is Palayoka river located at the National park Paanajarvi in Northern Kareliya, Russia.

The main technique used to address this goal was the sampling followed by the 6-step fractional filtration and ultrafiltration on various types of filters, with the sizes of pores equal to 0,45 μm, 0,22 μm, 0,1 μm, 100 кDa, 10 кDa, 1 кDa, both membran, and kernel. The analysis of the isolated of fractions of filtrate and retentate composition was carried by different analytical methods.

The content of mineral and organic components had been determined using the method of evaporation and calcination in filtrates and suspended substances. It was found, that the fulvic acids with molecular weights less than 1 кD (to 80-85 %) dominate the organic matter. The analysis of heavy metals was carried out by atomic absorption, mass spectrometry (ICP-MS) and anodic stripping voltametry in all filtrates of the samples and by the method of the X-ray fluorescent analysis (XRF) in precipitates on filters. Inspecting the spectrums of filtrates in initial samples with water as a background in the 320-720 nm^{-1} wavelength allowed identification of humic organic matter differential spectrum and the chromacity factors for different filtrates and ultrafiltrates. We observed a systematic difference in the spectra of all filtrates which allows to use the colorimetry as a robust method of detailed quantitative characterization of dissolved organic matter forms directly in the field. New methodical developments achieved in this work consisted in studying the transformation of the organic matter and heavy metals speciation directly in the river channel. We anticipate to apply this technique to other small rivers of the Central region of the European part of Russia to establish the link between climate conditions and metal and organic carbon speciation in natural waters within the context of global warming.

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Effects of Extreme Weather Events on ecosystem functions in temperate grassland and heath

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Extreme weather events are expected to increase in frequency and magnitude due to climate change. Their effects on ecosystem functioning are widely unknown. Here, experimental grassland and heath communities in Central Europe were exposed to various precipitation regimes of altered intra-annual frequency and magnitude of events including a simulated drought and a prolonged heavy rainfall event for three consecutive years in the EVENT-experiment (Jentsch *et al.* 2007). The magnitude of manipulations imitated the local 100-year weather extreme according to extreme value statistics.

Overall productivity of both plant communities remained stable in the face of drought and heavy rainfall, despite significant effects on the performance of single species and on community tissue die-back (Kreyling *et al.* 2008c). Nevertheless, drought events were found to alter Carbon uptake into the system and Carbon allocation within the plants (Mirzaei *et al.* 2008). Pronounced, species specific shifts were found for flower phenology (Jentsch *et al.* 2008). Several measures of soil biotic processes, namely fine root length, cellulose decomposition, and soil enzyme activities, remained remarkably stable during and after the application of the extreme weather events (Kreyling *et al.* 2008a). Plant community stability, measured as resistance against invasion by non-target species from outside the plots, however, was strongly influenced by the weather manipulations (Kreyling *et al.* 2008b).

Several functions were further modified by functional diversity, even though conclusiveness in this part is limited by the fact that only one species composition was available per diversity level within this case study.

Theories and concepts on biodiversity and ecosystem functioning (insurance hypothesis, redundancy hypothesis) may have to be revisited when extreme weather conditions are considered.

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The effect of storms on the biogeochemistry of forested ecosystems in a maritime climate

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Atmospheric deposition in Ireland is dominated by sea-salts, which reach the surface through wet, dry and occult deposition. Extreme storm events have been found to cause the episodic acidification of soil and surface waters in maritime regions, the so-called 'sea-salt effect', where the deposition of large amounts of marine derived sodium and possibly magnesium displace hydrogen and inorganic aluminium from the soil exchange complex into soil and surface waters (Pedersen and Bille-Hansen, 1995; Harriman *et al*., 1995). A correlation has been found between the frequency of sea-salt events and the North Atlantic Oscillation. In addition, the NAO may lead to cyclical changes in aluminium and acidity of surface waters on a decadal time scale, potentially masking trends occurring due to changes in acid deposition (Evans *et al*., 1991; Hindar *et al*., 2004). It is predicted that there is likely to be an increase in the number of storm events particularly during winter over the North Atlantic (IPCC, 2007).

In Ireland, levels of atmospheric pollution are low. As such, the maritime climate and frequency of storms along the west coast provide an opportunity to examine the effects of sea-salt episodes on ecosystem processes without a strong influence from acid deposition. Three Level-II forest plots have been intensively monitored since 1991, as part of the International Co-operative Programme on assessment and monitoring of air pollution effects on forests. These are a semi-natural oak (*Quercus petraea*) woodland and two sitka spruce (*Picea sitchensis*) plantations. The oak woodland and one of the coniferous plantations are located on the west coast and exposed to frequent Atlantic storms. Continuous monitoring of throughfall, stemflow, humus-water and soil-water (at two depths: 25 cm and 75 cm) has been carried out at these sites on a weekly or fortnightly basis since 1991. The frequency and magnitude of storm events and the response of forest geochemical cycles at these plots is presented. In addition, the implications for ecosystem processes with regard to future climate change scenarios are discussed.

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Role of vegetation cover in the water balance of a drained forested peatland in southern Finland

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Drainage of peatlands was introduced 35–50 years ago in a large scale to increase wood production in Finland, and currently drained peatlands cover about one fourth of the total forest area. During the past decades the stand volumes of peatland forests have increased and simultaneously the drainage ditch networks have deteriorated as a result of sedimentation and vegetation invasion. The present focus of operational peatland forestry is on harvesting of stands and maintenance of old ditch networks. The need for ditch network maintenance is estimated to be about 1600 km^2 per year, but there is a concern about negative impacts on stream water quality and aquatic habitats. Decision criterion for ditch network maintenance is based on the condition of the ditches, although it is well recognized that a vigorous fully stocked tree stand effectively decreases soil moisture in the rooting zone through evapotranspiration. Meteorological and hydrological measurements were set up in an artificial catchment of 2.4 ha, located on a drained pine bog about 33 km north of Helsinki, and isolated from its surroundings by ditches. The objective was to quantify the water balance components of a forested peatland. The area was drained in 1985 and the ditches were dug down to a depth of about 1 m with a spacing of 30 m. As a consequence of vegetation invasion the depth of the ditches is currently about 0.5 m, and according to the present maintenance guidelines of operational forestry, the ditch network should be cleaned. Precipitation in the open, throughfall, snow depth, snow water equivalent, and depth to water table at 49 tubes was manually measured during 2007–08, when there was an exceptionally wet and mild period. Catchment runoff and water table level at one observation tube were recorded continuously. Peat soil properties were measured in situ and in laboratory conditions. Precipitation outside growing season from 1 October 2007 to 28 April 2008 was 443 mm and runoff was 396 mm. The mean water table level of the 49 tubes during this period remained close to soil surface at the depth of 24–31 cm, as the drainage ditches were not able to lower the level deeper. The mean water table level decreased by 6 cm from October to the end of April and this decrease was estimated to correspond to a soil water storage change of about 14 mm. The total volume of runoff was 7% less than precipitation minus soil water storage change, which was likely to be a result of canopy interception. The throughfall measurements during the growing seasons of 2007 and 2008 indicated canopy interception losses of 12 and 6%, respectively. From May to September precipitation and runoff totalled 316 and 57 mm, respectively, in 2007, and 268 and 46 mm in 2008. Evapotranspiration was estimated to be the highest loss term during the growing season when it was 259 mm in 2007 and 222 mm in 2008. As a result of evapotranspiration, the level of the water table during the growing season dropped well below the wintertime fluctuation range. The results indicate that maintenance of the ditch network in the present study catchment appears unnecessary, because it is not likely to further lower the growing season water table levels. Evapotranspiration of Scots pine stand of 150 m^3 ha^{-1} effectively decreased the water table levels during the growing season, but the question remains how mature stands are needed in different climatic regions to maintain optimal soil moisture conditions.

Linking the terrestrial and aquatic system at various scales in a heterogeneous boreal landscape: A tool to assess the vulnerability of surface waters

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We report from the interdisciplinary, multi-scale Krycklan Catchment Study (KCS) in northern Sweden. The aim of KCS is to elucidate the role of winter processes, landscape characteristics and catchment scale on the concentration and export of DOC and other solutes during snow melt. In the study we used detailed soil transect investigations together with 15 intensively monitored catchments ranging over three orders of magnitude in size, from 3 ha to over 6780 ha. By using isotope hydrograph separation methods to define hydrological flow paths we have found that the majority of snow melt (~80%) reaches the stream via subsurface flow pathways in forested catchments. In contrast, flow pathways through the wetland dominated catchment has a larger component of snowmelt (<50%) caused by overland flow over frozen wetland surface. Although runoff generation in both catchments generally could be explained by the transmissivity feedback concept, the results suggest that there is a spatial variability in the flow pathways during snow melt in the spring controlled by soil frost. As a result, the contrasting flow pathways during the spring flood causes large variations in the dynamics of dissolved organic carbon (DOC). In forested catchments, the DOC concentration increased by a factor two to three during the snow melt period as the subsurface flow pathways activated new soil DOC sources in the organic-rich riparian soil bordering streams in the region (Ågren *et al.* 2007). In contrast the DOC concentration in the wetland dominated catchments decreased to approximately one third of the baseflow level because of the large overland flow component diluting baseflow DOC. No effect of catchment scale could be found for hydrological flow pathways but the DOC concentration during both base flow and peak flow decreased as the catchments became larger. The results suggest that the amount and timing of snow melt and the extent of soil frost have a large influence on the DOC concentration in small streams and rivers in the region. Most climate scenarios indicate that warming will be greatest in northern latitudes and especially strong during the winter months. A shift in the extent and timing of snow cover and soil frost could thus affect the flux and concentrations of DOC from these northern landscapes.

Rainfall distribution is the main driver of runoff under future CO_2-concentration in a temperate deciduous forest

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Reduced stomatal conductance under elevated CO_2 results in increased soil moisture, provided all other factors remain constant. Whether this results in increased runoff critically depends on the interaction of rainfall patterns, soil water storage capacity and plant responses. To test the sensitivity of runoff to these parameters under elevated CO_2, we combine transpiration and soil moisture data from the Swiss Canopy Crane (SCC) FACE experiment with 104 years of daily precipitation data from an adjacent weather station to drive a three-layer bucket model (mean yearly precipitation 794 mm). The model adequately predicts the water budget of a temperate deciduous forest and runoff from a nearby gauging station. A simulation run over all 104 years based on sap flow responses resulted in only 5.5 mm (2.9%) increased ecosystem runoff under elevated CO_2. Out of the 37986 days (1.1.1901 to 31.12.2004), only 576 days produce higher runoff under in the elevated CO_2 scenario. Only 1 out of 17 years produces a CO_2-signal greater than 20 mma^{-1}, which mostly depends on a few single days when runoff under elevated CO_2 exceeds runoff under ambient conditions. The maximum signal for a double pre-industrial CO_2-concentration under the past century daily rainfall regime is an additional runoff of 46 mm (year 1938). More than half of all years produce a signal of less than 5 mma^{-1}, because trees consume the ‘extra’ moisture during prolonged dry weather.

Increased runoff under elevated CO_2 is 9 times more sensitive to variations in rain pattern than to the applied reduction in transpiration under elevated CO_2. Thus the key driver of increased runoff under future CO_2-concentration is the day by day rainfall pattern.

We argue that increased runoff due to a first-order plant physiological CO_2-effect will be very small (<3%) in the landscape dominated by temperate deciduous forests, and will hardly increase flooding risk in forest catchments. It is likely that these results are equally valid for other ecosystems, as all underlying processes on which our argument is based remain the same. Monthly rainfall sums are unsuitable to realistically model such CO_2 effects.

Predicting the probability of severe droughts and changes in potential GPP under changing climate

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Severe droughts during the growing period are currently rare in the boreal climate zone. The predictions of the future climate change do, however, suggest that rainfall events during the growing season may be more sparsely distributed but more intense. In addition, the predicted increase in temperature will lead to higher evapotranspiration. As a consequence, periods of drought may become more frequent. It has been suggested that this might reduce the biomass production of boreal forests. The soil water balance depends on soil properties, evaporation, plant transpiration, climatic conditions and micrometeorology, and their interactions. Therefore the probability of drought cannot be simply derived from scenarios of future climate, but a model taking into account the weather, soil and plant interactions is required.

In this study we estimated the potential Gross Primary Production (GPP) and the number of drought days with a model that couples a simple model of photosynthetic production based on meteorological parameters (air temperature, photosynthetically active radiation and water vapour pressure deficit) (Mäkelä *et al*. 2008), with a model for soil water conditions. We estimated the daily tree and understorey evapotranspiration (ET) during periods of no water stress using a semi-empirical model fitted to eddy-covariance measurements and calibrated it against measurements of soil water content at Hyytiälä research site in Central Finland. In the model, ET is also driven by meteorological conditions: temperature, irradiation and water vapour pressure deficit, modified by parameters reflecting stand properties (species, leaf area index, etc.). For periods of limited water availability, we reduced the GPP estimated for non-stressed conditions, according to the model of stomatal conductance during a drought by Duursma *et al.* (2008).

The soil water model was based on a model by Duursma *et al*. (2008). It utilises the open-bucket principle: soil water storage was described by the water holding capacity, i.e. the volumetric difference between water storage at the wilting point and at field capacity. The water storage is filled by precipitation and snow melt, while the water is depleted by evapotranspiration of both trees and ground vegetation, as well as drainage.

We used the combined model to calculate the potential GPP and probability of drought days under current climate conditions in a 10km*10km grid covering the whole of Finland. We then repeated this calculation with a simple simulation of climate change, increasing the temperature (by 3 or 5 °C) and modifying the amount of precipitation (±10% from current). There are few drought days in current climatic conditions, and the drought risk concentrates on the coastal areas, where the precipitation due to sea effect is smaller than in inland areas. The results of the simulation indicate that the increase in drought risk under changing climate is rather modest, with the risk being greatest in soils with low water retention capacity. The benefit of increased temperature to the potential GPP is larger than the reduction due to drought; in all scenarios that we tested the potential GPP was increased. The increase was smaller on sites where the water retention capacity is low, and if decrease of precipitation was simulated. For sites with deeper soils, and with increase of mean temperature of 3 °C and precipitation of 10% (as per the A2 scenario), the increase in potential GPP was up to 27%.

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Net nitrate production and consumption in different habitats of a restored river corridor: flooding and seasonal effects

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Although the number of river restoration projects has increased in recent years, scientific understanding of the underlying principles determining how hydromorphological variability in restored corridors of rivers relates to ecosystem functioning, to biodiversity and to water quality is still limited. The large interdisciplinary project cluster RECORD aims at increasing the mechanistic understanding of coupled hydrological and ecological processes in restored river corridors. Two adjacent sections of the river Thur corridor in northeast Switzerland are studied. One of the sections is channelized, as is most of the river corridor, the other section was recently re-naturalised, e.g, by removing embankments. The spatial heterogeneity of hydrologic and biogeochemical functioning and of biodiversity are assessed and how they vary with season and disturbance by flooding events. In this particular subproject we want to better understand the role of different habitats within the riparian system to act as sink or source of nitrogen.

The spatial and temporal variability of soil moisture and soil solution composition is monitored on two transects extending perpendicular from the river. The transects cross habitats including weakly colonized gravel, overbank material densely overgrown with the reed gras *Phalaris arundinacea*, silver willow bushes planted during the river restoration in 2002, and a mixed deciduous forest dominated by ash. Here we will present data from a first year of monitoring between summer 2008 and spring 2009. By comparing the results with those of other RECORD subprojects, we will try to understand the variability with season and during flooding events in terms of carbon and nutrient availability, microbial activity and diversity, plant uptake and redox conditions. By considering major hydrologic flow directions and exchange between saturated and unsaturated zone we want to identify important linkages within the riparian system.

Preliminary results from a comparison between different water compartments indicate strong net nitrate production in the *Phalaris* zone and the deciduous forest while the area planted with willow exhibits net nitrate consumption (Table 1). A major flooding event in summer 2008 reduced the net nitrate production of the grass zone and the forest only to a relatively small degree.

Table 1. Dissolved organic carbon (DOC) and nitrate concentrations in the river water and in the soil solution from different habitats along a transect perpendicular to the river (mean ± SD of different sampling points) during a flooding event in August 2008

water source	"DOC 1 day before flooding [mg C/L]"	"DOC 1 day after flooding [mg C/L]"	"NO3 1 day before flooding [mg N/L]"	"NO3 1 day after flooding [mg N/L]"
river	2.5	2.3	1.9	1.5
Phalaris	14 ± 8	8 ± 2	5 ± 3	2.3 ± 0.9
willow	9 ± 6	7 ± 2	1.0 ± 0.7	0.8 ± 0.5
forest	15 ± 6	13 ± 2	13 ± 4	7 ± 1

Effects of extreme rain events on carbon gas fluxes from boreal lakes

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We explored the CO_2 and CH_4 fluxes from two boreal lakes in southern Finland throughout an open-water period when summer precipitation doubled from the usual 200–220 mm to 413 mm. The lakes differed in trophic status (chl a 17.8 and 48.7 mg m^{-2}) and water colour (100 vs. 20 mg Pt L^{-1}) and are located only a few kilometers apart. To increase the reliability of our flux estimates we carried out our weekly measurements, using tow independent methods, i.e. floating static chambers and concentration gradients. We also examined the fluxes in relation to biological carbon uptake and mineralization in the epilimnion of the pelagic zone.

The chambers resulted in higher fluxes, but irrespective of the method, both lakes appeared to be heterotrophic and were annual sources of carbon gases. However, with the annual CO_2 flux of 6.85 (chambers) or 5.43 mol m^{-2} (gradients), the humic lake had higher emissions than the clear-water lake, where the fluxes were 3.97 and 3.38 mol m^{-2}, respectively. The annual CH_4 flux from the clear-water lake was 28.5 (chambers) or 20.5 mmol m^{-2} (gradients) and from the humic lake 20.7 or 16.2 mmol m^{-2}, respectively. There were interlake differences in seasonal flux patterns, but in general the pattern was similar to those found in lakes in North America. A deviation from previously studied lakes was the summer peak in carbon gas fluxes and thus, the most drastic changes in fluxes occurred during or just after the heavy summer rains, which began in late June and lasted till the end of July. In the humic lake the resulting peak in CO_2 and CH_4 flux was responsible for 46% and 48% of the annual flux, respectively. Before the rains the clear-water lake was a small sink of CO_2 or had near-zero efflux, but afterwards became a source. In the humic lake, biological mineralization usually explained the majority of the fluxes, but at the time of the peak flux in August, it was clear that the CO_2 efflux could not have been due to the biological mineralization of carbon in the lake. In the clear-water lake the association between the biological processes and fluxes was smeared, i.e. in June the fluxes were in balance with the biological processes, but in spring and later in summer more excess CO_2 was produced than was discharged through the lake-atmosphere interface. Our study demonstrates that the link between catchment and the lake is probably more immediate than anticipated and is strongly controlled by hydrology. Although the bulk of the carbon gas fluxes generally occur during turnover periods in spring and autumn, the efflux of CO_2 and CH_4 can be significant even in summer, if there is an extreme rainfall episode. In Northern Europe these high extremes of precipitation are very likely to increase in magnitude and frequency due to climate change.

Hot spots and hot moments of DOC export in a subarctic peatland catchment

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In the Stordalen catchment, located in subarctic Sweden near Abisko, we studied from snowmelt to late autumn, the application of the 'hot moments and hot spots' conceptualization to the source areas and transport of dissolved organic carbon (DOC). The catchment is dominated by birch forest, permafrost peatlands and arctic heath above the tree line. A secular trend in increasing temperatures and winter precipitation have lead to a rapid loss of permafrost in the lowland peatlands suggesting that there might be an increase in peatland generated DOC and as a result a change in the overall quality of the exported DOC. Discharge and DOC samples from 8 different sites within the catchment enables the assessment of the relative importance of each major landscape unit in determining their relative importance in the quantity and quality of DOC export

Higher DOC concentrations were found in water leaving the peatlands and from the surface layer of the birch forest but these source areas only became connected to the streams during periods that corresponded to periods of high discharge, either in response to large inputs and/or minimal storage capacity.

A positive relationship between DOC quality, as determined by specific UV absorbance (SUVA), and discharge was found indicating that during times of high discharge, when the peatlands were hydrologically connected to the streams, a lower quality DOC was exported. However, this general relationship changes over the seasons and is different for each landscape unit. Lakes are found to play a role in modifying the quality of DOC as it is pass through them as flow moves downstream.

Dynamics of Organic Carbon Fluxes in Estonian Catchments, 1992–2007

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The soil contains a third of the world's terrestrial carbon. More than 20% of it is stored in the Northern peatlands (Post et al, 1982; Gorham, 1991). The global warming has started to destabilize the sinks, gradually turning them into sources (Freeman et al, 2001; Tranvik & Jansson, 2002). In Estonia, there are 10,091 km^2 of peatlands, constituting 22.3% of the total area. The increasing number of drought days during the last 50 years, which constitutes a threat of an increased flux of dissolved carbon (Freeman et al., 2004), has been observed also for Estonia (Tammets, 2007). The aim of the current study was to explain the trends of the organic carbon in the Estonian streams for the period 1992–2007. The national environmental monitoring programme initiated the measurements of organic carbon (TOC) in the Estonian streams in 1998. We reconstructed the earlier concentrations of TOC by the link with the permanganate oxygen consumed (POC; Xu & Thomson, 2008). TOC & POC data of 64 weirs was studied. The determination coefficients between TOC and POC were over 0.75 for the nine North Estonian streams (Kasari, Vihterpalu, Vasalemma, Keila, Pirita, Jägala, Loobu, Valgejõgi, Pudisoo). The R^2 values in the rest of the sampled weirs were below 0.7. Likewise, the temporal trend of both TOC and POC data was insignificant. In North Estonia, a weak but significant ($R^2=0.09$, $p<0.05$) rising trend of TOC concentrations was observed (Fig. 1). This may be resulted from high percentage of peatlands and influence of calcareous bedrock (Cirmo & Driscoll 1996) in North Estonian catchments. The trend accords with earlier data from Northern catchments (Freeman et al., 2001, 2004; Tranvik & Jansson, 2002), being influenced by the global warming effects (Freeman et al. 2001. 2004) and/or changes in atmospheric deposition chemistry (Monteith et al 2007), and demonstrating a complex positive feedback in the global C cycle.

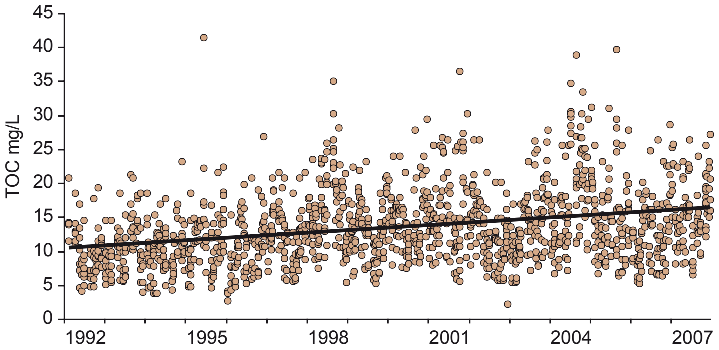

Fig. 1. The trend of TOC concentration in North Estonian streams.

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Responses of carbon and water fluxes following drought events in combinations with warming and elevated CO_2

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The impact of elevated CO_2, warming and drought on heath ecosystem processes are investigated in the CLIMAITE project closely following the modelled climatic scenario for Denmark in year 2075 (Mikkelsen *et al*. 2008). The experiment is unique as it evaluates the interactions between drivers on ecosystem processes across scales ranging from ecosystem to leaf gas-exchange, primary production and biodiversity, in order to unravel the complex multi-factor impacts on water, carbon and nitrogen cycles.

Here we focus on the recovery after drought as an example of an extreme event, which is expected to become more frequent in the future. To understand how quickly the ecosystem recovers following drought we intensively monitored plant carbon uptake, plant water consumption, soil activity and carbon release before, during, and after drought events. Water shortage was observed to decrease plant carbon uptake and limit the soil carbon release, whereas both processes increased when soil water was not limiting. Moreover the cover and biomass of the dominant grass *Deschampsia flexuosa* strongly decreased in response to drought. Plant carbon uptake was increased by elevated CO_2 during and after the drought, but plant species differed in the response to re-wetting. Regeneration measured as enhanced plant biomass and carbon uptake increased significantly more in the drought treatments compared to controls for grass (*Deschampsia flexuosa*) and particular when combined with elevated CO_2. The dwarf shrub *Calluna vulgaris* recovered to the same extent in drought and control plots in response to rewetting. Soil respiration was found to recover after the first following rain event. Only plots with drought in combination with a permanent temperature treatment might show a longer recovery period. It seems that temperature in combination with drought has a negative effect on soil respiration, whereas elevated CO_2 might have the opposite effect and compensates for the negative drought effect.

Therefore the balance and between water shortage and re-wetting potentially impact the source and sink strength of the ecosystem. To illustrate the dynamics of these counteracting processes we present several other examples of response patterns from drought periods differing in intensity and length, from year 2006, 2007, and 2008. In addition we present synthesis results based on modelling of the net ecosystem impacts on carbon and water fluxes in response to drought and re-wetting.

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The influence of soil moisture dynamics on nitrogen cycling and nitrous oxide emissions from soils

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Soils are a dominant source of nitrous oxide, N_2O, a potent greenhouse gas. Soils release an estimated 9.5 Tg N_2O-N year-1 (65% of global emissions according to IPCC, 2001a). The complexity of drivers of N_2O production and emissions has hindered our ability to predict the magnitude and spatial dynamics of N_2O fluxes. Soil moisture can be considered a key driver because it influences oxygen supply, which feeds back on N_2O sources (nitrification versus denitrification) and sinks (reduction to N_2). Soil water content is directly linked to dissolved oxygen and to redox potential, which regulate microbial metabolism and chemical transformations in the environment. In this study we explored the role of soil moisture and feed backs to soil redox dynamics in a predictive model of soil N_2O emissions operating at the daily scale. We modeled the nitrogen cycle by adapting equations used for wastewater treatment plant nutrient removal. We developed a physically-based mechanistic model to compare the nitrogen cycle species values, obtained by considering soil at constant soil moisture content, with a scenario modelled with the use of Richard's equation coupled with transport equation, thus accounting for the variability of the soil moisture content. The scenario shows how advection fluxes alter the N-cycle reaction rates. Model results are supported by observations in a soil column experiment performed at the laboratory scale under different hydrological conditions. In particular, the soil column results show that the saturation process has an immediate impact on redox. These results illustrate that the increase in the magnitude of trace gasses emissions varies non-linearly, given the coexistence of anoxic and aerobic condition in the aggregate, while the response to short rainfall events is mainly related to the initial soil condition. We also measured nitrate ammonification at the beginning of the experiment and at the end, using soil of the column at different soil moisture content, to quantify the role of soil moisture on this process.

Do changes in flood pulse frequency disturb soil carbon dioxide emissions in floodplains?

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Pulsed flood events directly control ground processes through soil wet-dry cycles. Rapid soil microbial response to incident moisture availability often results in almost instantaneous C and N mineralization, followed by shifts in C/N of microbially available substrate, and an offset in the balance between nutrient immobilization and mineralization (Austin et al., 2004). Climate change scenarios for semiarid zones predict changes mainly on rainfall frequency and intensity instead of total annual rainfall. However, we unknown howf changes of flood frequency will disturb soil CO_2 emissions. Therefore, an experimental study was performed in order to evaluate the effect of flood duration and frequency on soil CO_2 fluxes in a semiarid floodplain. During 4 months through triplicate experimental plots, 2 distinctive flood treatments (high frequency and short duration (HS) and low frequency and long duration (LL) were performed and soil CO_2 fluxes measured repeatedly after each inundation.

After flood ended when soil starts to dry, CO_2 assimilation rates were lowest in both HS and LL treatment as compared to control (Fig. 1). Soil respiration increased few days after dried achieving rates as measured in control plots. Around 70 days after inundation end, CO_2 fluxes on flooded plots showed significant differences control until ($p<0.05$; One-way ANOVA); however, 73–77 days after inundation no significant differences were asserted on CO_2 assimilation rate ($p>0.05$; One-way ANOVA). Significant differences were not founded between HS and LL ($p>0.05$, T-test) throughout the experience. Hence, flood enhances soil microbial activity increasing CO_2 emissions but changes on flood frequency and duration did not disturb significantly those soil CO_2 fluxes.

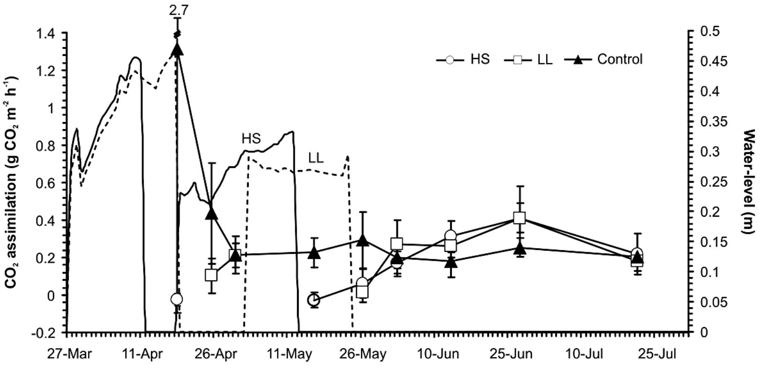

Fig. 1. Mean soil CO_2 fluxes and water-level in the flood treatments. (Vertical bars represent CO_2 standard deviation for n=27).

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Contribution of extreme precipitation events to dissolved nitrogen and carbon fluxes in a subtropical montane Chamaecyparis forest in Taiwan

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Information from (sub)tropical ecosystems on the role of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) is scarce as most studies originate from the temperate zone. In (sub)tropical regions unique precipitation events (e.g. typhoons) might have a strong influence on the fluxes of DON and DOC as positive relations between fluxes with forest floor leachates and the amount of precipitation were reported for temperate forests (Michalzik *et al*. 2001). Our aim was to quantify fluxes of mineral nitrogen, DON and DOC and to determine the importance of high precipitation events for these fluxes in a subtropical montane Chamaecyparis obtusa var. formosana forest in northern Taiwan.

Samples from throughfall, forest floor percolates and seepage (60 cm) were taken at fortnightly intervals for three years (January 2005 – December 2007) and analysed for DOC, DON and mineral N. Precipitation events were classified on the basis of bulk precipitation as regular events (< 200 mm /2 weeks: 55 events), storms (200–400 mm/2 weeks: 10 events) and heavy storms (> 400 mm/ 2 weeks: 9 events).

In general, fluxes of DON and DOC with soil solution were very large, emphasizing their role in the C and N cycle of this ecosystem, while mineral N fluxes were small (Tab. 1). Events with > 200 mm/2 weeks (26% of all events) caused 60% of the water flux and accounted for 62 and 73% (nitrate), 45 and 60% (ammonium), 52 and 60% (DON) and 53 and 60% (DOC) of fluxes in forest floor percolates and seepage, respectively. We concluded that outstanding water fluxes during storm events are mainly responsible for the large fluxes of DOC and DON in this ecosystem.

Table 1. Average water, mineral N, DON and DOC fluxes in throughfall, forest floor percolates and seepage (January 2005 – December 2007). Numbers in parentheses indicate standard errors (n=3, years 2005-2007).

	Water flux (mm a^{-1})		NO_3^--N (kg N ha-1 a^{-1})		NH_4^+-N (kg N ha^{-1} a^{-1})		DON (kg N ha^{-1} a^{-1})		DOC (kg C ha^{-1} a^{-1})	
throughfall	3965	± 244	2.8	± 0,8	2.0	± 0,3	2.9	± 0,7	87.0	± 25,5
humus layer	3910	± 244	1.6	± 0,7	1.3	± 0,4	14.9	± 2,3	882.4	± 87,1
seepage	3805	± 244	1.9	± 0,5	1.3	± 0,7	5.6	± 0,2	462.0	± 35,1

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Use of the method of the spectrophotometry at the control of the stand of the dissolved organic matter in the river flow

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Work is directed on the methodical study of the forms and mobility of the dissolved organic matter (OM) of the humic organic nature and its transformation, which determines the migration of heavy metals (HM) in the natural waters.

In the works, dedicated to study the complexing of heavy metals with OM in the river flow by using the step fractional filtration and ultrafiltration, three circumstances are rarely considered: 1) the safety of distribution of dissolved OM after separation the molecular weights as a result of ultrafiltration, and also other reasons for instability dissolved OM under any interaction with the filter material; 2) the adoption by filtrates weakly polymerized OM of filters themselves under the insufficient degree of cross-linked of their carcass; 3) the possible temporary instability of filtrates with to dissolved OM, connected with its biodegradation under photolysis and second non-sterility of filtrates, and also with the coagulation under the high concentrations of organic matter.

By the method of spectrophotometry the characteristics of initial samples and filtrates had been got in the interval of wavelengths 400-590 nanometers (differential spectrum OM). Regular difference in the spectrum of all filtrates and samples allows the use of a spectrophotometry as one of control methods for the authenticity of data according organic matter under the field and laboratory conditions.

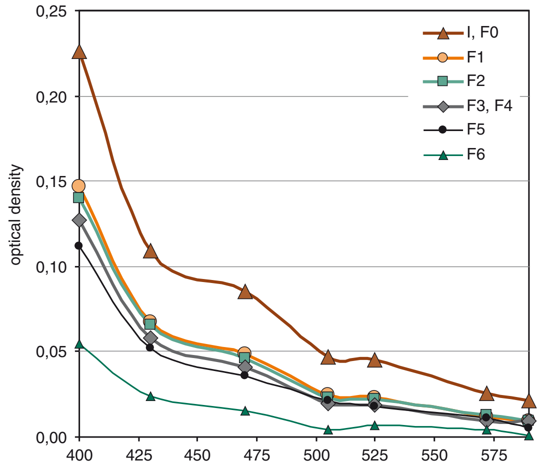

Figure 1. The absorption spectrum of dissolved OM under the step filtration of sample from the mouth part of river Palayoki in the place of fall it in the Lake Pyaoozero (Northern Karelia). I – initial sample; F0 – sample, which passed through the lavsan filter (diameter of pores is 100 μm); F1 - track membrane filter (Lavsan, 0,45 μm); F2 – track membrane filter (Lavsan, 0,22 μm); F3 – teflon membrane filter (0,1 μm); F4 – ultrafiltration membrane (nitrocellulose, 100 kD); F5 – ultrafiltration membrane (nitrocellulose, 10 kD); F6 – ultrafiltration membrane (nitrocellulose, 1 kD).

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Strong solute increase in remote high mountain lakes in the European Alps – a response to climate warming ?

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Over the past two decades, a substantial rise in solute concentration at two remote high mountain lakes in catchments of same metamorphic bedrock (gneiss, micaschists) in the European Alps has been observed (Thies et al. 2007). At Rasass See (2682 m, Italy), electrical conductivity has increased by a factor of 18 (Fig.1) and the concentrations of the most abundant ions magnesium, sulfate and calcium have reached the 68-fold, 26- and 18-fold values. At Schwarzsee ob Sölden (2796 m, Austria), electrical conductivity has increased by a factor of 3.

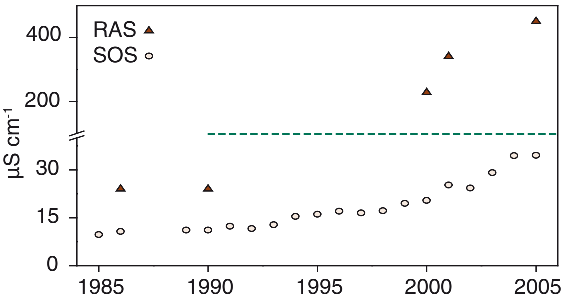

Fig. 1. Electrical conductivity in two alpine lakes in the period 1985–2005, Rasass See (RAS: triangles) and Schwarzsee ob Sölden (SOS: dots). Horizontal dotted line indicates a break in the y-axis scale. Modified from Thies et al. 2007, with permission of the American Chemical Society.

In addition to the increased values of major ions, very high nickel concentrations have been found recently at Rasass See (i.e. 243 µg L^{-1}), which exceed the nickel limit for drinking water by more than one order of magnitude. The pronounced change in lake water chemistry is attributed to the solute release from rock glaciers in both lake catchments, which has intensified as a response to the recent increase in air temperature in the Alps. Glacial melt water draining into the lakes has caused solute concentrations to increase since the 1990s, while direct anthropogenic impacts, bedrock weathering and current atmospheric deposition as source for enhanced ion and metal values are considered to be negligible for both high alpine sites. The observed larger solute increase at Rasass See is attributed to a greater impact of glacial melt water from a larger size rock glacier, situated at a lower elevation. In addition, lake volume and estimated annual water residence time of Rasass See are four to five times smaller compared to Schwarzsee ob Sölden. High mountain freshwaters may become increasingly impacted by melt waters from active rock glaciers, which are widespread in cold-climate mountain regions around the globe and are located near the local boundary of permafrost, thus being sensitive to ongoing and anticipated future climate warming (cf. IPCC 2007).

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The fate of allochthonous dissolved organic matter in Lake Pääjärvi (Finland) as seen by a coupled hydrological-decomposition model

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The fate of allochthonous dissolved organic matter (DOM) in a receiving lake was assessed with a coupled hydrological-decomposition model. The environmental forcing of the hydrological MyLake model included daily inputs of solar radiation, wind, air moisture as well as the water and the DOM from rivers discharging to Lake Pääjärvi. Accounting for the bathymetry of the lake, the MyLake model mixed river water and allochthonous DOM to the water column, which was described at 2-m depth intervals. The dynamics of ice cover, the mixing and stratification of the water column was calculated according to environmental forcing at the intervals of one day for a ten year period 1995–2005.

To assess the biological decomposition of DOM, we carried out >500 d-long bioassays in dark at different temperatures and described the kinetics of mineralization by a first-order kinetic model, which separated DOM in three pools of bioavailability i.e. labile, semilabile, and refractory. The photochemical mineralization of DOM was measured for the determination of apparent quantum yields for the photochemical mineralization of dissolved organic carbon. The modelling based on the apparent quantum yields and incoming solar radiation predicted well the photochemical mineralization measured in the lake in situ when the temperature-dependence of reaction was accounted for.

The hydrological model coupled with a decomposition-module describes the concentration of DOM altogether or separately for the different classes of bioavailability at one day intervals throughout the water column. The labile DOM (8% of total DOC) is quickly utilized in the top of water column. Vernal and autumnal turnovers mix the semilabile DOM (15% of total DOC) to the deeper parts of water column, where it is a remarkable substrate for the heterotrophic food web of the lake. The majority of DOM (77%) is refractory and resists biological decomposition during a theoretical water residence time of the lake (3.5 years). Photochemical reactions decompose the refractory DOM in the top 0.2 meter of the water column, which covers only ca. 1% of the mean depth of the lake (15 m). Therefore, abiotic photochemical reactions mineralize only minor part of allochthonous DOM. The model predicted well the concentration of DOM monitored in the lake indicating that the major regulators of the DOM in Lake Pääjärvi are the allochthonous input and its biological decomposition.

Is surface water DOC increase linked to acid deposition through charge-density controlled OM solubility?

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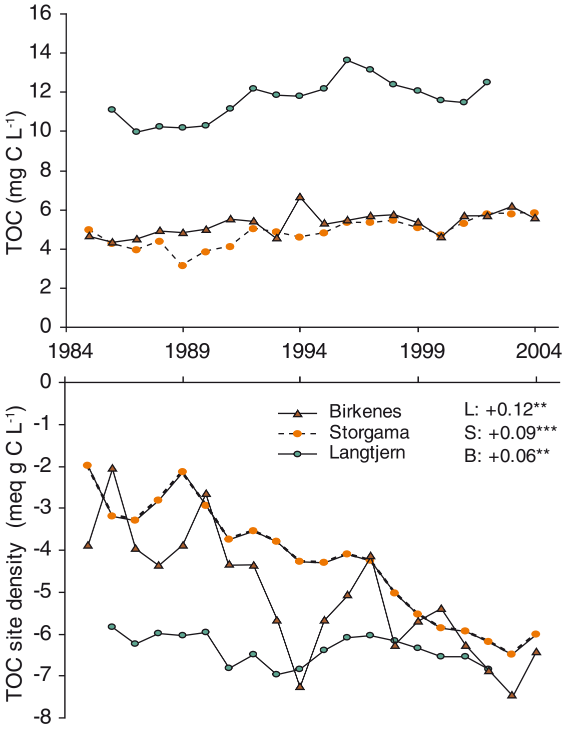
Dissolved organic carbon (DOC) concentrations in freshwaters have increased considerably in boreal ecosystems in the past decades, possibly as a response to reduced acid deposition (Monteith et al. 2007). Long-term trends and variations in sulphur and seasalt deposition were shown to statistically explain long-term trends and patterns in DOC in three acid-sensitive streams in Norway (De Wit et al. 2007). This suggests that organic matter (OM) solubility or retention in catchment soils is affected by soil solution acidity. A mechanistic understanding of these relations is still lacking.

De Wit et al. (2007) showed that a negative change in DOC charge density (μeq/mg C) occurred where DOC increases were most pronounced (see figure). Humic charge density has been used to explain DOC solubility in response to pH changes in batch experiences (De Wit et al. 2001) but the concept has not been tested at the watershed scale.

Here we aim to test the hypothesized relation between DOC charge density and upward trends in DOC by calculating DOC charge density for time series of lakes and rivers in the UK, Sweden, Finland, Czech Republic, Canada and US.

Charge density will be calculated using the chemical speciation model WHAM Water, which includes speciation of labile Al and other major cations and anions.

If the hypothesized relation between upward DOC trends and increasing negative charge density is substantiated in study, implementation of this relation in models describing ecosystem response to acidification might be considered.



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Understory vegetation alleviates nitrogen leaching and acid production

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Understory vegetations may control nitrate (NO_3^-) leaching. Cutting off of sasa bamboo, understory vegetation of mixed forest, made NO_3^- leaching high (Fukuzawa et al., 2006). Nitrogen saturation will occur in coniferous forest, where understory vegetation is usually scarce, when atmospheric nitrogen input exceeded 10 kg N ha^{-1} yr^{-1} (Wright et al., 1995; Ohrui and Mitchell, 1997). Understory vegetation has developed with prolonging logging interval in coniferous plantation stands in Japan. Nitrate leaching at the Japanese cedar (*Cryptomeria japonica*) stand with abundant understory vegetation was less than that with scarce one (Baba et al., 2004). We aimed to examine the contribution of understory vegetation to nutrients cycling, especially nitrogen, in Japanese cedar stand by comparing nutrient budgets in with and without understory vegetations. In addition, we examined contribution of chemical weathering to the acid buffer reactions.

Stand age of Japanese cedar plantation in Shichinohe (Haginosawa), Aomori, is 50 years old in 2006. Andisols has developed on andesitic Holocene tephra. We installed stainless pan-lysimeters beneath O horizon and at the depth of 10, and 40 cm in duplicate in April, 2004 and then cut off understory vegetation in July (cutting plot). Soil percolated water samples were also taken at the control plots in triplicate. We measured major ions by ionchromatography (Shimadzu, LC 10A Ion Chromatographic Analyzer) and silica by colorimetry of molybdenum blue method (Shimadzu, UV-mini 1240 Spectrophotometer). Acid (H^+) production due to N transformation ($[H^+]$load) was calculated after van Breemen et al. (1987). The total acid production ($[H^+]$prod), mobilization of base cations, and mobilization of silica were estimated after Mulder et al. (1987). Strontium isotopes (^{86}Sr and ^{87}Sr) were determined by mass-spetrography (TRITON).

Nitrate leaching increased at the depth of 10 cm in the cutting plot, compared with the control. It made $[H^+]$load larger in the cutting plot than the control. Silica mobilization also increased accompanied with $[H^+]$load. Strontium isotope ratio (^{87}Sr / ^{86}Sr) was negatively proportional to $[H^+]$load. These indicate that acids produced by N transformation were partly buffered by chemical weathering. Based on our results, understory vegetations alleviate nitrogen leaching and acid production due to N transformation. When acid production increased by removal of understory vegetations, chemical weathering contributes to acid buffer reaction. Soils in our study site, therefore, will not significantly acidified owing to understory vegetations and weathering.

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Are soil organic phosphorus and carbon cycling linked?

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The understanding of the biological processes in phosphorus (P) cycling in soils remains limited, in particular when compared to the understanding of organic carbon (C) cycling. McGill and Cole (1981) proposed that carbon and nitrogen are stabilized together in soils, and that the release of nitrogen from organic matter occurs accidentally during oxidation of carbon, i.e. driven by the search of soil organisms for energy. In contrast, organic P would be stabilized due to the phosphate group and released by phosphatases which are secreted under P deficiency. This concept was revised by Gressel and McColl (1997) who suggested that on a biological time scale, P mineralization is coupled with C mineralization. However, on a pedogenic time scale, the geochemical processes of apatite weathering, P sorption and leaching ultimately result in low P availability and potential uncoupling of organic P and C cycling.

We will present evidence from a number of studies in which P and C cycling do or do not appear to be linked, and we will try to elucidate the processes behind. For example, sorption studies with organic P compounds support the concept of selective stabilization of soil organic P (e.g. Celi and Barberis, 2005). In a study of repeated drying and rewetting of previously C-amended soils, CO_2-flushes were positively related to changes in microbial C, while changes in resin-extractable inorganic P were not related to changes in microbial P (Butterly et al., 2008). Thus, P cycling can be uncoupled from C cycling if physicochemical processes are dominating. Under field situations, however, losses of soil organic C are often accompanied by losses in organic P, as revealed by a review of P dynamics in tropical agroecosystems as well as by results from a long term field experiment with different crop rotations, stubble management and tillage treatments in Australia (Bünemann et al., 2006; Nziguheba and Bünemann, 2005). Both studies also showed that high C availability, e.g. in systems with perennial plants and pastures, is required for the build-up of soil organic P from mineral fertilizer P. Similarly, C additions in laboratory incubations resulted in a redistribution of P from inorganic to organic and condensed forms of P, mainly in the region of monoester P or as pyrophosphate as seen by ^{31}P solution NMR (Bünemann et al., 2008). Thus, microbial immobilization can disrupt the coupling of C and P release during decomposition of plant residues in soil, depending on the quality of the plant residue (Ha et al., 2008). The main gap in concepts of organic P mineralization lies in the limited understanding of the role of extracellular enzymes from the P and C cycles in the degradation of soil organic phosphorus, and we will present recent results that help to fill this gap.

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Changes in water colour between 1986 and 2006 in subcatchments of the River Nidd, Yorkshire, UK

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Organic soils, particularly peats, are a major source of dissolved organic carbon (DOC), and hence colour, to surface waters. In Britain, upland areas, which are dominated by organic soils, make up 30% of the land area, but supply over 70% of potable water. Over the last years 20 years, the degree of discolouration of this water has increased (Watts et al., 2001). While coloured water is not considered a direct health risk, it does pose indirect risk to health because the treatment process of chlorinating coloured water may produce carcinogens such as trihalomethanes.

Over the same period, concentrations of DOC have increased in freshwaters draining catchments containing organic soils across Europe and North America (Monteith et al., 2007). A range of hypotheses have been put forward as potential driving mechanisms (Evans et al., 2006), many of which are linked to climate change, such as increased production of DOC, changes in the hydrological export of DOC and increased biological activity due to elevated atmospheric carbon dioxide. Others have suggested that changes in the chemistry of atmospheric deposition may be the key driver, while some believe that land use change is major factor. The exact driver(s) that can quantitatively explain the observed increase in DOC concentrations, and hence water colour, remain open to debate and are in need of further research. In addition, most water colour and/or DOC records are for sites at a catchment/lake outlet. Few studies have looked at the spatial variability in water colour/DOC time series in adjacent catchments or subcatchments.

In 2006, we collected monthly water samples from 15 subcatchments of the upper River Nidd, which is one the largest water-gathering grounds in Yorkshire, that had previously been monitored for water colour throughout 1986. The underlying geology of the Upper Nidd is mainly millstone grit with bands of sandstone and shale, the soils are blanket peat on the upper slopes and organic rich gleys on the lower slopes, vegetation is dominated by acid grasses, *Calluna vulgaris* heather and *Sphagnum* moss and the major land use is sheep grazing. In 2006, the water samples were analysed for water colour, plus pH, conductivity, DOC, major cations and anions, aluminium, iron and silicon. Between 1986 and 2006, mean annual water colour increased in all the subcatchments. However, there was considerable variation in the increase, which ranged from 11 to 135%. Based upon the percentage increase in water colour the subcatchments were divided into three groups, where (1) the increase was less than 50%, (2) the increase was between 50 and 80% and (3) the increase was greater than 80%. Based on these grouping, it was evident that it was the catchments that had the smaller mean annual water colour values in 1986 that had shown the largest increase in water colour over the 20 year period. These catchments are also the largest catchments where a greater contribution of flow originates from depth, as indicated by the larger silicon concentrations and pH values. Possible reasons for the disparity in water colour increase between subcatchments includes changes in adsorption of DOC within the mineral horizons of the soil on the lower sloped as a result of changes in acid sulphur deposition and/or changes in hydrological flowpaths as a result of land use change.

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Link between increased DOC in freshwaters and decline in atmospheric sulphur deposition: Evidence of soil processes from laboratory experiments

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Concentrations of dissolved organic carbon (DOC) have increased in freshwaters draining areas with organic soils across parts of Europe and North America over the last two decades. Recent analysis of regional freshwater data has revealed a correlation between the increasing trend in DOC concentrations and a decreasing trend in freshwater sulphate and chloride concentrations that have been driven by the decline in acid sulphate and seasalt deposition over the same period (Monteith et al., 2007). A decline in acid sulphate and seasalt deposition could increase the solubility of DOC by increasing soil water pH and decreasing ionic strength, which in turn could also increase biological activity and the production of DOC during organic matter decomposition. However, the interpretation of Monteith et al. (2007) assumes that stream water data reflects the chemical and biological processes operating in catchment soils that control the supply of DOC. As many factors control DOC dynamics in freshwaters, it is difficult to be certain of a causal deposition-DOC link on the basis of correlation analysis in field monitoring data alone.

To test the credibility of the deposition-DOC mechanism, we carried out controlled laboratory experiments on organic soils collected from five of the UK catchments studied by Monteith et al. (2007). Cores were collected from the top 10 cm of peat and organo-mineral soils. Vegetation was removed. Peats were saturated, and organo-mineral soils were unsaturated. All soils were kept at a constant temperature in an incubator at 8 and 16 °C. A combination of high and low seasalt and acid sulphate deposition loadings (0.9, 15.1, 2.8, 34.0 kg S ha^{-1} yr^{-1}, respectively) in a 2x2 factorial design were applied at weekly intervals over a 40 week period. Deposition treatments were chosen to reflect the range observed at the field sites.

Results showed that DOC declined in soil waters in response to both acid sulphate and seasalt loadings, with the greatest declines seen in response to seasalt treatments due to a decline in soil water pH. Mass balance calculations and soil respiration measurements were used to estimate to what degree the decline in DOC was attributable to depletion in the DOC pool due to continual removal of soil water and/or a reduction in biological activity due to increased acidity. Batch experiments, where 10g of soils was shaken with 100 ml of solution with seasalt and acid sulphate concentrations in the range 0–24 mg SO_4 L^{-1} for 20 hours, confirmed the importance of changes in chemistry for DOC solubility. Preliminary calculations suggest that declining deposition is a credible hypothesis for increased DOC in freshwaters, however further work is required to upscale the result to include the impact of hydrology in altering the transport of DOC from soil to stream.

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An interaction between N and C cycling withconsequences for the global carbon budget

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Forest soils in areas with high atmospheric N-deposition often show lower CO_2-concentrations in the soil atmosphere than in low deposition areas, and this results in low CO_2-emissions despite high above-ground production (Fleischer, 2003). Inhibition of nitrification in (sieved) soils from these areas resulted in additional CO_2-release and the difference between this disclosed gross heterotrophic respiration (GHR) and the net release (net heterotrophic respiration, NHR) was the result of a strong within-soil CO_2-sink in the saprophytic subsystem of the soil (Fleischer & Bouse, 2008). Therefore, soil respiration solely determined as CO_2 emitted as NHR (the common situation) may lead to serious underestimates, and to misinterpretations of the function of the soil system, especially in areas with high N-deposition.

One interpretation that should be reconsidered is the acclimation of the soil respiration response in a warmer world. Such conclusions were based on soil warming experiments in the field or at the laboratory. They did not result in expected increases of CO_2-emissions (Giardina & Ryan, 2000; Luo, Y. et al, 2001, Strömgren, 2001). The interpretations of such studies are still controversial (Davidson & Janssens, 2006).

Soils were incubated at different temperatures for one month. Supply of NH_4^+ increased the within-soil CO_2-sink and none, or very limited, increase of CO_2 occurred from 8° to 18 °C. Instead, when nitrification in the original unfertilized soil was inhibited and GHR was disclosed, there was a large increase in CO_2-emissions. The within-soil CO_2-sink is hiding the CO_2-increase and this may have led to acclimation as an explanation of the temperature response. Less CO_2 than projected from general knowledge on microbial response to increased temperature is released. However, the explanation is not biological acclimation of respiration, but rather within-soil CO_2-uptake. This effect may vary between areas with different atmospheric N-deposition. In general, as the N and C-cycles are not self-goverened, more focus should be on their interactions. Following projected increases in global N-depositions the within-soil CO_2-sink described (Fleischer & Bouse, 2008) will probably increase in strength.

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Factors regulating nitrogen retention in forested watershed during the development of Japanese cedar stand

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Nitrogen (N) loss and retention mechanism in forested ecosystem is one of the major concerns to ecologists because it has been widely reported that elevated N deposition induced serious N loss beyond plant N demand (so-called "N saturation"; Aber et al. 1998). Internal N cycling between plant and soil is key of importance to understand watershed N retention. Forest clear-cutting experiments have been studied well, and can provide sufficient knowledge on plant-soil-stream interaction. However, recovery processes from clear-cutting is still limited. We investigated N dynamics in some watersheds consist of Japanese cedar plantations, age of which is defined as passed years after clear-cutting and subsequent afforestation. Conventional forest management here is practiced by watershed. As a result, stand age is even within a watershed, but is various among watersheds. The use of these watersheds with various stand age can help to isolate the effects of stand development processes after clear-cutting.

Our study site is located in Nara Prefecture, central Japan, which received 2 900 mm precipitation in annual means and 13–14 kg N ha-1 year-1 as mean bulk N deposition (2004-2007). Streamwater NO_3^- concentrations remarkably increased just after clear-cutting, peaked in 3 year-old-stand watershed, and then decreased to pre-cut level in 15 year-old-stand watershed. More details on streamwater chemistry are available in Fukushima and Tokuchi (2008). Stream N export was 13, 4.6, 4.8, 4.9, and 3.5 kg N ha-1 year-1 in 6-, 17-, 32-, 43,- and 90-year-old-stand watershed, respectively. There was strongly negative correlation between stream NO_3^- concentration or N export and plant N uptake in all stands (aged 1 to 45 years old) but in 90-year-old stand, where plant N uptake declined. Net N transformations in soil revealed lower nitrification rate in 90 year-old stand than in younger stands. In addition, retained N in microbial biomass was greater in 90 year-old stand than in younger stands. These results suggest that in terms of watershed N retention, declined plant uptake of N should be compensated to alternation of soil microbial biomass and activity, which is likely caused by the change in C availability of soil organic matter via litterfall.

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Role of soil engineers in the transfers of C-N-S in a regenerating cutover peatland

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Soil organisms, because they change soil physical and chemical properties as well as microbial communities, are efficient engineers that play a key role on the soil nutrient dynamics. Although the coupling of carbon (C) and nitrogen (N) in soil have been well studied, such studies in peat soils are scarce and even unavailable for sulphur (S). The aim of our study was to access the impact of peat bioturbation by a plant (*Eriophorum angustifolium*) and/or an epi-anecic earthworm (*Lumbricus rubellus*) in the coupling of C-N-S in a regenerating cutover peatland, using simultaneously three isotopic tracers (^{13}C-^{15}N-^{34}S). We thus focused on C-N-S transfers in the rhizosphere and drilosphere which are representative of the plant and/or earthworm activities.

Labelled organisms (two plants or three earthworms, Table 1) were introduced in unlabelled peat mesocosms (2 litres). Plants, earthworm tissues, representative peat samples of the rhizosphere and the drilosphere and bulk peat were analyzed for their δ (‰) ^{13}C, ^{15}N and ^{34}S by using an elemental analyser-isotope ratio mass spectrometry (20-20 IRMS, Europa Scientific) after 3 and 18 days of incubation in a climatic chamber.

Table 1. δ^{13}C-^{15}N-^{34}S (mean ‰ ± S.E.) of the unlabelled and labelled *E. angustifolium* (n = 15) and *L. rubellus* (n = 12). Means followed by the same letter are not significantly different (*t-test* with *P* > 0.05).

		Natural abundance ***Unlabelled organisms***	**Enrichment** ***Labelled organisms***
δ^{13}C	*E. angustifolium*	-27.0 ± 0.1a	295.7 ± 87.5b
	L. rubellus	-26.6 ± 0.1a	1170.1 ± 90.7c
δ^{15}N	*E. angustifolium*	5.9 ± 1.0a	690.3 ± 85.0b
	L. rubellus	14.8 ± 0.7c	4620.9 ± 224.8d
δ^{34}S	*E. angustifolium*	23.7 ± 1.0a	31.8 ± 1.7b
	L. rubellus	11.4 ± 0.3c	217.7 ± 10.4d

We demonstrated that the peat rhizosphere rapidly enriched in C and N from labelled plants as well as from labelled earthworms, but also in S from labelled plants. Rapid C and N enrichment but not S of casts and burrows from labelled earthworms were also demonstrated. There was also a significant N transfer from labelled earthworms to unlabelled plants within 15 days (Fig.1). Nitrogen first passed through the peat rhizosphere and then reached the roots and shoots of *Eriophorum angustifolium*.

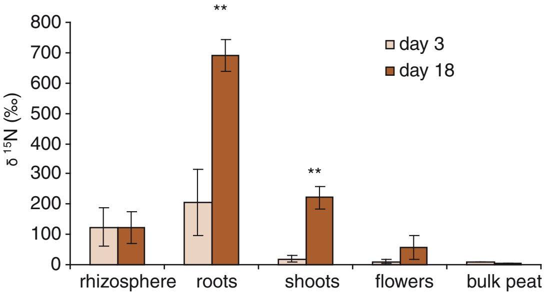

Fig. 1. ^{15}N enrichment (δ ‰) of the peat rhizosphere, plants (roots, shoots and flowers) and bulk peat derived from labelled earthworms at day 3 and day 18 (mean ± S.E., n = 4, t-test ** P < 0.01).

Our study highlighted the key role of soil engineers in the cycling of C-N-S in regenerating cutover peatlands by enhancing C-N-S transfers and providing nutrient enriched peat hot spots which are expected to sustain higher microbial activities. Further studies will therefore focus on microbial communities and C-N-S microbial uptake in the rhizosphere and the drilosphere.

Interactions between carbon and nitrogen cycling

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The cycling of C and N in terrestrial ecosystems is tightly coupled. Removing or increasing the availability of one of the elements affects the dynamics of the other. I will discuss stoichiometric changes in the plant and soil system and results from ^{13}C and ^{15}N-double tracer experiments in forests to identify similarities and differences in the cycling of C and N. They suggest that ecosystems are more retentive for N than for C. In addition, I will debate the impacts of N inputs on C sequestration in plant biomass and soils of forests. By presenting results from high-altitude ecosystems in Switzerland, I will show that increasing atmospheric CO_2 decreases soil N availability which in turn limits growth responses.

Effects of changing redox conditions on the dynamics of dissolved organic matter, CO_2 and CH_4 in paddy soils

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The current knowledge about dissolved organic matter (DOM) dynamics in soils based mainly on observations and experiments in aerobic environments. We have only a limited understanding about the effects of changing redox conditions on production and composition of DOM although this fraction of soil organic matter is important for greenhouse gas emission and carbon storage in soils. In many ecosystems temporal and spatial changes of oxic and anoxic conditions are evident and might even increase in future. It is assumed that changing redox conditions are the key drivers of DOM dynamics in such ecosystems.

More detailed we tested the following hypotheses:

a. Continuous anoxic conditions result in larger DOM production than oxic ones
b. Short oxic periods interrupting anoxic conditions further promote DOM production
c. As the consequence of a) and b), DOM production increases with the number of redox cycles and therefore with the length of cultivation of paddy soils

We chose paddy soils as a model ecosystem because these soils are anoxic during the rice growing period and oxic during harvest and growth of other crops. Furthermore, paddy soils have oxic and anoxic horizons. Soils of a unique chronosequence of paddy soil evolution (50 to 2000 years, China) were studied in direct comparison to non-paddy soils of the same age. In these soils, exposed to different redox conditions over defined periods of times, the dynamics of DOM, CO_2, CH_4 and other redox sensitive elements were followed in laboratory experiments. In the latter redox conditions were changed every 3 weeks from oxic to anoxic and vice versa. Besides analysis of the composition of the soil solution including low molecular weight organic and the gas phase we also quantified the biodegradability of DOM at oxic and anoxic conditions.

The measured redox potentials of -50 mV to 250 mV at anoxic conditions and 350 mV to 550 mV at oxic conditions were in the expected range and proofed the appropriate setting of the chosen incubation method. We further observed increasing contents of dissolved organic C (DOC; up to a factor of 6) with proceeded time of anoxic conditions in the incubation experiment. The DOC contents also increased with the length of cultivation, i.e. with increasing number of redox cycles occurred in the field before sampling. Hence, the 2000 year old paddy soil showed highest DOC production. Changing the redox conditions from anoxic to oxic and vice versa had large effects on the dynamics of CO_2 and CH_4. Carbon mineralization as measured by CO_2 evolution doubled at oxic conditions in comparison to anoxic ones. Methane production increased with the duration of paddy soil cultivation whereas non-paddy soils showed similar values as atmospheric concentrations without significant effects of the length of soil evolution.

The unique chronosequence of paddy soil evolution as a model ecosystem and the long-term incubation experiments with these soils enabled us to deeply improve our understanding of the relationship between changing redox conditions and the dynamics of dissolved organic matter, CO_2 and CH_4.

Increased dissolved organic carbon (DOC) in Central European streams is generated by ionic strength reductions rather than decreasing acidity or climate change

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DOC trends were investigated at two forested catchments in western Czech Republic. They represent geochemical end-members of ecosystem sensitivity to acidification (acid-sensitive granitic Lysina catchment vs. acid-resistant serpentinitic Pluhuv Bor catchment). Despite very different bedrocks, soils and stream chemistry, mean discharge-weighted DOC concentrations were similar at both catchments between 1993-2007: 18.8 mg L-1 at Lysina and 20.2 mg L-1 at Pluhuv Bor (Fig. 1.). Between 1993 and 2007 DOC increased significantly (linear regression) at both catchments: the mean annual increase was 0.42 mg L^{-1} yr^{-1} ($p<0.001$) at Lysina and 0.43 mg L^{-1} yr^{-1} ($p<0.001$) at Pluhuv Bor. Thus we observed a 64% increase in DOC at Lysina and 65% at Pluhuv Bor (Fig. 1).

The long-term increase in DOC was correlated with a decrease in ionic strength (IS) at both catchments ($p<0.001$), which resulted from declining atmospheric deposition. Deposition of 30–39 kg S ha^{-1} yr^{-1} was observed between 1991–1993 and it declined to 7–11 kg S ha^{-1} yr^{-1} in 2004–2006, but only granitic Lysina was significantly acidified by this acidic deposition. Well-buffered Pluhuv Bor showed no decrease in soil or stream pH, as all incoming SO_4 from the atmosphere was buffered by exchangeable cations in the magnesium-rich soils. Acid input was only manifested by rising IS, leading us to conclude that declining acidity did not play a role in the observed DOC increase at Pluhuv Bor. Data from low flow events throughout the study period further supports this conclusion. At acidic Lysina, DOC increased and IS decreased during low flow periods (25th precentile of runoff) despite the fact that pH did not change. At well-buffered Pluhuv Bor, acidity decreased during low flow, but IS and DOC remained unchanged.

Climate change is not driving the increase in DOC at our study sites, because neither temperature, annual precipitation nor discharge (annual or weekly) show statistically significant trends during the study period.

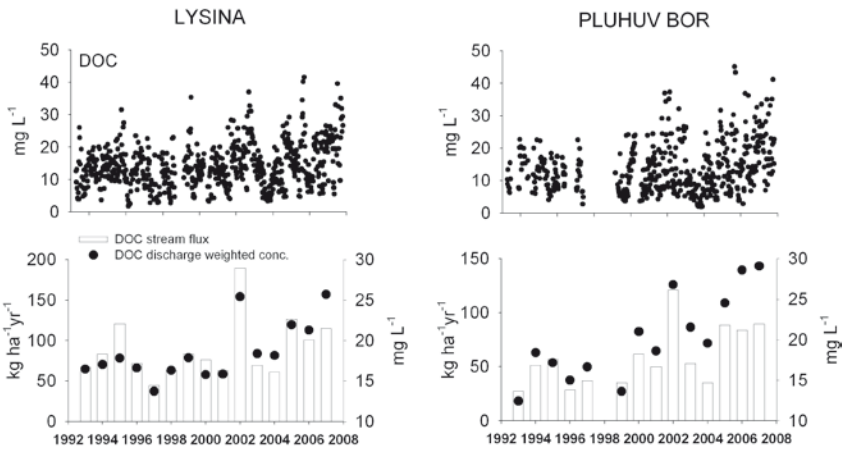

Fig 1. Streamwater DOC concentrations and fluxes measured at the Lysina and Pluhuv Bor. Upper panels represented weekly samples, lower panes annual fluxes and discharge-weighted mean annual concentrations.

Abnormally high CH_4 concentrations in two small freshwater boreal lakes

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Exceptionally high concentrations of methane were found in hypolimnetic water of two small (surface areas 5.1 and 6.2 hectares, maximum depths of 18 m and 10 m, respectively) freshwater boreal lakes. This and the carbon isotope composition of dissolved inorganic carbon (DIC) suggest high rates of methanogenesis in the major body of water column of both lakes.

In June 2008 the measured CH_4 concentrations in the epilimnion were ten times higher compared to equilibrium concentrations, indicating high efflux to the atmosphere. In the upper part of hypolimnion the concentrations were 1000-fold compared to the epilimnion. The overwhelmingly highest concentrations were measured at the lower part of the hypolimnion (2 m above the bottom of the lakes), where the CH_4 concentration was in one lake 200 000 times and in the other one 2 000 000 times higher compared to the equilibrium concentration with atmosphere.

The hypolimnetic concentrations were remarkably higher than those observed in anoxic hypolimnion of other small lakes in the same area (Kankaala et al. 2006, 2007), and were comparable to those measured above potential gas hydrates in offshore southwestern Taiwan (Chuang et al. 2006).

Also the carbon isotope composition of DIC was significantly different in hypolimnion of the two lakes when compared to other water layers or hypolimnia of neighboring lakes. This is typical for microbiological methanogenesis in which the resultant CH_4 is isotopically light and residual DIC becomes increasingly enriched.

Abnormally high CH_4 and CO_2 concentrations support the hypothesis that the two lakes are meromictic. This is in good agreement with the other chemical results. It is highly unlikely that the water layers would ever mix in the future, but if that happens, the resulting efflux of CH_4 would be drastically high.

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The impact of changing acidity on carbon and nitrogen cycling in peatlands

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Peat soils have traditionally sequestered vast stores of carbon (C), but since the onset of the industrial revolution and the growth of agriculture, these ecosystems have been exposed to increased nitrogen (N) and sulphur (S) deposition, increasing the acidity of peatlands and potentially threatening their function as carbon sinks. While N deposition remains high, S deposition has declined sharply in the last few decades due to legislation on the use of fossil fuels, and many ecosystems are consequently recovering from acidification. We are testing the hypothesis that peatland C and N cycles are being strongly altered by acidity change and that rising pH will increase the loss of C and N as dissolved organic matter (DOM), due to both increases in biological production and increasing DOM solubility. We have established field experiments at two UK peat ecosystems exposed to low and high levels of N pollution and are attempting to manipulate soil pH which solutions aimed at replicating historic S deposition peaks and more alkaline pre-industrial conditions. Initial measurements of C and N losses in gaseous and dissolved forms are presented.

Possible linkages between surface water stoichiometry and nuisance growth of the aquatic macrophyte *Juncus bulbosus*

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Norwegian surface waters are characterised by distinct regional gradients in background concentrations of carbon (C), nitrogen (N) and phosphorus (P), mainly as a result of large variation in precipitation amounts (0.5–5 m yr^{-1}), catchment biogeochemistry, soil/vegetation characteristics, and atmospheric deposition of N compounds (3–25 kg N ha^{-1} yr^{-1}). The large variation in the stoichiometry of essential nutrients may have significant impacts on the spatial distribution and species composition of aquatic plants.

In parts of Norway, nuisance growth of the aquatic macrophyte Juncus bulbosus has become a serious problem in many watercourses during the last 2–3 decades. One hypothesis is that the big expansion has been governed by elevated N deposition giving skewed N, C and P stoichiometry in surface waters. This is underpinned by a remarkable overlap between N deposition patterns and the regional distribution / historical development of problematic Juncus growth. To explore possible links between mass occurrence of Juncus and the regional patterns in the stoichiometry of C, N and P in surface waters, a synoptic survey of 155 lakes across Southern Norway was carried out in autumn 2007. The survey included extensive chemical analyses of relevant C, N and P species in lake samples, along with observations and measurements of Juncus occurrence, abundance and growth.

The collected data captured well the large chemical gradients, with concentrations of total N, P and organic C varying with factors of 14, 15 and 40, respectively. The possible linkages between stoichiometric gradients in the lakes and the status of Juncus growth are currently under evaluation.

Spatial and temporal variability of soil solution below a N saturated mature spruce before and after clear cut

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In spring 2005 121 suction cups were implemented in a 2 × 2 m grid below the main rooting zone (40cm depth) of a N saturated mature spruce stand. Seepage water was collected monthly during the vegetation period and analyzed for NO_3^-, SO_4^{2-}, PO_4^{3-} and Cl^-. For the samplings in July and October additionally pH and the concentrations of Al, Ca, Mg, Mn, K, Na, and NH_4^+ were measured. After the clear cut in January 2006 sampling and analyzing was done again monthly from April to December 2006 at exactly the same places as in the mature stand. Data were examined with conventional statistics and with geostatistical methods. Semivariograms were calculated and models were fitted for most ions and elements in the soil solution.

In the mature stand mean concentrations of NO_3^- (35–21 mg l^{-1}) and SO_4^{2-} (17–20 mg l^{-1}) were highest while other ions and elements had means between 1 and 5 mg l^{-1}. PO_4^{3-} and NH_4^+ could not be detected in the soil solution. Spatial variability was highest for NO_3^- and lowest for Na. Temporal variability was lower compared to the spatial variability for most ions. NO_3^- was significantly correlated with concentrations of Al, Ca, Mg, Mn and pH. This indicates the importance of NO_3^- with respect to cation leaching and soil acidification. Also several other ions and elements were significantly correlated among each other.

Geostatistical analysis revealed that NO_3^- had autocorrelation ranges between 17–19 m and high structural variances (65–81%). Al, Ca and Mg had ranges between 10 and 13 m and between 60 and 80% of the semivariance could be explained by structuring. SO_4^{2-}, Cl^-, K, Na, and Mn showed spatial dependencies below 10 m. The calculated structural variances were between 65–80% for Cl^- and Mn while the other parameters had structural variances below 50%.

After clear cut the mean concentrations for most ions and elements showed lower values in April 2006 but increased during the vegetation period. This behavior was most pronounced for NO_3^- which showed increasing mean concentrations from 10 mg l^{-1} in April 2006 to 150 mg l^{-1} in December 2006. In contrast to the mature stand temporal variability after the clear cut for most ions and elements was high, while the spatial variability was lower. Semivariograms showed that the spatial structures for most ions and elements vanished after the clear cut. Autocorrelation ranges were shorter and structural variances were considerably lower (Fig. 1). Differences in spatial and temporal variability as well as in autocorrelation range and strength have important implications for sampling strategies depending on the parameter under investigation and prior treatments.

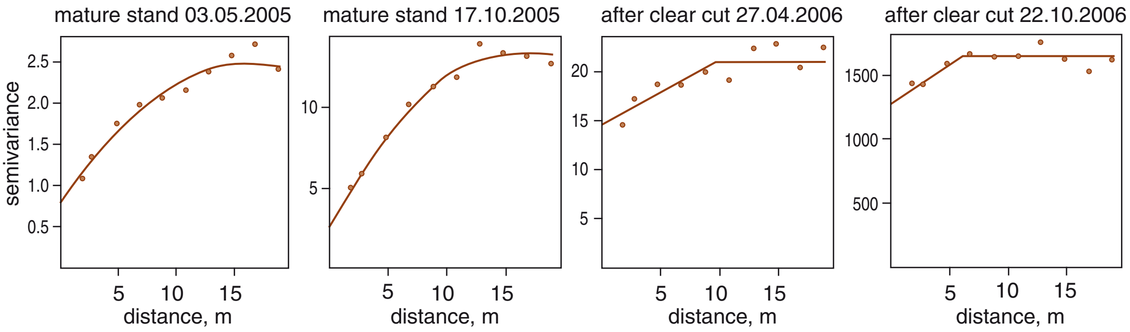

Fig. 1. Modelled semivariograms of the NO3- concentrations in soil solution before and after clear cut

Long-term trends in aluminium export from acidified, nitrogen-saturated, forest catchments and its impact on phosphorus cycling in lakes

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Inorganic aluminium (Al_i) hydrolyses in lakes as pH increases due to internal alkalinity generation. Hydrolysis causes precipitation of colloidal $Al(OH)_3$, which has large surface area and strongly binds phosphate-phosphorus (PO_4^--P). This process affects three parts of the in-lake P cycle. (1) In the photic zone, $Al(OH)_3$ binds PO_4^--P, reducing P bioavailability for primary production. (2) In the hypolimnion, settling $Al(OH)_3$ sorbs PO_4^--P liberated from sedimenting seston, further reducing pool of bioavailable P. (3) In the sediment, $Al(OH)_3$ prevents PO_4^-–P release to the water column after reductive dissolution of $Fe(OH)_3$. Here, we evaluate major sources and forms of Al exported from catchments of the Bohemian Forest lakes, Czech Republic, during pre-industrial time (<1850), acidification, and recovery (1990–2008).

Soils in the Bohemian Forest catchments are strongly acidified (pH_{CaCl2} <4.5, base saturation <15%) due to high atmospheric deposition of sulphur (S) and inorganic nitrogen (N), and are N-saturated. Terrestrial NO_3^- export currently equals or exceeds atmospheric inputs of inorganic N. Al is exported from soils as Al_i and Al bound by organic complexes (Al_o). The Al_o export is tightly associated with export of dissolved organic carbon (DOC) (Fig. 1a), whereas that of Al_i is with leaching of strong acid anions (SO_4^{2-} and NO_3^-) (Fig. 1b). Al export was dominated by Al_o in the pre-acidification period (<1850). Al_o was the major source of Al_i for the lake, being released from Al-DOC by solar radiation. During the anthropogenic acidification phase (1850-1990), the contribution of Al_i to terrestrial Al export continuously increased, being mostly associated with increasing SO_4^{2-}. The proportion of Al_i associated with NO_3^- leaching increased in the ~1970s due to N-saturation of the catchments. Currently, after a drop in S deposition, NO_3^- has become the dominant strong acid anion and the major Al_i carrier. N-saturated catchments respond strongly to environmental disturbances with elevated NO_3^- leaching, e.g., after the summer drought in 2003 and after forest decline caused by bark beetle outbreak since 2004 (Fig. 1c). The elevated NO_3^- leaching is compensated by elevated Al_i export that contributes to greater abiotic PO_4-P immobilization in lakes.

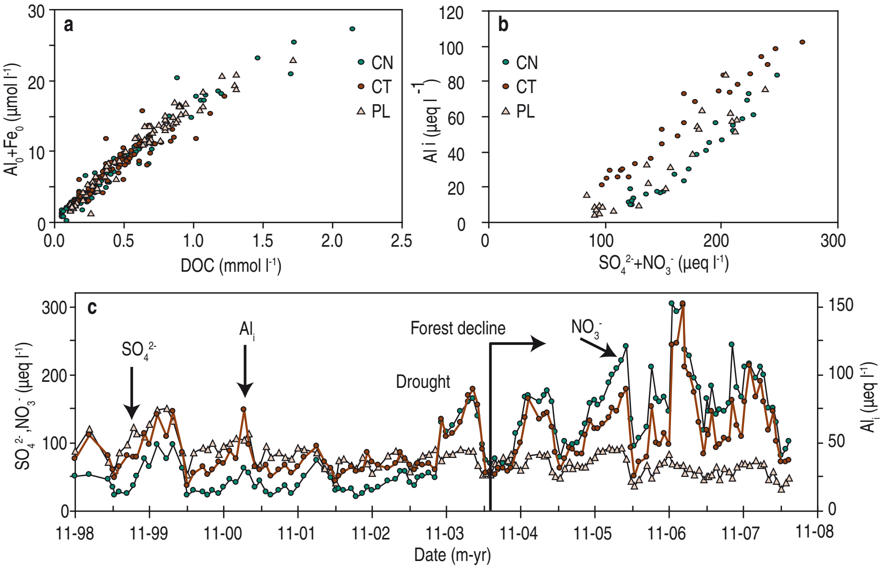

Fig. 1. Al concentrations in (a) lake tributaries and (b) lakes (CN, Černé; CT, Čertovo; and PL, Plešné) in the Bohemian Forest in 1984–2007, and (c) in the major inlet of PL lake, before and after forest decline.

Controls on the role of boreal lakes in landscape carbon cycling

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Majority of organic carbon (C) in Finnish lakes and boreal lakes in general originates from surrounding forests and peatlands. Lakes in the boreal zone are thus predominantly net heterotrophic, evading both carbon dioxide (CO_2) and methane (CH_4) to the atmosphere and burying organic C in sediments. There are about 56 000 lakes larger than one hectare in Finland, covering 10% of the country's total area. Subpopulations of 209 and 122 lakes, located between latitudes 60° and 69°, were randomly selected from the Nordic Lake Survey data base for carbon gas (Kortelainen et al. 2006, Juutinen et al. 2008) and sediment C stock studies (Pajunen et al. 2000, Kortelainen et al. 2004), respectively. Land use of the surrounding catchments (forest %, peat %, field %, water %) and water chemistry (4 seasons, 4 depths) were determined for each lake. These data sets demonstrate that in the boreal zone, lakes are important conduits for transferring terrestrially fixed C into the atmosphere. Both pCO_2 (partial pressure of CO_2) and C stock in the sediments were highest in small, shallow lakes. pCO_2 didn't correlate strongly with lake water total organic carbon (TOC) concentrations. By contrast, pCO_2 was associated with redox processes and lake trophic state suggesting heterotrophic microbial processes being primarily limited by nutrient availability. The annual CO_2 evasion from Finnish lakes was estimated as 1.4 Tg C, approximately 20% of the average annual C accumulation in Finnish forest soils and tree biomass (covering 51% of the total area of Finland) in the 1990s. Average annual C accumulation in lake sediments during the Holocene was significantly lower, although areal C stocks in lakes are significantly larger than in forest soils. Randomly selected Finnish lake data bases thus demonstrate that boreal lakes contribute significantly both to landscape C pools and fluxes and consequently to C sequestration at boreal landscapes. Links between biogeochemical cycles and controls on the role of lakes in landscape C cycling will be studied by comparing lake specific C evasion/accumulation ratio to lake chemistry, lake morphometry, catchment land use and sediment properties.

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Streamwater chemistry in highly contrasting lithologies

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Catchments underlain separately by three geochemically contrasting single rock types were studied. All eleven selected small catchments are situated in the Slavkov Forest and are forested by Norway spruce *(Picea abies)* plantations (Kram 2006). Chemical composition of streamwater was monitored in each vegetation season and under different hydrologic conditions in 2001–2003. Mean streamwater pH values of the individual catchments ranged from 4.1–4.5 (leucogranite) to 7.0–7.3 (serpentine). Results from the three selected monolithologic catchments with the highest sampling frequency are presented in Fig. 1 and Tab. 1 Serpentine streamwaters exhibited high concentrations of Mg and Ni and low concentrations of K. Amphibolite catchments were able to neutralize acidic water input and created the most favorable hydrochemical conditions for biota in streams. Extremely low pH and ANC values and very high Ali concentrations toxic for biota were found in streams draining leucogranite. Streamwater pH showed slight long-term increase at a rate of 0.01 pH yr^{-1} ($p<0.05$, MK test) at extremely acidic Lysina (Fig. 1).

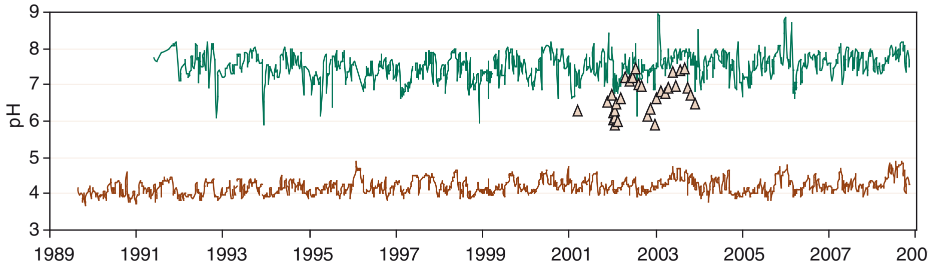

Fig. 1. Temporal patterns of streamwater pH at Pluhuv Bor (upper line, 960 samples), Na Zelenem (triangles, 31 samples) and Lysina (lower line, 1188 samples) between September 1989 and November 2008.

Table 1. Streamwater concentrations at the 3 geochemically contrasting forested catchments in 2001–2003.

Compound	Unit	Leucogranite (Lysina)		Amphibolite (Na Zelenem)		Serpentine (Pluhuv Bor)	
		Arit. mean	Stan. dev.	Arit. mean	Stan. dev.	Arit. mean	Stan. dev.
pH	pH unit	**4.2**		**6.5**		**7.3**	
H+	µeq L^{-1}	**62**	21	**0.4**	0.4	**0.05**	0.04
Mg^{2+}	mg L^{-1}	**0.5**	0.2	**3.3**	1.1	**18.6**	6.3
Ca^{2+}	mg L^{-1}	**2.0**	0.8	**7.2**	2.6	**3.1**	2.4
K^+	mg L^{-1}	**0.6**	0.2	**0.8**	0.2	**0.3**	0.3
Al inorganic	µg L^{-1}	**0.35**	0.13	**<0.01**	<0.01	**<0.01**	0.03
Al organic	µg L^{-1}	**0.14**	0.07	**0.01**	0.01	**0.02**	0.04
Ni	µg L^{-1}	**0.8**	0.6	**1.2**	0.6	**89**	46
DOC	mg L^{-1}	**15**	7	**6**	2	**16**	11
HCO_3^-	mg L^{-1}	**0**	0	**15**	13	**68**	39
ANC Gran	µeq L^{-1}	**-64**	25	**+249**	218	**+1110**	633
ANC ch.bal.	µeq L^{-1}	**-28**	23	**+334**	235	**+1321**	579

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The effect of Scots pine, Norway spruce and silver birch on the chemical composition of stand throughfall and percolation water in Northern Finland

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The weathering potential of soil solutions collected in Scots pine, Norway spruce and silver birch sites to release elements from the mineral soil material of a podzolic soil has earlier been studied in a tree species experiment located in Kivalo, Northern Finland (66°N, 26°E) (Lindroos et al. 2003). In this laboratory experiment, no systematic differences were found between the potential of the soil solutions from the three sites to release elements through weathering from the mineral soil, even though there were some differences in the quality of the soil solution collected below the organic horizon. The aim of the study presented here was to determine the effect of tree species on the chemical composition of stand throughfall and percolation water on the same three stands in field conditions. We hypothesized that the quality of the stand throughfall and percolation water would be affected by the tree species, especially in the case of deciduous trees.

In the tree species experiment in Kivalo, the 70-year-old forest stands (pine, spruce, birch) were established on the same geomorphological formation where the soil material is composed of till and the soil type is podzol. The climatic factors and original soil properties in all the forest stands were similar. The study area had originally been a homogeneous spruce stand, and the study sites were established after clear-cutting and prescribed burning. There were three study plots, 25 × 25 m in size, for each tree species (9 plots in total). Stand throughfall (TF) was collected during the snow-free periods during 2000–2003 using 20 bulk deposition collectors located systematically on one of the three plots for each tree species. Bulk deposition was collected in an open area close to the tree species experiment. Soil percolation water (PW) was collected during the snow-free period using zero-tension lysimeters located below the organic layer (depth 0 cm) and at a depth of 10 cm in the mineral soil. There were 5 lysimeters at each depth on each of the plots. The pH was measured on the water samples as well as elemental concentrations using ICP-AES, cations and anions using IC, total N using FIA, and dissolved organic carbon (DOC) on a TOC analyser. Aluminium fractionation was carried out on the PW samples as described in Derome et al. (1998).

The mean pH values in TF and PW (0 and 10 cm) were the highest on the birch plots, and the lowest mean pH in TF and PW (0 cm) on the pine plots. The highest mean Al concentrations in PW also occurred on the pine plots. The birch plots had the lowest mean DOC concentration in TF, while the values were almost the same on the spruce and pine plots. There were only small differences in the DOC concentrations in PW (0 and 10 cm) between the sites. The Ca and Mg concentrations in PW were the highest on the birch plots. Birch seems to have a decreasing effect on the acidity and an increasing effect on the Ca and Mg concentrations in water passing down through the forest ecosystems in this experiment.

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Trends in forest soil acidification status in relation to sulphur and nitrogen deposition during 1996-2006 in Finland

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Forest soil acidification in relation to acidifying deposition in Finland and elsewhere in Europe has been studied extensively during the last two decades. In Finland, no clear signs of increased acidification or lost of buffering and neutralising capacity have so far been detected in upland forest soils (e.g. Derome et al. 2007). The deposition of SO_4 into forest soils has decreased strongly due to the reduction in SO_2 emissions (e.g. Lindroos et al. 2006). The aim of this study was determine the trends in the acidification status of soil water during the period 1996–2006 that has been characterized by a clear decrease in SO_4 deposition. The stands where the monitoring has been carried out are located along a climatic gradient throughout Finland (5 pine, 5 spruce stands) and belong to the EU Forest Focus/ICP Forests monitoring network.

The SO_4-S deposition in stand throughfall decreased clearly during 1996–2006, and the decrease was the strongest at the beginning of the period and in southern Finland. There was between-year variation in nitrogen deposition, but no clear decrease. Although a decreasing input of acidifying deposition into the forest soil, there were no clear trends, in general, in the pH values, total Al or Al^{3+} concentrations in the soil water collected at depths of 5, 20 and 40 cm below the ground surface in these naturally acidic podzolic soils. The soils in these stands seemed to be well buffered against the changes caused by the acidic input from deposition.

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Coupled Biogeochemical Cycling of C and S in Karstic Environments, Southwest China

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The research on relationship between catchment erosion and eco-environmental change is one of frontier sciences in the Earth's surface geochemistry. Crustal weathering by sulfuric acid and its relationship to carbon cycling has become one of the most interesting subjects for geochemists. In recent years, we studied water geochemistry of rivers draining karstic areas as well as soil carbon and sulfur in southwest China. It has been recognized that the studied river waters have high content of total dissolved solids, and the estimated weathering rate of carbonate rocks in southwest China is 97t km^{-2} year^{-1}, and 25t km^{-2} year^{-1} in CO_2 consumption, which is among the highest weathering rates estimated for the world river basins.

The studied river water has high SO_4^{2-} contents. As evidenced mainly by sulfuric isotope composition of SO_4^{2-} in river water, soil and rain water, the sources of SO_4^{2-} are of origins mainly of atmospheric deposits (dry and wet acid deposits) and oxidation of sulfide minerals mainly from coal-containing strata in the middle reach and from sulfide ore deposits from the upper reaches of the Wujiang River, one of main tributaries of Yangtze River and the largest river draining karstic areas in southwest China. Combined with isotopic composition of dissolved inorganic carbon (DIC) and stoichiometric analysis of water chemistry, the origins of SO_4^{2-} indicate that sulfuric acid had significantly taken part in chemical weathering of carbonate rocks. Chemical weathering of carbonate rocks by sulfuric acid is one of CO_2 sources. The flux of CO_2 released to atmosphere was estimated to be 8.2 t^{-1} km^{-2} year^{-1}, and the calculated total flux of CO_2 release due to carbonate weathering by sulfuric acid in southwest China amounts to 4.4×10^{12} g^{-1} year^{-1}, which is 33% of CO_2 consumption by weathering of carbonate rocks.

The riverine carbon fluxes from the karstic terrains in southwest China to lower reaches of Yangtze River and Pear River are high. Carbon isotope compositions of dissolved inorganic carbon in rivers show that a large amount of dissolved inorganic carbon has an origin of oxidation of organic carbon from soil in karstic areas. The relationships between sulfate and bicarbonate ions and their isotope composition suggest that the oxidation of organic carbon most likely was enhanced by sulfate and also nitrate reduction in the catchment.

This work shows that sulfuric acid-involved catchment weathering can change carbon cycling, and should have been taken into consideration in modeling global carbon cycling, and further indicate that human activities in many ways can accelerate chemical erosion of river basins and modify biogeochemical cycling of substance.

Acknowledgement

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Identifying Indicator Plants of Heavy Metals in Zabol Quadrangle (SE of Iran) by GIS

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The research is contrived the capability of recognizing indicator plants of heavy metals in anomalous areas located in Zabol quadrangle (250K scale). The achievement is carried out by utilizing of geostatistical method and GIS. Soil, geology, geochemistry, vegetation, as well as heavy metals concentration (specially lead) and stream sediments samples data were made GIS- ready. Based on statistical incorporation of weight evidences method, heavy metals anomalous areas were identified. Then anomalous and vegetation layers were overlaid and the spatial correlation among them were indicated by using Chi-square. The observed spatial correlation among several plant types of flora and heavy metals anomalous areas indicates that *Astragalus* sp., *Astragalus glaucanthus*, *Tamarix* sp., *Acantholimon* sp. are common plant species of these types which steer as indicator plants of heavy metals in Zabol quadrangle.

Keywords: Indicator plants, Heavy metals, Zabol, Iran, GIS, Geostatistics, Astragalus, Tamarix sp., Acantholimon sp..

Role of nitrogen in sequestration of carbon in agricultural soils

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The Kyoto protocol recognizes cropland management as a human-induced strategy to sequester CO_2 in agricultural soil. The amount of carbon stored in croplands is low compared to most other land types and thus there is a great potential to increase the carbon content through management practice.

At the same time actions are taken, especially in industrialized countries, to prevent nitrogen leaching from agricultural soils in order to decrease eutrophication (Fleischer et al, 2000). Farmers are encouraged to use catch crops, buffer stripes and to create wetlands with economic aid from the local governments. The Swedish environmental quality objectives, “Zero eutrophication” and “Reduced climate impact” (Miljömålsportalen, 2008) aim for both decreased anthropogenic N transport to the Baltic sea and for strong actions towards decreased climate gas emissions.

There might be a conflict between these actions to prevent eutrophication and to decrease climate gas emissions in agriculture and thus there is a need for evaluation of the strategies used today, and if changes have to be made. Previous results indicate that there is a complex role of nitrogen e.g. in nitrate leaching, eutrophication and for increasing carbon sequestration in the soil. In addition to soil carbon increase as a result of longterm use of catch-crops, within-soil C-sequestration has been identifies (Fleischer & Bouse, 2008). This process shows, with nitrification as a key step, considerable variation in the study area, during the year. Preliminary results have shown a clear difference between two fields grown with or without catch crop but otherwise with the same long term management. Emissions of CO_2 were almost 4 times higher after harvest from the field with catch crop compared with the field without catch crop (0.471 g CO_2 m^{-2} hr^{-1} compared to 0.132 g CO_2 m^{-2} hr^{-1}). This shows that the organic material added to the field with catch crop had increased the carbon content of the soil but that this carbon was lost after harvest. If this high emission remains for a long period of time the positive effect of the catch crop as a carbon sink would be lost.

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Investigating interactions among carbon, nitrogen, and calcium cycles in a Northeastern U.S. forest

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Nutrient availability in forests of the Northeastern United States has been dramatically altered by anthropogenic activities. Acid deposition has not only increased nitrogen (N) availability, but has also been linked to soil acidification and a loss of base cations, largely calcium (Ca). We are studying the long-term effects of a Ca addition on carbon (C) and N cycling in a forested catchment in the Adirondack Park, New York, USA. In 1989, calcium carbonate (lime) was added to two subcatchments within the Woods Lake Watershed while two additional, subcatchments were left as controls. Eighteen years after the Ca application, both soil pH and exchangeable Ca concentrations remain elevated in the organic horizons and upper mineral soils of the treated subcatchments, relative to the controls. The forest floor in all subcatchments is very large (100–200 t ha^{-1}) and measurements show that the organic layer in the limed plots is significantly larger than in the controls. This pattern appears to be driven by differences in the mass of the Oa horizon. Percent C and N in the Oe and Oa horizons do not vary significantly between treatments. The larger mass in the limed subcatchments results in greater C accumulation in the forest floor of limed plots (82 t ha^{-1}) relative to controls (35 t ha^{-1}). Carbon and N stocks in the mineral soils are greater in control subcatchments for all soil depths. Ongoing research includes investigation of decomposition rates and leaf litter production to understand how these processes may influence forest floor mass and soil C and N dynamics.

Relationships between needle nutrient composition in Scots pine and Norway spruce stands and the respective concentrations in the organic layer and in percolation water

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Mineral nutrients play an essential role in plant metabolism. In this study (Merilä & Derome 2008), we explored how the N, S, P, Ca, K, Mg, Zn and Mn concentrations in percolation water (PW) and organic layer (OL) are reflected in the respective elements concentrations in Scots pine and Norway spruce current needles.

The study plots comprised 13 Scots pine (*Pinus sylvestris* L.) and 14 Norway spruce (*Picea abies* (L.) Karst.) plots belonging to the European intensive forest monitoring network (UN-ECE/ICP Forests Level II programme). The plots were located on mineral soil sites throughout Finland, covering forest site types ranging from herb-rich to xeric heath forests. All the plots, except for the four ICP/Integrated Monitoring plots established in nature conservation areas, were located in semi-natural, managed forests.

The nutrient status of the stands was determined on the basis of a dataset comprising plotwise mean N, S, P, Ca, K, Mg, Zn and Mn concentrations in the current needles of all pine and spruce plots collected in 1999, 2001, 2003 and 2005. PW was collected at 4-week-intervals during the snowfree period in 1999–2005 using zero tension lysimeters located immediately below the organic horizon in 7–8 of the pine and 6–8 of the spruce plots. The annual mean element/ion concentrations of all the PW samples from each plot, weighted by the volume, were utilized in linear mixed model analyses to investigate the degree to which the mean concentration of an element or ion/chemical component in PW accounted for the variation in the concentration of the respective element in the needles. The OL was sampled for chemical analyses on all the plots during 1995–1997at the beginning of the monitoring programme. The nutrient concentrations were calculated as mean concentrations for each plot per dry weight and per organic matter. Linear regression analysis was applied to study the relationship between the element concentration in the needles and the concentration of the respective element in the OL. Similarly, linear regression analysis was used to test the dependence of needle P, K, Ca, Mg, S, Zn and Mn concentrations on the needle N concentration.

For both tree species, N and Ca had the highest covariation ($R_{adj}^2 \geq 0.73$) between nutrient concentrations in the OL and in the needles. Mean N, S, P, K, Zn and Mn concentrations in PW significantly explained the variation in the respective needle concentrations on the spruce plots, and of K, Zn, and Mn in PW on the pine plots. The annual variation in needle element concentrations did not account for the respective variation in PW. Our results suggest that plant metabolism regulates the nutrient concentrations in the current needles more strongly in pine than in spruce, whereas the supply of soil nutrients is more clearly reflected in the nutrient concentrations of spruce.

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Evolution of controls on phosphorus availability in aquatic ecosystems: peri-glacial to recent times

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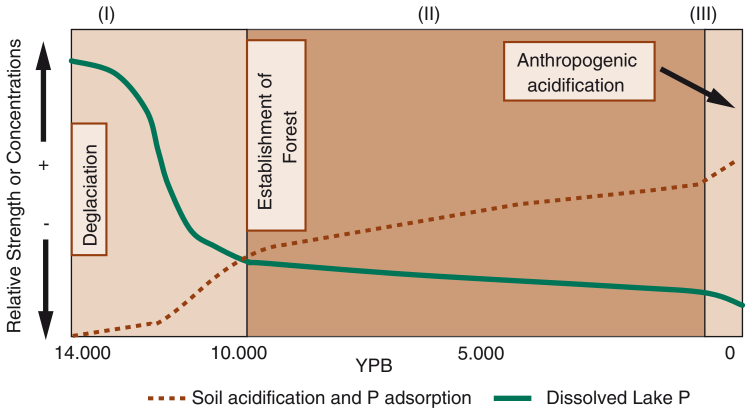
Phosphorus (P), commonly a limiting nutrient in acidic forest soils and draining waters, is supplied primarily from the weathering of apatite ($Ca_5(PO_4)_3(OH,F,Cl)$). We assessed the mobility of P using studies of forest soils and soil solutions, draining streams and downstream lakes, stream sediment, and lake sediment cores. The data indicate that bio-available P in lakes decreases substantially after deglaciation. This decline is controlled by the following evolving processes: (I) Immediately after deglaciation (13–14 000 YBP), glacial sediment (till, outwash, loess) and exposed bedrock were rapidly weathered and leached of labile minerals, including accessible apatite. Concentrations of dissolved P were high, and detritus was rich in unweathered apatite. As the apatite became depleted in soils, dissolved P decreased. (II) With the establishment of forest vegetation (ca. 10–11 000 YBP), weathering rates increased because of elevated soil CO_2 and the production of dissolved organic carbon (DOC), promoting the dissolution of primary mineral Al and Fe, the illuvial accumulation of secondary $Al(OH)_3$ and $Fe(OH)_3$ in soils, and an associated increase in P adsorption on these hydroxide surfaces. Concurrently, Al-DOC and Fe-DOC complexes were exported to surface waters. In the water column of streams and lakes, photo-oxidation of the complex produces inorganic Al and Fe, with consequent precipitation and sedimentation of $Al(OH)_3$ and $Fe(OH)_3$. The $Al(OH)_3$ sorbs and irreversibly removes P from the water column, reducing P concentration. In addition, pedogenesis in humid, temperate climates results in progressive acidification of soils, which increases the anion adsorption capacity of secondary Al and Fe hydroxides, increasing the strength of terrestrial retention of P in soils, thereby reducing P in runoff. (III) Anthropogenic acidification (e.g., acid deposition and possibly biomass harvesting) reduces lake sediment P concentrations because of increased retention of P by acidifying soils, and reduced internal loading from sediments enriched with $Al(OH)_3$ due to elevated terrestrial Al export. Weathering during phase (I) favors a eutrophic status for surface waters. Soil processes during phase (II) cause progressive oligotrophication. Recent acidification (III) probably further contributes to lake oligotrophication, but its complex effect on trophic status is not clear yet. The time scale for (I) is likely only a few thousand years at most, and depends largely on the establishment of vegetation. Processes (II and III) continue to the present.



Effect of cutting understory vegetations on nitrogen mineralization

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Understory vegetations alleviate nitrogen leaching. Nitrogen leaching increased by removal of understory vegetation because nitrogen uptake by understory decreased. Other factors such as temperature, moisture, and activity of microorganisms will affect on N leaching, when understory vegetation was cut off. We, therefore, estimated activity of N mineralization in the plot, where understory vegetations were cut off and compared with that in the control.

We selected the control plot with understory vegetation and the plot that understory vegetations were cut off in 2006 (cutting plot), in Japanese cedar (Cryptomeria japonica) stand. Stand age of Japanese cedar plantation in Shichinohe (Haginosawa), Aomori, is 50 years old in 2006. We buried soil cores, which attached with ion exchange resin (IER) at the top and the bottom of the core after DiStefano & Gholz (1986) in both plots. We also buried the soil cores in the plot, where understory vegetations were cut off in 2004 (previous cutting plot). Soil cores were incubated for a month from May to November and left during November to next May. Inorganic nitrogen in soils was extracted by 2 M potassium chloride (KCl) and that in IER was 1 M KCl. Ammonium (NH_4^+) was determined by colorimetry of indophenol blue method (Shimadzu, UV-mini 1240 Spectrophotometer). Nitrate (NO_3^-) was measured by colorimetry of hydrazine reduction procedure (Hayashi et al., 1997). The sums of change in inorganic nitrogen in soil core and accumulated nitrogen in IER at the bottom were regarded as the amounts of mineralized nitrogen. We also took soil percolated water using pan-lysimeters and determined NH_4^+ and NO_3^- by ionchromatography (Shimadzu, LC 10A Ion Chromatographic Analyzer).

There was no difference in mineralized N amounts before cutting off understory vegetations. Mineralized N amounts in cutting plot increased immediately after cutting off understory vegetation in 2006 and that was significantly larger than those in control plot. However, there was no difference between mineralized N amounts in control plot and in previous cutting plot. The difference in mineralized N amounts in cutting plot was observed until August in 2007 but disappeared in 2008. Based on the results in cutting plot and comparison with previous cutting plot, effect of understory vegetation cutting on N mineralization continued 2 years after cutting. Nitrate leaching in previous cutting plot always exceeded those in control plot. This suggested that increases in NO_3^- leaching were ascribed to not only N mineralization but also decreases in uptake of N and water by understory vegetation. In particular, effect of decreases in uptake of N and water would become more important in 3rd year, when effect of understory vegetation cutting on N mineralization reduced.

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Effects of harvesting and site preparation on nitrogen and carbon biogeochemistry in boreal forests

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Timber harvesting and site preparation are inevitable aspects of forestry but are known to drastically alter the biogeochemistry of forest ecosystems and increase the potential for harmful nitrogen (N) and carbon (C) leaching to recipient ground and surface waters. While modern and sustainable forest practices seek to minimize the intensity and duration of this leaching, we lack long-term empirical data to evaluate how successful it has been and what is the additional impact of site preparation after harvesting.

For more than 10 years we have studied the impact of stem-only harvesting, site preparation (shallow disc ploughing) and stand establishment done according to current forestry practice on the biogeochemistry of small forested catchments in eastern Finland. The amount of N and C in logging residues left on site at harvesting was 305 kg ha^{-1} and 42 656 kg ha^{-1}, respectively. Five years after clear cutting (3 years after site preparation), living ground vegetation C and N pools had not returned to pre-harvesting levels and pools of N and C in the soil (organic layer+20 cm) averaged across the clear-cut had decreased by 187 kg ha^{-1} (12% decrease) and 7 550 kg ha^{-1} (17% decrease), respectively. However, there were clear differences between the various site preparation surfaces (undisturbed, ridges and furrows) within the clear cuts. Undisturbed surfaces had the highest living vegetation N and C pools whilst the ridges had the highest soil pools. Leaching fluxes of N and C were also the highest from the ridges. Ten years after clear cutting (8 years after site preparation) the soil N pool for the whole clear cut had exceeded the pre-harvesting level by 142 kg ha^{-1} (9% increase). Soil C pool has also increased by 4061 kg ha^{-1} but it was still lower (8%) than before harvesting and site preparation. The ridges still had the highest soil N and C pools, although decreased, and pools for undisturbed and furrows had increased. N and C leaching from below the B horizon over the first 7 years after clear cutting totalled 3 kg ha^{-1} and 42 kg ha^{-1}, respectively. The measured stream water export load of N and C accumulated over the first 10 years since clear-cutting was 6 kg ha^{-1} and 221 kg ha^{-1}, respectively.

Harvesting and site preparation had an positive impact on soil N pool and negative on soil C pool over the 10-year study period. N released from logging residues was effectively retained, either in the soil or vegetation, reflecting the N-limiting status of boreal forest ecosystems. The recovery of the soil C pool seemed to take longer. Site preparation had little additional effect on leaching fluxes and stream water export loads compared to harvesting effects. The effect of both treatments compared to pre-harvesting levels indicated that current stem-only forestry practice has only a short and small (insignificant) impact on N and C leaching. However, the impact of the recent trend for whole-tree harvesting and intensification of decomposition and leaching due to climate change (milder winters in particular) is less clear.

Oxygen transport in the rhizosphere of *Vallisneria spiralis* controls nitrification coupled denitrification and methane fluxes in river reaches with different nitrogen loadings

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In eutrophic freshwater ecosystems, benthic phanerogams exploit dissolved inorganic nutrients from water, with potential consequences for sedimentary microbial processes, namely less competition between plants and bacteria for pore-water nutrients. Macrophyte species which exhibit radial oxygen losses (ROL) from root hairs also develops oxic interfaces in anoxic and ammonium rich sediments, thus stimulating bacterial nitrification. In turn, the produced nitrate can diffuse into the anoxic sediment and favor bacterial denitrification with N_2 delivery into the atmosphere. This study aimed at analyzing oxygen release in the rhizosphere of *Vallisneria spiralis* and its implication for nitrogen transformation and losses, and methane reoxidation in two river reaches with different nitrogen loadings.

From April to November 2008, in three occasions representing spring, summer and autumn conditions, 32 transparent plexiglass microcosms containing transplanted *V. spiralis* individuals (16) and bare sediments (16) were deployed for three weeks on the bottom of two segments of the Mincio River (Northern Italy). The two river reaches differed for water column nitrate concentrations (10 and 70 μM). All microcosms were then recovered, transferred in liners and brought to the laboratory. Standard light and dark incubations (Dalsgaard et al, 2000) were then performed in order to measure gas (O_2, CO_2 and CH_4) and inorganic nitrogen fluxes (NH_4^+, NO_2^- and NO_3^-) in a subset of microcosms. Nitrification coupled denitrification was measured after flux measurements with $^{15}NH_4^+$ injection into the pore-water through silicone septum within the microcosms wall (Nielsen, 1992; Caffrey and Kemp, 1992). N fixation was finally estimated with the acetylene block method on the remaining microcosms (McRoy et al., 1973; Howarth et al., 1988).

Photosynthetic quotients in microcosms with *V. spiralis* were consistently below 1 and significantly lower than those measured in bare sediments. The missing O_2 quota was assumed to be the result of O_2 transport to *Vallisneria* roots and ROL. Inorganic nitrogen fluxes evidenced a significant N uptake by the plant leaves, especially in the more eutrophic river reach. In spring, in the *V. spiralis* microcosms nitrogen losses from nitrification coupled denitrification were significantly higher in the eutrophic river reach (34±8 μmol N m^{-2} h^{-1}) than in the oligotrohic segment (16±3 μmol N m^{-2} h^{-1}). Overall, nitrification coupled denitrification was instead negligible in bare sediments at both sites. Concurrently, net methane fluxes in vegetated cores (2±2 μmol m^{-2} h^{-1}) were significantly lower than those from bare sediments (83±9 μmol m^{-2} h^{-1}), likely due to a higher CH_4 reoxidation within the *V. spiralis* rhizosphere. Results from pore-water analyses were consistent with flux measurements, evidencing much lower CH_4 concentration and much higher NO_3^- concentrations in microcosms with benthic vegetation. The main conclusion of this work is that *V. spiralis* affects sedimentary processes with ROL and that the extent of interactions between plant and microbial process is modulated by nutrient availability in the water column.

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Testing the link between dissolved organic carbon and bacterioplankton trophic groups concentration in organic-rich boreal rivers and lakes of NW Russia (Arkhangelsk region and Northern Karelia)

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High concentration of Dissolved Organic Matter (DOM) and thus, colloidal status of the main nutrient for heterotrophic bacterioplankton in boreal rivers and lakes require detailed and seasonally-resolved studies on the bioavailability of organic carbon, having both autochthonous and allochtonous origin.To gain better understanding of the biogeochemical mechanisms that control dissolved organic carbon migration in surface boreal waters, we studied in 2007–2008 structural and functional characteristics of bacterioplankton (number of different trophic groups, period of duplication and respiration intensity) in rivers and lakes of the White Sea basin (r. Pinega and its tributaries and surface streams of Karelian region in the Paanajarvi National Park). In all sampled rivers and surface streams, strong positive correlations between [DOC] and concentration of autochtonous eutrophic microorganisms and between [DOC] and concentration of facultative oligotrophes were observed ($r^2 = 0.95$ and 0.99, respectively, Figure). Our results suggest strong control of DOC on both microbial diversity and biomass but also on the rate of microbiological production/degradation processes. At the same time, the OC speciation (size fractionation pattern) in the river is not affected by autochthonous processes of microbial activity, rather it is acquired during the OC colloids formation in surface soil horizons and wetlands (swamp zones) and thus preserved till the terminus of the river (the lake or the sea). Therefore, although microbiological processes in boreal high-latitude surface waters are likely to be controlled by the amount and chemical nature of dissolved organic carbon, the effect of these processes on [OC] and its speciation in streams is rather minor.

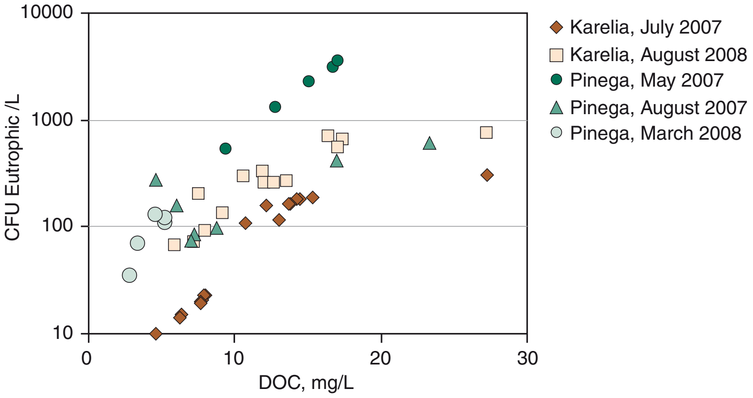

Fig. 1. Dependence of the concentration of autochtonous eutrophic bacteria (colony forming units) and Dissolved Organic Carbon in rivers and streams of the White Sea basin in different seasons

Element ratios in large Norwegian rivers in relation to marine eutrophication

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The Norwegian monitoring programme on Riverine Inputs and Direct Discharges (RID) to Norwegian coastal waters started in 1990, and is part of the joint monitoring programme under the "OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic" (http://www.ospar.org/). A total of 46 large rivers are currently included in the Norwegian RID-programme, of which 10 rivers are sampled monthly and 36 quarterly since 2004. Before 2004 the 36 rivers were sampled once a year in addition to 109 other rivers that are no longer included in the programme. The total drainage area of the 46 presently monitored rivers is about 180 000 km^2, which constitutes about 50% of the total Norwegian land area draining into the convention seas (Skagerak, North Sea, Norwegian Sea, and Barents Sea). The parameters monitored and the loads estimated includes nutrients, suspended particulate matter, total organic carbon, silicate, metals (Cd, Hg, Pb, Cu, Zn, As), PCB7 and the pesticide lindane.

Based on the RID-data, in this presentation we will assess the contribution of element ratios (N:P:Si) in Norwegian rivers spatially and temporally in relation to marine eutrophication. Element ratios in surface waters are result of nutrient availability (geology, deposition), catchment (in-soil processes, hydrology) and in-stream (biological processing, sedimentation) processes. The relative importance of these processes at various spatial scales is poorly understood.

Variability in weathering losses of Ca and Mg from forest soils within a small catchment in eastern Finland

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Earlier we reported on the depth distribution of total Zr, CaO and MgO concentrations in 11 upland podzolic soil profiles within a small forested catchment located in eastern Finland (Starr et al. 2006). The results indicated that the depth distribution differed between the different types of glacial drift deposits: ground moraine till, recessional moraine over till and sorted (glacio-fluvial) sand over till.

In this study we report on the weathering loss of Ca and Mg, earth alkaline metals that are important to the fertility and acid buffering capacity of the soil. We determined the long-term (Holocene) mean annual weathering losses (depletion) of these elements ($\text{mmol}_c\ m^{-2}\ a^{-1}$) from the uppermost soil layers (E and Bs horizons) using Zr as an internal standard and soil parent material as a reference. Cores were taken down to a depth of 3.5 m and elemental concentrations in the <2 mm fraction determined using XRF. Stone content was taken into account in calculating the weathering losses.

Annual weathering losses of Ca+Mg varied from 7.1 to 29.4 $\text{mmol}_c\ m^{-2}\ a^{-1}$, depending on the combined thickness of the E+Bs horizons. Since the mean combined thickness of the horizons was the greatest for profiles developed on glacial sand, compared to the moraine deposits, the weathering losses were the greatest for this type of deposit (mean 17.1 $\text{mmol}_c\ m^{-2}\ a^{-1}$). Although containing less fines (weatherable surface area) than the moraine deposits, the greater weathering loss from the sand deposits may be attributed to greater transport of water (and therefore weathering agents and products) through the more permeable sand deposits. There was no relationship between weathering losses and elevation, but the relative relief of the catchment was only 49 m and the slopes relatively shallow.

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The influence of soil and bedrock properties on background P concentrations in boreal headwater catchments

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Forest land covers 76% of the total land area of Finland. About 30% (1315 tn a^{-1}) of the total Finnish phosphorus TP loading to surface waters comes from the background loading (to which anthropogenic actions have not contributed) from the forest land. Previous studies (Mattsson et al. 2003, Kortelainen et al. 2006) have shown that background P loading depends on the catchment properties like slope and stem volume. In these studies, however, the geological and soil texture characteristics were not included into the model although both may play a role in P leaching and transport. To study the potential influence of these factors, we classified bedrock geology and soil type of 14 small, undisturbed headwater catchments. Water quality was measured during 1997–1999. The total suspended solids (TSS), TP, dissolved phosphorus (PO_4-P) and magnesium (Mg) concentrations during this period were used as response variables (see Mäkinen et al. 2006) which we tried to explain by factors related to geology and soil texture. The TP concentrations varied considerably both seasonally and interannually. Observed stream water TP concentrations ranged from 3 to 180 µg l^{-1}.

Bedrock was classified into 3 categories according to fertility (infertile, mid-fertile and fertile). Infertile rock species are e.g. granite, gneiss and quartzite and mid-fertile e.g. gabro, diorite and fyllite. The fertile rock species consist of limestones or mafic and ultramafic rocks like peridotite and komatite. Soil was classified according to erosion sensitivity into 3 categories: i) mainly sandy till areas, ii) sandy till areas with less than 1/3 fine-grained sediments and iii) fine-grained till areas with fine-grained sediments or peat in main channels. In addition, till geochemistry was classified according to the contents of Mg and P. Statistical analysis was made with stepwise regression to reveal which of the above described geological and soil texture characteristics have explanatory power.

The level of background leaching of P as well as its regional variability are still poorly known. This can result in biased estimation of the contribution of other pollutant sources (like agriculture & forestry). Our results - as they enable more accurate estimation of background leaching on regional level - improve total load estimates.

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Impact of N deposition on soil and tree biochemistry in both broadleaved and coniferous stands in the UK

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Critical N load maps indicate that the majority of broadleaf woodland and also conifer woodland in the UK currently exceeds the critical load for nutrient nitrogen, although widespread effects of excess nitrogen deposition are not evident except at woodland edges. Research indicates a trend towards more nitrogen demanding species in beech stands close to forest edges. Edge effects are very important for small plantations and thus of a high significance to woodland in England where forests are fragmented and there is intensive agricultural and farming activities, in addition to intensive road traffic. Spatial variation in nitrogen deposition, particularly of reduced nitrogen, together with deposition (mapped at a 5 km resolution) may contribute to an overestimate of the proportion of UK woodland affected by excess nitrogen deposition. At the same time, the extent of exceedance at woodland edges will be underestimated. While the national maps show the average deposition to different land types in each grid-square, there is a huge range both within and between 1-km grid squares. The greater exceedance risk near emission sources is of particular concern because deposition increases substantially closer to the source. Therefore, to assess the effects on the environment, a resolution of 5 km is limited, given the local variability in reduced N deposition. It is crucial to understand the nature of effects of N deposition on forest and soil biochemistry at a smaller scale and the effects of variability in N deposition on forested area. The aim of this study was to evaluate the impacts on N deposition on soil and forest biochemistry along N gradient from a pollution source and also at a regional scale.

An intensive study has been carried out for three years at coniferous (Corsican pine) and broadleaved (Beech) forests at two sites, Thetford (East Anglia) and Alice Holt (South of England), with contrasting N deposition history. In addition, at the Thetford sites, a detailed study was carried out along a 200 m N gradient from a pollution source under both forests. Annual averaged NH_3 emission is between 12 and 70 ug m^{-3} and total annual wet N deposition is between 15 and 35 kg ha^{-1} at the Thetford site. At the Alice Holt site, these are between 0.56 and 1.68 ug m^{-3} and 8 and 12 kg ha^{-1}, respectively. Emission of NH_3 has a contrasting seasonal pattern, which is very low in the winter, higher in the spring and autumn and the highest in the summer. In addition to the contrasting pollution, Alice Holt is the wetter site with 800mm annual mean precipitation, as compared to the much drier Thetford site where precipitation is down to 600mm. Soils at Thetford have very little soil organic C content of 45 kg ha^{-1} in the top 20 cm of soils in contract with the soils at Alice Holt with C content of 65 kg ha^{-1}.

The results of this study suggest that N deposition has a significant negative effect on soil acidity and a positive effect on available N (as NO_3-N and NH_4-N) in the soils under both coniferous and broadleaved woodlands. Tree N uptake has also increased with increase in N deposition, which has reduced the uptake of P and K. Uptake of Ca and Mg has not yet been affected. Litter decomposition was negatively related with N deposition along the N gradients, however it is difficult to distinguish between the acidity and N effects on this process. Litter decomposition rate is almost two times higher at the lower N deposition sites at Alice Hot compared to the high N deposition sites at Thetford. Leave/needles litterfall biomass is twice as much at the Thetford sites as compared with the Alice Holt sites, which leads to much higher accumulation of litter on the top soils at Thetford. The results also suggest that N deposition might increase Beech flowering, but reduce seeding and fruiting. The overall results from this study suggest that soil KCl extractable NH_4-N, soil C/N ratio, tree foliar and litter N concentrations and P/N ratio are reliable indicators for evaluating the effects of N deposition.

Dynamic modelling of UK forest soils to changes in acid deposition using SAFE model

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Both observed and modelled data have been examined from the ten UN-ECE Level II forest health monitoring sites in the UK to examine the changes and potential impact on soil solution resulting from changes in acid deposition inputs. The sites represent a range of forest tree types, soil sensitivities and pollutant deposition inputs found in the UK. The dynamic biogeochemical SAFE model was used to explore temporal changes in soil and soil solution chemical parameters that have been used as indicators for potential forest ecosystem and tree damage in national and international assessments of critical loads. The observed data and model results show that there is significant inter site variation. The model indicates that the historical pollutant inputs have resulted in significant soil acidification at most of the sites. Model predictions generally match current day observations. Recently declining pollutant inputs has reduced and in some cases reversed the trend of increasing soil acidification. A discussion of the results in terms of critical loads, recovery, their wider implications and uncertainty is presented.

Filter materials for phosphorus removal from wastewater in treatment wetlands– a review

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Traditionally, locally available sands and soils have been used as filter media in sub-surface flow wetlands for retaining P, even without any data about P removal efficiency (Johansson Westholm, 2006), for example sand filters or gravel (Rustige et al., 2003). The objectives of this paper are to summarize existing information on different filter media used for phosphorus removal from wastewater in constructed wetlands that could be applied to one database, with the advantages and disadvantages of each amendment and to clarify relationship between P retention capacity, pH level and the Ca(CaO) content of the filter media.

The most commonly used materials are categorized as natural materials (considered in 39 papers), industrial byproducts (25 papers) and man-made products (10 papers). In our analysis on P retention and influencing factors, we used only results of batch experiments. Among the great variety of filter media studied, most of materials had pH level >7 and high Ca (CaO) content. The highest P removal capacity showed various industrial byproducts (up to 420 g P kg^{-1} for some blast furnace slags (BFS)), followed by man-made filter media (max 40 g P kg^{-1} for heated opoka) and natural materials (max 5.2 g P kg^{-1} for dolomite) (Table 1). We found a significant positive Spearman Rank Order Correlation between the P retention and CaO and Ca content of filter materials ($R^2 = 0.51$ and 0.43, respectively), whereas the relation of P retention to pH level was weak ($R^2 = 0.22$) but significant.

Table 1. Maximum and minimum P retention capacities of natural materials, industrial by-products and man-made products. Ca and CaO contents for the introduced materials are also given.

	Maximum P retention, g P kg^{-1}	Ca% (CaO%)	Material; reference	Minimum P retention, g P kg^{-1}	Ca% (CaO%)	Material; reference
Natural materials	47.5	-	Gravel, Mann and Bavor, 1993	0.001	0.06	Soil, Sakadevan and Bavor, 1998
Industrial by-products	420	-	BFS, Mann and Bavor, 1993	0.026	7.0	Ochre, Heal et al., 2003
Man-made products	40	30.1 (42.1)	Heated Opoka, Brogowski and Renman, 2004	0.24	0.1	Estonian Leca, Vohla et al., 2005

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Effects of wild boar (*Sus scrofa* L.) grubbing on carbon and nitrogen pools in Swiss forest ecosystems

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Wild boar (*Sus scrofa* L.) populations have steadily increased in Switzerland during the past two decades (Geisser and Reyer 2005). As a consequence, reports of wild boar grubbing damage in forests and agricultural fields have become much more frequent as these omnivore animals obtain a large portion of their diet by rooting or grubbing in the soil. While the economical damage of these events has been discussed intensively, considerably less attention has been given to how wild boar grubbing affects forest ecosystem processes.

Wild boar grubbing involves disrupting the understory vegetation and impacts the top 15 cm to 70 cm of the organic and mineral soil (Genov 1981). This has a strong effect on forest soil physical, hydrological, chemical and biological properties (e.g. Groot Bruinderink and Hazebroek 1996; Moody and Jones 2000). Although several studies have shown how grubbing alters some of these properties (e.g. Groot Bruinderink and Hazebroek 1996; Moody and Jones 2000), we are not aware of any comprehensive study that has investigated the impacts of grubbing on soil carbon (C) and nitrogen (N) pools at the ecosystem level. Thus, the objective of our study was to assess how grubbing affects soil C and nitrogen (N) pools in different forest ecosystems of Switzerland. We collected forest floor (all surface organic layers combined) and mineral soil samples (0 to 30 cm) on paired plots (freshly grubbed, non-grubbed) in mixed hardwood stands growing on both alkaline (6 stands) and acidic parent material (6 stands) at low elevations (400 to 700 m) as well as in mixed conifer stands on acidic parent material (4 stands) at high-elevation (1200 to 2000 m). Samples were analyzed for C and N (LECO induction furnace; LECO Corp., St. Joseph, MI) and soil C and N pools calculated.

Preliminary data indicate that grubbing by boars significantly reduces the thickness of the forest floor and therefore reduces forest floor C and N pools. In contrast, our preliminary analyses showed that mineral soil C and N pools of the top 0 to 15 cm were higher on grubbed compared to the non-grubbed plots, while the pool of the 15 to 30 cm mineral soil layer remained unchanged. Thus, our results significantly improve our knowledge of how a natural disturbance (wild boars) might alter soil C and N pools in forested ecosystems and will be of great importance for predicting how ecosystem characteristics and forest processes might be altered when the abundance or spatial distribution of wild boars change in Switzerland.

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Dissolved N_2O and CO_2 concentrations in soil solution under a temperate old-growth forest and their associated mechanisms

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Soil solutions at 15 cm and 60 cm depths under a Korean pine and broadleaf mixed forest stand at Changbai Mountain, northeast China, were sampled using porous ceramic suction cups during the period from July 2006 to August 2007, to study the dynamics of dissolved N_2O and CO_2 concentrations in solution and their associated key driving mechanisms. The multiple phase equilibration procedure and combination with a gas chromatograph was used for measurement of dissolved N_2O and CO_2 concentrations of solution. The actual concentrations of both dissolved gases in soil solution could be obtained by the continual three phase equilibration method. During the period of sampling, the concentrations of dissolved CO_2 in soil solution at 15 cm and 60 cm depths ranged from 5.3 to 10.7 and from 3.1 to 6.2 µg CO_2-C ml^{-1}, respectively, and the dissolved N_2O concentrations at both depths ranged from 2.4 to 13.4 and from 3.2 to 28.0 ng N_2O-N ml^{-1}, respectively. The seasonal change in concentrations of dissolved CO_2 and N_2O in solution under such forest stand was significant, with differences at both depths. Addition of nitrogen sources, especially of ammonium sulfate can significantly affect the concentrations of dissolved CO_2 and N_2O in solution at 15 cm and 60 cm depths under such forest stand. The results suggest that rainfall after thawing in late spring can promote the accumulation of dissolved N_2O in soil solution at 15 cm and 60 cm depths, particularly at the latter with addition of ammonium sulfate. There was a more pronounced seasonal change in dissolved CO_2 concentrations of soil solution at 15 cm depth compared to that in concentrations at 60 cm depth. According to the stepwise regression analysis, 29% of the variance in dissolved CO_2 concentrations of solution at both depths was accounted for by the concentrations of water soluble organic C, and 34% of the variance in dissolved N_2O concentrations at 60 cm depth by the concentrations of water soluble organic N. Hence, both water soluble organic C and organic N can contribute to the formation of dissolved CO_2 and N_2O in soil solution under such forest stand, respectively.

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Decreasing concentrations of dissolved organic carbon (DOC) in the soil solution in southern Sweden during the 1990's

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Recently, a number of studies have reported increasing trends of dissolved organic carbon (DOC) concentrations in surface waters (lakes and streams) across Europe and North America. Different processes have been proposed to explain the DOC-trends such as decreased sulphur and sea-salt deposition, climate change, nitrogen deposition, local changes in land use or a combination of interacting factors. A continuous rise in the DOC-levels is hypothesized, either to pre-industrial levels or levels never before seen, with impact on the global carbon cycle and in-stream and lake ecology. Due to joint European efforts the deposition of acidifying substances in Sweden has decreased and surface water and soil surveys show clear signs of recovery from acidification. The increased levels of DOC in surface waters in Sweden could be the result of increased soil pH and decreased levels of aluminium in the soil solution, both factors affecting the solubility of soil organic matter (SOM). Additionally, decreases in the ionic strength have been proposed to increase the DOC-flux. DOC levels in areas recovering from acidification should, accordingly, increase both in the soil solution as well as in the surrounding surface waters as pH rises and the input of ions such as sulphur and/or chloride decline.

Here we present soil water data (50 cm soil depth in recharge areas) from the Swedish Throughfall Monitoring Network (23 sites) and other long-term studies (42 sites) situated primarily in the southern part of Sweden. Data cover the period 1986-2008, during which the sulphur deposition dropped from 9 to 3 kg S ha^{-1} y^{-1} and many lakes and streams exhibit recovery from acidification in this region. In soil water, the decreasing concentrations of major anions (primarily sulphate) and cations (primarily calcium and aluminium), and increasing ANC can largely be ascribed to the reduced S deposition. pH remained fairly constant or decreased slightly (Figure 1). However, opposite to the DOC trends in surface waters, the DOC concentrations in soil solution in recharge areas *decreased* considerably during the study period. Hence, it seems to be two different processes causing the DOC trends in soils and surface waters. With respect to the small changes in pH, we propose that the decreasing concentrations of DOC in soil solution are coupled to the diminished ionic strength, changing the ion exchange properties of SOM as well as on minerogenic oxide and hydroxide surfaces. The results indicate more efficient coagulation of organic matter in the soil horizon above 50 cm depth, possibly the B-horizon. Additionally, the results support the theory that processes in discharge areas and peat lands rather than dry soils uphill govern the surface water DOC trends. Hence, the processes controlling the surface water DOC trends should be searched for in riparian soils.

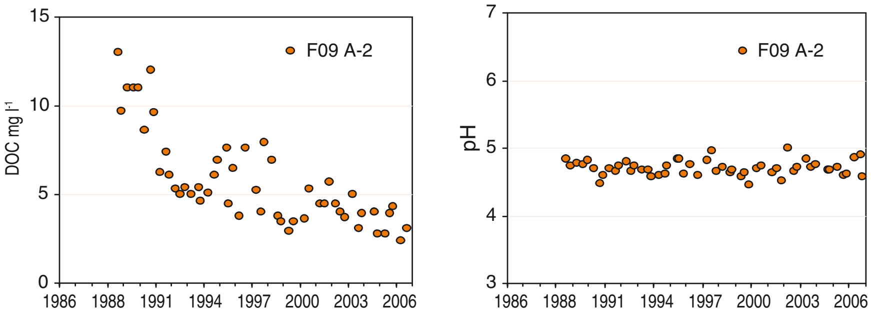

Fig. 1. The concentration of DOC (left) and pH (right) in the soil solution.

Ditch network maintenance – effects on stream water chemistry and benthic fauna

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In order to increase tree growth, drainage of wet mineral soils and peatlands became a common forest practice in Sweden during the 20th century with a peak in the 1930's. Approximately 15% (or 1.5 million hectares) of the peat-covered wetlands has, at some point in time, been drained. Due to environmental concern, drainage ceased in the 1980's and is now prohibited by law in most parts of Sweden. However, drainage during the clear-cut phase still occurs if necessary. With time, the function of the ditch network decreases due to sedimentation, debris and ditch vegetation impeding free flow. As a consequence, the groundwater level rises and the oxygen levels in the soil decreases. Hence, maintenance of existing ditch networks is an increasing important aspect in Swedish forestry today.

The effects of clearing old ditches on stream water chemistry is unclear but it has been suggested that the effects should be similar to those that occurred after the initial ditching (Joensuu et al., 2002). An increase in the load of suspended solids, nitrogen and phosphorous as well as an increase in pH has been reported in a number of studies, whereas the concentration of DOC decreased or was not affected (i.e. Manninen, 1998). The effects on mercury have never been studied but other forest operations have resulted in an increase in the methylmercury load (i.e. Porvari, 2003). Thus, it is hypothesised that clearing old ditches also will affect the concentration and transport of mercury.

In May 2007, the IVL Swedish Environmental Institute and Sveaskog (Sweden's largest forest owner and leading supplier of timber, pulpwood and biofuels) started a joint collaboration ditch-clearing project called DiVa (www.ivl.diva.se). The project is also funded by the World Wide Fund for Nature (WWF), the Swedish Environmental Agency and the Swedish Forest Agency. The short-term (< 2 years) effects on stream water chemistry (i.e. nutrients, acidity, DOC and mercury) and benthic fauna will be studied before and after ditch network maintenance using two different methods ("traditional clearing" and "clearing involving sediment-traps"). Two research areas have been established, one in the southern part and one in the northern part of Sweden. In each research area there is one reference catchment area and two catchment areas which will be cleared according to the different methods mentioned above. So far, the results indicate high levels of DOC (10–70 mg l^{-1}) with mercury concentrations above average (THg varied between 2–20 & MeHg between 0.6–1.4 ng l^{-1}). The first ditch-clearing operation will take place in the autumn of 2009.

Fig. 1. Ditch network maintenance in Sweden. Photo: Per Petersson, Sveaskog.

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Spatial status and retention potential of phosphorus in riparian wetlands located in south region of TaiHu basin, China

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South region of TaiHu Basin is increasingly threatened by eutrophication, and phosphorus (P) cycling between sediment and overlying water plays an important role. In this study, we investigated P status and its movement over interlayer of sediment-water in riparian wetlands located in south region of Taihu Basin. Two sets of laboratory-scale simulation systems (i.e., static columns and steady-flow flumes), featured wetlands in dry season and rainy season, were carried out to understand the characteristics and mechanism of P interaction between sediment and overlying water. As a whole, significant increases in total P (TP) and $NaHCO_3$ (pH=8.5) extractable P (Olsen-P) occurred with the increase of NaOH+EDTA extractable P (NaOH+EDTA-P) in wetland sediments. After the comparison of P adsorption capacity (Q_{max}) and TP in sediment, we concluded that there was a high risk of P exporting from sediment. In the static column experiments, dynamics characteristics of dissolved reactive phosphorus (DRP) in overlying water can be divided into buffer reaction, rapid adsorption, and slow adsorption in order. A quasi U-pattern curve was observed in the steady-flow flume experiments, i.e. DRP in the overlying water decreased at first and then increased. Given upstream water containing high P concentration flowing over tested wetland during rainy season, the ecological role of P interception might be weakening.

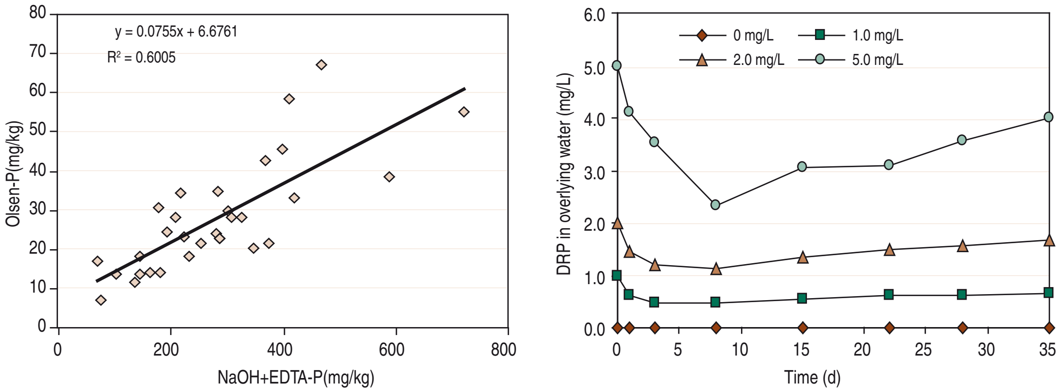

Fig. 1. Relations between NaOH+EDTA-P and Olsen-P in wetland sediments (left), DRP dynamics of overlying water in steady-flow simulation experiments (right).

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Quantifying aboveground N uptake from wet deposition: effect of tree species, N load and leaf phenology

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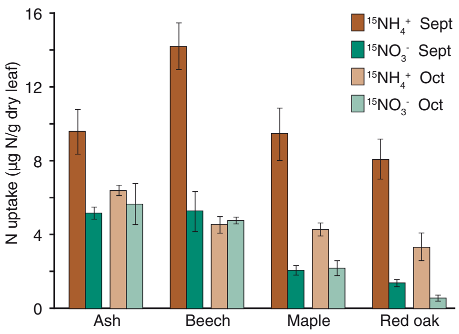
Semi-natural ecosystems such as forests are exposed to higher inputs of atmospheric pollutants originating from anthropogenic sources. This increased deposition has caused changes in biogeochemical processes, which may have adverse effects on forest structure and functioning. Therefore, an accurate quantification of total atmospheric deposition is required. One widely known technique is the throughfall method, in which the amount and quality of water above and beneath the canopy are compared. Total atmospheric deposition is then quantified by a so-called canopy budget model (Draaijers and Erisman, 1995), which estimates ion-exchange reactions between the canopy and throughfall water. Although this model is applied worldwide, it has rarely been validated (Staelens et al., 2008), and dry deposition and canopy exchange of nitrogen (N) generally cannot be quantified accurately from throughfall measurements. Therefore, this study focused on the assessment of aboveground N uptake from wet deposition, which can be quantified directly by the application of ^{15}N labelled sources. A better understanding of the direct aboveground N uptake by different tree species under varying N pollution levels may lead to an improved canopy budget model.

In two subsequent experiments, dissolved ^{15}N was applied by spraying rainwater containing ammonium (^{15}N-NH_4Cl) or nitrate (^{15}N-$NaNO_3$) onto living leafed twigs. First, the method was tested *in situ* on young trees of four deciduous tree species, i.e. European beech (*Fagus sylvatica* L.), common ash (*Fraxinus excelsior* L.), red oak (*Quercus rubra* L.), and sycamore maple (*Acer pseudoplatanus* L.) in September and October 2007. Next to this, ^{15}N uptake was determined *ex situ* during the growing season of 2008 for 3-year-old saplings planted in pots to eliminate the effect of varying soil nutrient availability on the aboveground uptake by leaves and branches. The tree species included here were European beech, pedunculate oak (*Quercus robur* L.), common birch (*Betula pendula* L.), and Scots pine (*Pinus sylvestris* L.). In this second experiment, rainwater with different concentration levels of ^{15}N-NH_4Cl and ^{15}N-$NaNO_3$ was used. To assess the effect of leaf phenology, the application was conducted in September and October of 2007 and in April, August and October of 2008.

Results from the first experiment (Fig. 1) show that the dissolved N uptake differed significantly ($p < 0.05$) between tree species, N compounds, and treatment dates. Foliar uptake of $^{15}NH_4^+$ was significantly higher than of $^{15}NO_3^-$ for all species in September and only for maple and red oak in October. Furthermore, ammonium uptake was the highest for beech in September, while this was the case for ash in October. Nitrate uptake of maple and red oak was significantly lower than beech and ash both in September and October. Results of the second experiment will also be presented.



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Nitrate in soil water in a steep nitrogen deposition gradient in Swedish forests

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The forests in Sweden are generally considered as nitrogen limited, which means high nitrogen retention and low nitrate leaching. However, in the southern part where the nitrogen deposition is the highest, the C/N ratios are often lower than 25 which could indicate a risk of increased nitrate leaching (Gundersen *et al*., 1998). In the Swedish Throughfall Monitoring Network (Hallgren Larsson *et al*., 1995), nitrate in soil water at 50 cm depth have been measured at about 100 sites for up to two decades. The sites lie in a deposition gradient with the highest deposition (about 14 kg N ha^{-1} y^{-1}) in the southwest, and the lowest deposition (about 2 kg N ha^{-1} y^{-1}) in the north. This dataset can contribute to the assessment of the risk of nitrate leaching from Swedish forest soils.

At 80% of the sites, all measurements in the time series were below 0.5 mg l^{-1}, and on most of them the concentrations were very low, below 0.01 mg l^{-1}. However, on 20% of the sites, the nitrate concentrations in soil water were over 0.5 mg/l, in some cases just occasionally but in other cases the enhancement was more constant (Fig. 1). At the sites with the highest nitrate concentrations, the average concentration was 1–2 mg l^{-1}. If concentrations in this order of magnitude would become common over larger forest areas in southern Sweden, e.g. due to increased decomposition rates due to higher temperatures in the future, the leaching contribution from forests to the eutrophication of the sea could increase substantially. Almost all of the sites with enhanced nitrate concentrations are situated in the southern part of Sweden, where the nitrogen status is the highest. However, many of the sites in the southern part show no enhanced nitrate levels in soil water. The differences between different sites in southern Sweden can be explained by soil type, tree species, ground vegetation, land use history, the local climate and how exposed the sites are to deposition.

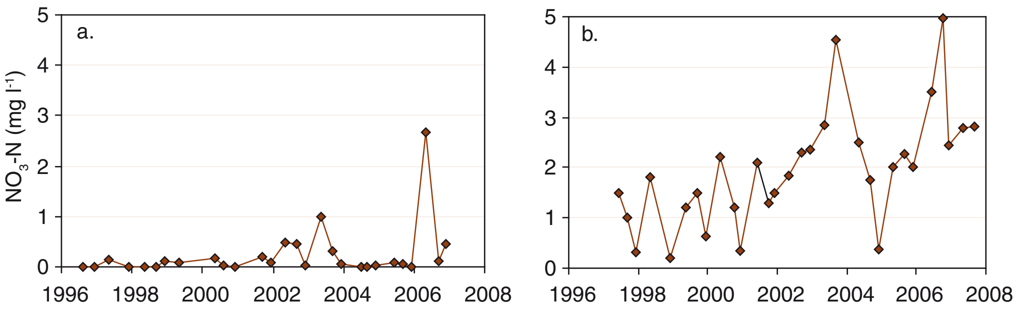

Fig. 1. Nitrate (NO_3-N) in soil water at 50 cm depth in Bullsäng (a) and Vallåsen (b) in southern Sweden.

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Nitrogen uptake in temperate heath vegetation and soil microbes is influenced by elevated temperature, CO_2 and drought

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Temperate terrestrial ecosystems are currently exposed to climatic and air quality changes with increased atmospheric CO_2, increased temperature and prolonged droughts. The responses of natural ecosystems to the changes are focus for research, due to the potential feedbacks to the climate. We here present results from a field experiment in which the effects of these three climate change factors are investigated solely and in all combinations at a temperate heath dominated by Heather (*Calluna vulgaris*) and Wavy hair-grass (*Deschampsia flexuosa*) (Mikkelsen *et al*., 2008).

Climate induced increases in plant production may increase plant root exudation of dissolved organic compounds such as amino acids, and the release of amino acids during decomposition of organic matter. Such free amino acids in soil serve as substrates for soil microorganisms and are also acquired as nutrients directly by plants. We investigated the potential climate change induced changes in distribution and uptake of amino acids in an in situ pulse labelling experiment with $^{15}N^{13}C_2$-labeled glycine (amino acid) injected into the soil.

The aboveground biomass production of *Calluna* increased in warmed plots and in elevated CO_2 plots, which caused a dilution of tissue nitrogen concentration. In contrast to *Calluna*, the biomass of fine roots and green leaves of grasses decreased in warmed plots (without elevated CO_2). This suggests that, in response to the climate change treatments, *Calluna* was superior in competition for water and nutrients during peak growing season. Furthermore, a higher proportion of fine roots of grasses was found in the upper soil horizons and this led to higher nitrate concentration in the sub-soil.

The soil microbes were superior to plants in the short term competition for the added glycine, as indicated by an 18 times larger ^{15}N recovery in the microbial biomass compared to the plant biomass. Furthermore, the soil microbes acquired glycine largely as intact compounds, as shown by a ^{13}C to^{15}N ratio of 1.7.

Root nitrogen acquisition by grasses responded significantly to the climate change treatments, with larger ^{15}N uptake in response to warming and CO_2. Furthermore, a larger grass leaf biomass in the combined T and CO_2 treatment suggest synergistic effects of the two treatments.

Nitrogen plays an important role in this terrestrial ecosystem type and in ecosystem responses to climate change, with nitrogen controlling the feedback mechanisms of carbon sequestration (Emmett *et al*., 2004).

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Quantification of denitrifying bacteria in acidified Norway spruce forest soils using real-time PCR

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The denitrification is the main biotic process leading to loses of fixed nitrogen as well as removal of excess of nitrate (NO_3^-) from the soil environment. Reduction of NO_3^- to nitrite (NO_2^-) can be done by the diverse taxonomical groups of soil bacteria. The respiratory NO_3^- reduction as well as dissimilatory NO_3^- reduction to ammonia (NH_4^+) is done by the *narG* and *nap* operon, respectively. However, the reduction of NO_2^- to nitric oxide (NO) distinguishes the "true" denitrifiers from other nitrate-respiring bacteria. This reaction is catalyzed by two different types of nitrite reductases, either a cytochrome cd1 encoded by *nirS* gene (*nirS* denitrifiers) or a Cu-containing enzyme encoded by nirK gene (*nirK* denitrifiers). The *nirS* denitrifiers are located mostly in rhizosphere, while the *nirK* denitrifiers are more abundant in bulk soil. These two groups can be also classified as markers of denitrification.

The objective of this work was to quantify the amount of *nirK* denitrifiers in bulk soil using the real-time PCR targeting *nirK* gene operon. The results from two sites: Site A (Plesne Lake watershed) and Site B (Certovo Lake watershed) were compared.

Soil samples (organic litter layer, organic humified layer and mineral layer) from sites located in the watersheds of two glacial lakes in the Bohemian Forest (Czech Republic) were collected during the spring 2008. For the isolation of genomic DNA from soil, the SoilMaster™ DNA Extraction Kit (Epicentre Biotechnologies, Inc.) was used according to manufacturer instructions. Real-time quantitative PCR was carried out with a StepOne instrument (Applied Biosystems) by using SYBR green as the detection system. The amount of nirK denitrifiers was evaluated as copies of *nirK* gene per gram of soil.

Results from different soil layers showed that the amount of *nirK* denitrifiers was significantly highest in organic humified layer (2.44×10^9 copies of *nirK* gene.g^{-1}) at Site A. At Site B the highest amount was in mineral layer (3.45×10^{10}, Table 1). Significantly higher amount of *nirK* denitrifiers was at Site B than at Site A. This indicates that the potential amount of N which can be lost by the denitrification process is higher at Site B where the amount of *nirK* denitrifiers is one-order higher than in Site A.

Table 1. Amount of extracted DNA and *nirK* denitrifiers in different soil layers at Site A and Site B

	amount of extracted DNA µg.g^{-1}	amount of *nirK* denitrifiers copies of *nirK* gene.g^{-1}
Site A		
organic litter layer	14.8 (4,4)	1.23x109 (1.43x108)
organic humified layer	20.6 (6.6)	2.44x109 (4.97x108)
mineral layer	28.7 (9.1)	3.68x108 (1.12x108)
Site B		
litter layer	7.2 (1.9)	3.76x1010 (1.75x1010)
humified layer	11.9 (4.2)	2.94x1010 (1.08x108)
mineral layer	3.1 (1.4)	3.45x1010 (1.37x1010)

- Standard deviations are shown in parenthesis

Water potential affects gross nitrogen mineralization and nitrification rates in forest and wetland soils

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Previous laboratory and field experiments examined that even mild drought stress reduced microbial activity particularly in the organic horizons of the spruce forest soil (Hentschel *et al*., 2007). The effect of drought on net rates of N mineralisation and nitrification has been investigated extensively, but the net rates underestimate gross rates and the response of gross rates is barely known.

The hypotheses of our study are: (1) lower water potential reduces gross N transformation rates in the forest, and (2) lower water table promotes gross N transformation rates of the top soil in the wetland. Soil samples were obtained from the Oi/Oe, Oa and Ah horizons in the spruce forest and the top 5 cm in the fen. We used the ^{15}N pool dilution technique to quantify and evaluate the effects of changes soil osmotic potential on gross N transformation rates. The water potential was adjusted by adding different concentrations of KCl.

Our first results suggest a significant inhibition of gross nitrifications rates in Oi/Oe layer following the decreasing water potential. With the water potential adjusted close to field capacity, a gross nitrification rate of 5.0 mg N kg^{-1}d^{-1} was observed, which decreased to 1.3 mg N kg^{-1}d^{-1} at water potentials < 1.0 MPa (Fig. 1).

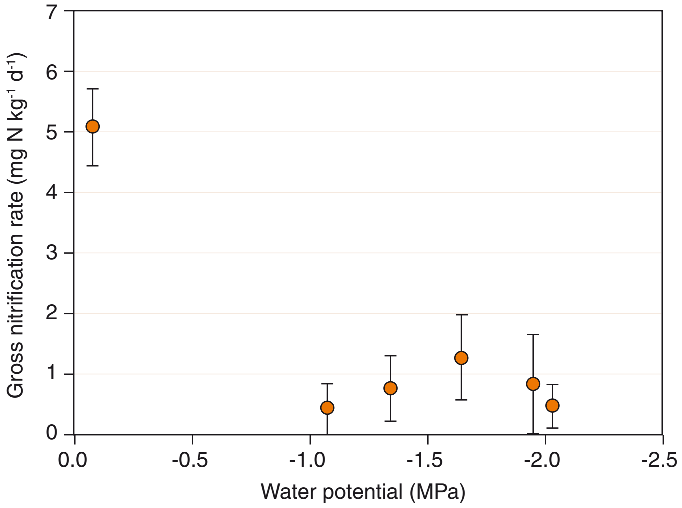

Fig.1. Effect of water potential on gross nitrification rates in Oi/Oe layer from spruce forest (avg ± standard deviation).

Gross nitrification seems highly sensitive to osmotic stress. Hence, decline of matric and osmotic potential induced by soil drought in the future, like predicted from climate change scenarios, will affect the N turnover in forest soils significantly.

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Nitrogen-Fixation in Boreal Forest Ecosystems

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Nitrogen-fixation is an ecosystem process of unique biological importance. Nitrogen limits productivity in most natural and agricultural ecosystems and biological N fixation serves as the gateway to the N cycle. Although anthropogenic N deposition and synthetic fertilizer production have greatly eliminated N limitations in many ecosystems, N-fixation remains a fundamentally important driver of ecosystem productivity most boreal ecosystems. Boreal forests are characteristically N limited (Tamm 1991) and northern forests have experienced relatively minor influences from anthropogenic N deposition because of their relatively remote, unpopulated setting. Forest ecosystems of tropic and temperate regions are plied with N fixed by a host of symbiotic and associative N organisms. Boreal forests, however, lack any significant presence of symbiotic herbs, shrubs or trees. Recent studies have amplified our understanding of associative N fixation in feather mosses and cyanobacteria in boreal and subarctic ecosystems (DeLuca *et al*. 2002; Houle *et al*. 2006). Nitrogen-fixation capacity has been identified in three common feather mosses (*Pleurozium schreberi, Hylocomium splendens*, and *Ptilium crista-castrensis*) and at least three genera of cyanobacteria (*Nostoc, Calothrix*, and *Stigonema*). Rates of N fixation in individual shoots of feather mosses are relatively low; however, the density of feather moss carpets combined with their broad geographic distribution make them a major contributor of N to boreal forests and perhaps the most broadly distributed sources of N (Zackrisson *et al*. 2009). Although P limitations control N fixation in tropical ecosystems, N deposition and recycling is likely a dominant driver in boreal regions. Nitrogen deposition via canopy throughfall (sourced from anthropogenic and natural sources) appears to be a primary regulator of N fixation in boreal forests (DeLuca *et al*. 2008; Zackrisson *et al*. 2009). In pristine ecological settings greatly free of anthropogenic N deposition, natural fertility gradients and islands have been found to influence N fixation in feather moss carpets by altering N and P deposition on moss carpets. Delivery of fixed N to resident trees and shrubs in the forest environment appears to be an indirect and protracted process.

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How does nitrogen fertilization affect soil respiration?

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When forests are nitrogen (N) limited, N additions may increase uptake of carbon dioxide (CO_2) through enhanced photosynthesis, and may increase carbon storage as a consequence of negative responses of soil organic matter (SOM) decay and soil respiration (SCE) to nitrogen additions. Where it is well documented how N-fertilization or deposition interacts with the aboveground ecosystem production, its effect on belowground production and respiration is less well understood. The majority of experimental nitrogen additions resulted in a decreased SCE, but how consistent is this response? One of the proposed mechanisms for this decrease is the suppression of microbial degradation processes in the soil and the reduction of litter inputs as a consequence of C-allocation shifts from foliage and fine roots to woody tissue such as stems, branches and coarse roots. To test this hypothesized mechanism, we performed statistical meta-analysis on 36 fertilization manipulation studies on soil processes in forest ecosystems.

Overall, SCE decreased with 12% as a consequence of experimental fertilization, and this response seemed to be mainly caused by a decrease in heterotrophic respiration, because microbial biomass and activity both declined to a similar extent (decrease of 13 and 17% respectively). There was no indication for a significant effect on autotrophic respiration. SCE decreased more with higher nitrogen addition doses, and the negative effect was larger when only nitrogen was added to the plots, in comparison to balanced fertilizers. Moreover, the suppression of SCE vanished under elevated [CO_2]. Adding CO_2 or more balanced fertilizers to the soil, probably elicits a positive response of plant productivity, and hence causes a higher root exudation or higher litter inputs. The higher substrate availability could compensate for the reduced specific decomposition rates, and thus explain the observations.

C-N interactions influence the potential for positive and negative feedbacks between the carbon cycle and the climate system. Therefore, determining the relative importance of the different C-N interactions and incorporating these in larger scale models appears a logical next step. This presentation contains results from a meta-analysis on one of these C-N interactions: the microbial response to N fertilization, with a strongly reduced soil C decomposition that could contribute to regional Net Biome Productivity.

Organic nitrogen cycling in Boreal lakes and catchments

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In the Boreal ecozone of eastern Canada most of the input of nitrogen from the atmosphere to catchments is in the form of inorganic N, with nitrate (NO_3) usually exceeding ammonium (NH_4). These inputs have remained relatively high for decades, and in southern Ontario now exceed the inputs (on an equivalent basis) of sulphate. In this study, we measured the mass budgets of the inorganic N species as well as organic N for 7 lakes and 19 individual tributaries for periods ranging from 20 to 30 years. In addition, N fluxes in throughfall and through the soil horizons were measured in 2 of these sub-catchments.

With few exceptions, little of the inorganic N escapes the catchments (Dillon and Molot 1990); most of the N leaves via runoff in organic form, i.e. as a component of the dissolved organic matter (DOM). Previous studies (e.g. Devito *et al*. 1989) have shown that wetlands are sites where this transformation takes place, with the input of inorganic N balanced by an effective output of an equivalent amount of organic N. Lakes are likewise effective traps of inorganic N (Molot and Dillon 1993) but we show here are also sinks for organic N, although the effectiveness (measured as the apparent settling velocity) is less than that for either NO_3 or NH_4. The transformation of organic N during photodegradation and respiration of DOM can be a significant source of inorganic N in these lakes, surpassing the NH_4 input from the catchment. If measurements of accumulation of N in lake sediments are combined with mass budgets, estimates of loss of N via denitrification to the atmosphere can be made; in this study, this is a significant N sink.

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Long-term nitrogen fluxes in a karst watershed: relative effects of precipitation, soils and vegetation

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Karst watersheds have rarely been studied with regard to the effects of airborne nitrogen (N) deposition. Soils of karst watersheds are often very heterogeneous leading to diverse hydrologic pathways very likely affecting N leaching. Together with quick response times and low residence time due to conducts that provide rapid water pathways, karst watersheds may differ in the response to N deposition compared to non-karst watersheds. Here, we present long-term N flux measurements (1993 to 2007) from an UNECE ICP Integrated Monitoring catchment in Austria. We summarize long term and interannual trends in N fluxes at the Zoebelboden watershed for the two dominating forest and soil types, a deep Cambisol with Norway spruce forest with a perched watertable (Figure 1) and a shallow Leptosol with a mixed beech-spruce-maple forest. Biweekly deposition and lysimeter data, climatic and soil moisture measurements, and hydrological modeling (BROOK90) is used to establish time series of N leaching at a daily resolution.

Whereas deposition is highest in late March, N leaching is highest in May after snow ablation. This seasonal trend is very constant but more pronounced at the Norway spruce stand. There, N leaching is 3 to 4 times higher than during the remaining season. Strongly increased N concentration and flux also occurs during high precipitation (Fig. 1). In total, the Norway spruce forest experiences 6 to 40 kg.ha^{-1}.y^{-1} NO_3-N leaching with a throughfall deposition of 16 to 30 kg.ha^{-1}.y^{-1} total N. The mixed beech-spruce-maple forest shows 4 to 8 kg.ha^{-1}.y^{-1} NO_3-N leaching with a throughfall deposition of 17 to 31 kg.ha^{-1}.y^{-1} total N. In both forests, NH_4-N leaching is very low. Taken all years together, the mixed forest is accumulating N and the spruce forest experiences a net loss of N. The long-term variation of N-leaching from karstic soils is dominated by precipitation but soil and vegetation properties play an important role.

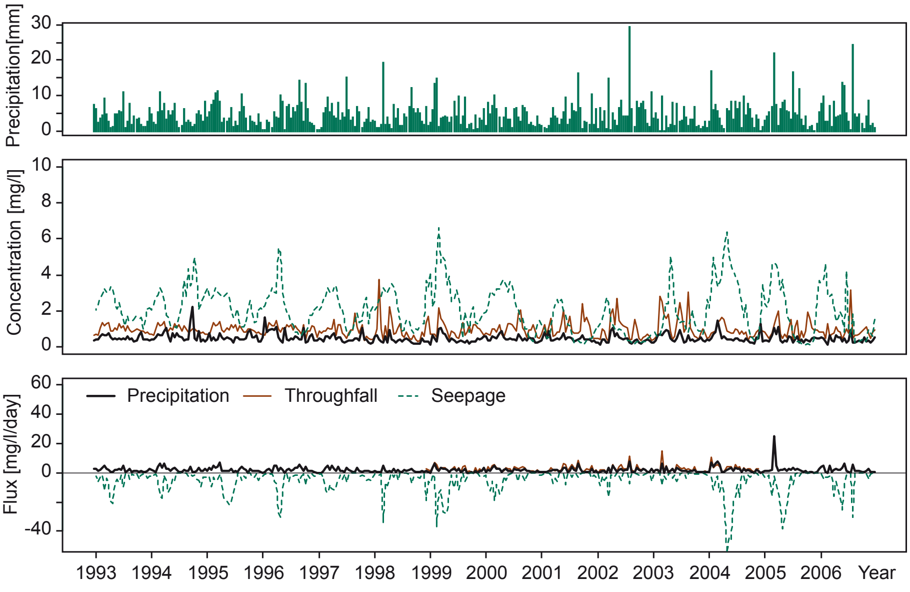

Fig. 1. Time series of NO_3 concentrations and NO_3 fluxes in precipitation, throughfall, and in seepage from soils the Norway spruce forest from January 1993 to December 2006..

Modelling Controls on Nitrogen Leaching from European Forests using Partitioning Tree Analysis

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Dissolved Inorganic Nitrogen (DIN) leaching causes surface water acidification and eutrophication. Often, there is a non-linear relationship between the atmospheric input of DIN and N-leaching that is poorly captured by existing models. We present the first application of the non-parametric partitioning tree approach (also known as classification and regression trees) to evaluate the key environmental drivers controlling DIN leaching from European forests. DIN leaching was classified as low (<3), medium (3-15) or high (>15) kg N $ha^{-1}yr^{-1}$ at 215 sites across Europe.

The analysis identified current throughfall NO_3^- deposition, the legacy of historic DIN deposition, and the flux of acid deposition ($NO_3^- + NH_4^+ + SO_4^{2-}$) as the primary drivers of DIN leaching, with site hydrology (precipitation and runoff fluxes), soil type, and the carbon content of the soil (%C, C:N) modifying the response. In addition to illuminating potential control mechanisms on DIN leaching, the partitioning method allows the development of dichotomous keys for classifying forests into risk categories for practical use in management and policy. Such nonlinear approaches thus show promise for understanding complex ecosystem responses to a wide range of anthropogenic stressors as well as an improved method for identifying risk and targeting pollution mitigation strategies in forest ecosystems.

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Nitrogen saturation in upland catchments – what have we learned in the last 15 years?

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The cumulative process of terrestrial nitrogen (N) saturation described by Ågren and Bosatta (1988) was first divided into biogeochemical stages by Aber (1989) for forest ecosystems and subsequently by Stoddard (1994) for forested catchments in terms of nitrate leaching. These schemes, based on North American studies, described a progression from tightly N limited systems with minimal leaching losses of inorganic N, through amplified seasonal patterns of nitrate loss with elevated nitrification and subsequently a breakdown of seasonal patterns and ecosystem decline. In the largely unforested uplands of the UK, various studies over the last 15 years have attempted to describe these processes of N retention, saturation and nitrate leaching.

A driving force behind this work has been the major discrepancy between observed and modelled N input-output budgets for upland catchments (Curtis *et al.*, 1998). Monitored catchments show only a small proportion of N deposition being leached, while the widely used FAB model for critical loads of total acidity (Posch *et al.*, 1997) predicts a very large proportion of N leaching losses relative to deposition inputs at long-term steady-state. Such major increases in nitrate leaching would require dramatic reductions in total N deposition to prevent critical load exceedance. It is therefore a key priority to determine the likelihood of N saturation and the increases in nitrate leaching predicted by FAB occurring over policy-relevant timescales.

There have been few if any published studies demonstrating increasing trends in nitrate leaching linked to progressive N saturation of terrestrial ecosystems. Several studies have attempted to identify terrestrial indicators of N saturation, generally focussing on C:N ratios of soil organic matter or litter layer horizons, or total catchment carbon pools relative to cumulative N load. More recently, isotopic tracers have been used to demonstrate very rapid immobilization of deposited nitrogen and show a large proportion of observed nitrate has been microbially cycled, i.e. direct hydrological nitrate leaching is rather minor. Furthermore, the latest results from 20 years of data within the UK Acid Waters Monitoring Network show a number of sites with significant increasing trends in nitrate leaching discernible above the "noise" of temporal variations at various timescales. Here we synthesize the results of various monitoring and experimental studies over the last 15 years to re-assess the evidence for N saturation in upland catchments of the UK.

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Insect herbivory influence on plant and soil N

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Insect herbivory that results in extensive defoliation has the potential to affect forest nitrogen dynamics. High-nitrogen leaf materials and insect excrement (frass) are deposited on the forest floor during the growing season, potentially providing a pulse of labile carbon (C) and nitrogen (N). Insect invasion of the New Jersey Pine Barrens pine-oak forests by the gypsy moth (*Lymantria dispar* L.) during the summer months of 2007 allowed us to examine the effects of defoliation and frass deposition on plant and soil nutrients.

Oak dominated forest stands likely to experience increasing levels of defoliation due to gypsy moth larvae were identified before larval emergence. The extent of defoliation was determined by conducting upward directed Light Detection and Ranging System scans (LIDAR) before emergence, at peak defoliation, and after canopy recovery. New leaf material was collected pre-defoliation and post recovery and analyzed for C & N content. Soil samples (0–10 cm) were collected pre emergence, at the peak of defoliation and after canopy recovery. Soil samples were analyzed for C, N inorganic N and microbial biomass N (MBN).

Three levels of defoliation were observed among the study sites (control; non-significant canopy removal, low defoliation; 68% of canopy cover consumed, and high defoliation; 100% of canopy consumed). Following defoliation in the high defoliation area, the second flush of oak leaves showed a 40% reduction in N content relative to the early season leaf material. The ericaceous shrub leaf N concentrations show a 50% reduction, whereas pitch pine revealed a 30% increase in N content (Fig. 1). Soil (0–10 cm) total C content, total N content and MBN did not vary significantly among levels of defoliation between pre and post defoliation dates. Soil extractable ammonium (Fig. 2) and nitrite were significantly greater in the high defoliation area than in either the control or the low defoliation areas. In late summer following leaf recovery, the low defoliation stand had 65% canopy coverage, and the completely defoliated stand had 39% canopy coverage compared to the control. However, in completely defoliated stands, total N in annual litterfall had increased by ca. 58% over the previous years (2003–2006), largely due to partially consumed leaf material and insect frass which fell in June. With the exception of extractable ammonium, soil N pools were largely unaffected. Because MBN pools also did not vary among levels of defoliation, the added “labile” N apparently remained in the litter layer through the growing season.

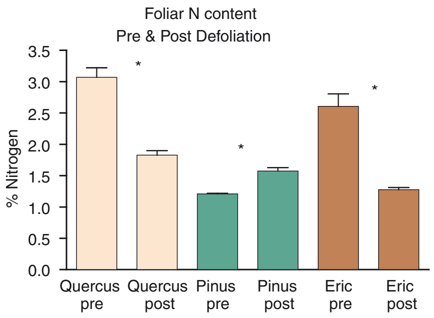

Fig. 1. Foliar N content, pre defoliation (May 9, 2007) and post defoliation (July 26, 2007), for pitch pine (*Pinus rigida* Mill), oak,(*Quercus alba* L). and ericaceous shrub leaves (*Gaylussacia baccata* Wang). Statistical analyses were performed by ANOVA on rank transformed data P < 0.05 n=3. Significant differences between sample events within species are marked with an asterisk (*).

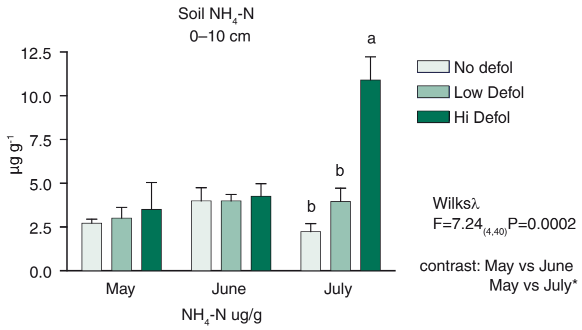

Fig. 2. NH_4-N concentration (µg g^{-1}) in soil (0–10 cm) from no defoliation, low defoliation and high gypsy moth defoliation plots. May 9, 2007 (pre-defoliation), June 14, 2007 (peak defoliation) and July 26, 2007 (full re-foliation). Tukey’s HSD means separation test followed significant difference determination by RMANOVA. P < 0.05 n=8. Treatment differences within each month of harvest are marked by lower case letters: a > b. Post-hoc contrast tests comparing May 9 soil with subsequent dates are indicated by asterisk.

Carbon and nitrogen interactions in deposition gradients from forest edges

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In many countries in Europe the forest area is highly fragmented throughout the intensively cultivated land. Due to the turbulence created by edges and forest 'islands' dry deposition of gasses and particles to forest surfaces can be up to a fourfold enhanced compared with the forest interior (e.g. de Ridder *et al*., 2004). Steep gradients have occured especially in forest edges close to ammonia sources such as husbandry farms (Spangenberg & Kölling, 2004). By neglecting forest edge effects, deposition to the forest area may be largely underestimated and correct scaling up of deposition estimates to European forests is difficult.

We i) used the 'natural' N deposition gradient in forest edges as a proxy to study the effect of N input on N and C cycling and ii) characterised to what extent forest edges are different from the interior of forests, where most earlier biogeochemical data are obtained. The objective of the first part was to gain fundamental understanding of C and N interactions in soil organic matter along steep N deposition gradients as found in forest edges. The purpose of the second part was to get information on biogeochemical cycles in forest edges for mapping and extrapolation of the features for the total forested area.

Two edges of Norway spruce and oak situated close to a high N emission farm area at Thyregod in Denmark were used. Throughfall and soil water were sampled monthly at six distances from the forest edge. We ran the CoupModel and the fluxes of N were calculated. Mineral soil was sampled in three different layers down to 30 cm depth and analysed for C, N. Bulk density was estimated for the same depths in order to quantify the pools of C and N. Forest floors were sampled and separated in foliar and non-foliar fractions and analysed for C and N.

Results and conclusions

- The N deposition to spruce was highest with a clear edge effect. No clear edge effect was observed in oak where N deposition was only half as high as in spruce. However, in the interior of the two forests N deposition was alike.
- Nitrate leaching was clearly affected by the N gradient. Nitrate leaching was highest in oak.
- Mineral soil C and N pools were not strongly affected by distance to the edge, but N pools tended to be greater in the vicinity of the edge in spruce.
- There was a clear indication in mineral soil C/N ratio that the N status differed strongly with distance to the forest edge. The gradient in mineral soil C/N ratio was most evident in oak, where the N input gradient was less pronounced in throughfall. This suggests that a part of the deposited N is taken up in the tree canopy close to the edge. The total N deposition to the oak stand may therefore be higher than N inputs to the soil by throughfall. Forest floor C/N ratios were poor indicators of N status. No clear pattern was evident with distance to the forest edge.

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Hot spots and hot moments: another look at nitrogen variability in Sierra Nevada forest soils

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Because of the extremely dry summers, rooting is entirely absent in the O horizons in many forest ecosystems in the Sierra Nevada Mountains of Nevada and California. Thus, decomposition/N mineralization and vegetation uptake processes are spatially discoupled, and the intense competition for N between roots and decomposers in the O horizon which characterizes more humid forest ecosystems is absent (Johnson et al., 1997; Stark, 1973). Because of this discoupling, the N returned in littterfall is not recycled to the trees until: 1) N supply exceeds microbial demand, and 2) N is leached to lower horizons where roots are present. Both O horizons and mineral soils of the Sierra Nevada Mountains of Nevada and California are extremely hydrophobic in summer, preventing summer rains from wetting mineral soils except in preferential flowpaths (Burcar et al., 1994). Recent studies have found very high concentrations of ionic forms of N in O horizon interflow solutions that flow over the top of mineral soils (Miller et al., 2005). We hypothesize that this O horizon interflow creates biogeochemical “hot spots” and “hot moments” (Schimel and Bennett, 2004) where it infiltrates into preferential flowpaths in the mineral soil. In re-examining data taken with various resin-based techniques and tension lysimeters in the Sierra Nevada Mountains, we consistently find positively- skewed distributions and extreme outliers in mineral N data indicative of hot spots. Fig. 1 provides an example of many such patterns observed. We also find considerable inter-annual variation in the exact location of such hot spots, suggesting that they are hot moments rather than consistent features of the landscape.

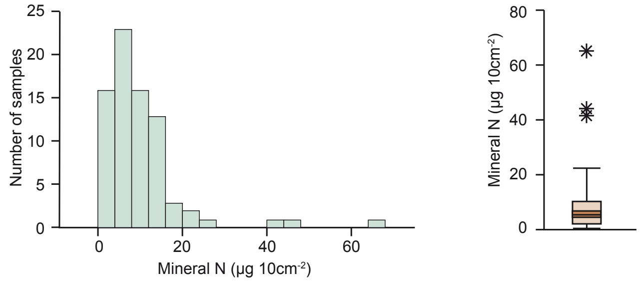

Fig. 1. Histogram (left) and box plot (right) of mineral N ($NH_4^+ + NO_3^-$) measured by ion exchange membranes (PRS^{TM} probes) in a forested site near Lake Tahoe, California. Asterisks in the box plot indicate extreme outlier values.

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Nitrogen balance of boreal coniferous forest

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When studying interactions between climate change and boreal forest ecosystems, nitrogen cycling in ecosystem cannot be left out. Nitrogen cycling is strongly linked to carbon cycling, as low nitrogen (N) availability limits productivity in boreal coniferous forests. Forest ecosystems also emit nitrous oxide (N_2O), which is a strong green house gas. N balance is a tool for understanding effects of N deposition to forests and interactions between forests and global warming.

In order to quantify the N balance in a boreal forest ecosystem we have measured N storages and fluxes since 1996 in a young pine stand at SMEAR II- measurement station at Hyytiälä, in southern Finland (61° 51'N, 24° 17'E). Comprehensive ecological and meteorological measurements have been running at the station continuously since 1995. The stand was established in 1962, and it is managed by the current recommendations for forests in economic use. Soil depth at the site is 0.05–1.5 m. Bedrock under the soil is very solid and is sealed with silt containing high portion of clay, enabling water to escape the system only by evapotranspiration or runoff. Studying of water and N flow out of the system is enabled by two mini catchments (900 m^2 and 300 m^2 in size) located at the site and closed with weirs. Wet deposition of N, throughfall and stemflow of N are measured from rainwater samples. Dry deposition of N is measured by DELTA-denuders (Sutton *et al*. 2001). Internal cycling of N in the forest is studied by measuring changes in storages (soil-N, needles, wood), as well as measuring the amount and quality (N content) of litterfall. N concentrations in the soil water are measured by lysimeters installed at different depths of the forest soil. All the water samples are collected fortnightly to monthly depending on the season and are analyzed for ammonium (NH_4-N), nitrate (NO_3-N) and dissolved organic nitrogen (DON). For more details of the site, see Hari and Kulmala (2005).

We found that N accumulates to the forest ecosystem. Approximately 1/10 of the N inputs are lost in the runoff, mostly in the form of DON. However, both N deposition and N runoff vary between years. N loss in N2O emissions from the soil is around 1/15 of the atmospheric N inputs. NOx-emissions from the ecosystem are hardly within the measurement range. There are high uncertainties related to N_2-fluxes from soil via denitrification and N_2-fluxes to soil via N_2-fixation. The current estimate is that these two processes counteract each other.

Soil is the greatest pool of N in the boreal forest ecosystem. Most of this N is bound to organic matter such as humus and proteins, both of which are slowly decomposable. Other important storages of N are wood, needles and fine roots. In the woody tissue N is immobilized for decades or hundreds of years, whereas the N in the needles and fine roots is in constant cycling. Of the total N stored in the ecosystem, approximately 1% is taken up by plants annually.

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Release of dissolved organic nitrogen in the decomposition of different organic soils

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Nitrogen (N) in stream waters is mostly in the form of dissolved organic nitrogen (DON), which according to recent studies can contribute to eutrophication of surface waters. Understanding of DON cycle in the source habitats i.e. terrestrial ecosystems is still inadequate. DON pool in soil is a heterogeneous collection of organic molecules that can be separated into more active low molecular weight DON (LMW-DON) and more passive high molecular weight DON (HMW-DON). The major input of DON into soil solution is decomposition of organic matter. However, it is not clear, in which proportions nitrogen is released into inorganic and organic forms and what are the controlling factors for this.

The aim of this study is to define how the N released in decomposition is distributed into inorganic and organic N forms and how the quality of organic material affects this distribution. Altogether 48 soil samples were collected from four different sites: upland mineral soil (mor humus; low and medium fertility type) and peatland (*Carex* and *Sphagnum* peat; two different degrees of humification). Living vegetation was removed and soil fauna killed by freezing. To study the effect of soil fauna, half of the samples were inoculated with enchytraeid worms. Soil samples were incubated for four months in growth chambers at +15 °C and at field capacity moisture condition. Soil water samples were taken every other week for the analysis of different nitrogen fractions (NH_4^+, NO_3^-, LMW-DON, HMW-DON). LMW-DON fraction was separated by ultrafiltration through a 1 kDa filter membrane.

Based on the results from the first three months the soil substrate has an influence on the release of the N fractions. The release of N was greater from peat than from mor humus samples. In the beginning of the experiment N concentration in soil water decreased indicating net N immobilisation. The rate of immobilisation decreased during the experiment and in 60% of the samples the immobilisation was changed to net N release. In peat samples, most of the dissolved N was in the form of NH_4^+. In mor humus, the proportion of DON from the total N concentration in the soil water increased during the incubation to such an extent that DON became the major fraction of dissolved N. The amount of LMW-DON is small, most often under detection limits, as well as the amounts of NO_3^-. At this stage of the study, the effect of the enchytraeids was not significant in the data.

Parameterization of an organic matter decomposition model to describe the quality of the released dissolved nitrogen

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In boreal zone, nitrogen (N) in stream water is mostly in the form of dissolved organic nitrogen (DON). Planktonic microbiota in surface waters is shown to consume DON, and consequently export of DON has a role in eutrophication of surface waters. A proper understanding of DON cycle in the source habitats - terrestrial ecosystems – needs to be pursued. The major inputs of DON into soil are atmospheric deposition, root exudation, ectomycorrhizal fungi, and organic matter decomposition. The quality of N released in decomposition varies, and it includes ammonium and DON in various proportions depending on e.g. the quality of the organic matter.

Several mathematical models are available for describing water and N dynamics in a catchment, but usually the models account merely for fluxes of dissolved inorganic nitrogen. Both inorganic and organic N are described in FEMMA model, which simulates hydrological and nitrogen processes in boreal forested catchments that are subject to forest management practices. FEMMA includes an organic matter decomposition scheme ROMUL which is previously applied in the context of carbon sequestration studies. ROMUL simulates the decomposition in three succession stages, each of which is represented by a pair of storages of organic matter and N. The storage pairs are for fresh litter material (L), complex humic substances with undecomposed organic debris (F), and humus material (H). When the decomposition proceeds, a proportion of carbon is released as CO_2 or transferred to the next succession storage. Along with C, N is either released or transferred to the next storage. In this study we modify the ROMUL model to describe N immobilization, i.e. uptake of N by soil microbes. The new model structure allows separation of the released or immobilized N into ammonium, low-molecular weight (LMW-) DON, and high-molecular weight (HMW-) DON. The model development was supported with a manipulation experiment, where the release of N in 24 mor humus samples was monitored in laboratory conditions. Mor samples were separated into L, F and H material according to their visual characteristics, and each separated sample was placed into containers. For defaunation the samples were twice successively frozen at the temperature of -20 °C and thawed. Twelve of the samples were inoculated with enchytraeid worms to identify the impact of soil fauna on the decomposition. The samples were incubated at field capacity moisture content and temperature of +15 °C in a growth chamber. During the incubation, soil water was collected regularly from the mor samples by using suction samplers. Total dissolved nitrogen, ammonium, nitrate, LMW-DON and HMW-DON concentrations were determined from the water samples. LMW-DON was analyzed from a water sample that was filtered through a 1 kDa membrane. The preliminary results of the manipulation experiment reveal that the concentration of total dissolved nitrogen first decreased in the soil water, which is an indication of net immobilization. A fraction-wise examination shows that the immobilization consumed ammonium in the soil water, while the concentrations of other N fractions increased indicating a small release. The highest rate of immobilization was found in L material. After the immobilization phase the highest rate of net N release was again detected in L material and the release was mainly in ammonium form. LMW- and HMW-DON were mainly released in F and H material. The experiment will continue for another two more months. After the experiment, the observed fractioning of the released nitrogen will be embedded into parameterization of the decomposition model ROMUL.

A comparison of the nitrogen cycle in pine, aspen and poor-fen systems in the Athabasca Oil Sands Region

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In contrast to many other areas in North America, increased industrial activity in the Athabasca Oil Sands Region (AOSR) has resulted in an increase of sulphur and nitrogen oxide (SO_x and NO_x) emissions which are expected to persist for many decades. This boreal region is traditionally considered to be N limited, but it is possible that elevated deposition of nitrogen may lead to a cascade of impacts as these systems become 'nitrogen saturated'.

In the AOSR, a mandate to protect local ecosystems from acidification was put in place. In order to evaluate potential impacts of elevated nitrogen deposition, a series of modeling techniques may be used, however, nitrogen dynamics within this boreal region are poorly characterized. In order to evaluate the potential impacts of elevated nitrogen deposition, a detailed understanding of nitrogen cycle processes in the dominant landscapes of the region is required. The AOSR is characterized by upland forests dominated by jack pine (*Pinus banksiana*) or trembling aspen (*Populus tremuloides*) as well as abundant wetlands. Five replicate study plots were established within each of these three dominant landscape types and various components of the nitrogen cycle were monitored over a two year period.

Despite the close proximity to active oil sands mining operations bulk deposition and throughfall at the study site is still relatively low (< 5kg ha^{-1} y^{-1}) compared to other parts of North America or Europe. However, nitrogen cycling within each of the three landscape types was found to be entirely different. For example, foliage, soil C:N ratios and nitrogen pools differed significantly between jack pine and trembling aspen stands. Other components of the nitrogen cycle including ammonification, nitrification, denitrification, decomposition, litterfall, nitrate leaching and ^{15}N natural abundance were also characterized and in several cases differed considerably among ecosystem type. These data were used to construct detailed N cycling budgets for each of these ecosystem types. This information is a crucial first step toward assessing the sensitivity of these ecosystems to enhanced N deposition and will potentially aid the parameterization of dynamic geochemical models.

Changes in stream organic N and C concentrations from boreal headwater catchments downstream to the coast

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Organic matter transported by streams and rivers from headwater catchments to the coast is affected by processes in the river and by changing land use along the river basin. Hence, the concentrations of total organic nitrogen (TON) and total organic carbon (TOC) show significant variability during the riverine transport from first order catchments to the coast. The TON and TOC concentrations were studied in 42 unmanaged and 21 managed first order catchments covered by forests and peatlands with an area ranging from 0.07 to 56 km^2 and in 36 river catchments and their sub-catchments with mixed land use and an area of 73 to 56 500 km^2.

In small pristine headwater catchments, the proportion of organic nitrogen of the total N load was very high, on average 91% (Mattsson *et al* 2003, Kortelainen *et al*. 2006). In headwater catchments where forestry practices have annually affected about 2.4% of the catchment area, comparable to average values in Finland, the proportion of organic nitrogen was somewhat smaller, on average 77% (Kortelainen *et al*. 1997). Downstream in the river basins, the proportion of organic nitrogen decreased and in river mouths the proportion was 51% (Mattsson *et al*. 2005). Although the proportion of organic nitrogen decreased from headwaters downstream, TON concentrations increased from on average of 340 $\mu g\ l^{-1}$ in first order streams through 400 in river sub-catchments to 550 $\mu g\ l^{-1}$ in river mouths. On the contrary, concentration of TOC was on average highest in headwater streams (17 $mg\ l^{-1}$), whereas in river mouths, the average TOC concentration was lower (13 $mg\ l^{-1}$). These results indicate that land use gradient from headwaters to lowlands affects TON and TOC concentrations and has significant effect on the stoichiometry of our study rivers.

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Nitrogen dynamics in decomposing Scots pine, Norway spruce and silver birch stems

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The contents of nitrogen (N) have generally been observed to increase in the early stages of decomposition in coarse woody debris and then to decrease slowly. That is potentially an important mechanism of nutrient retention in ecosystems after disturbances. We studied N dynamics in decomposing Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karst.), and silver birch (*Betula pendula* Roth.) stems in Finland (Palviainen et al. 2008). The oldest stems had decomposed for 34 (spruce and birch) or 45 (pine) years. Concentrations of N in both fallen logs and standing snags increased and C/N ratios decreased with time, and birch had significantly higher N concentrations and lower C/N ratios than pine and spruce. Whether dead stems were lying on the ground or standing, seemed to have little effect on N dynamics. Even though increased N contents were observed in some cases, N was generally released already in the early stages of decomposition, and faster from birch than conifers. Based on model analysis, from 40% (pine and spruce) to 50% (birch) of initial N was released within 30 years (Fig. 1). The results suggest that decomposing stems of Scots pine and Norway spruce, especially, retain N rather effectively in boreal forest ecosystems and form a long-term, small but steady N pool with a slow release rate. After 30 years, 60% of N is still retained in the stems of pine and spruce, twofold to the percentage of remaining mass.

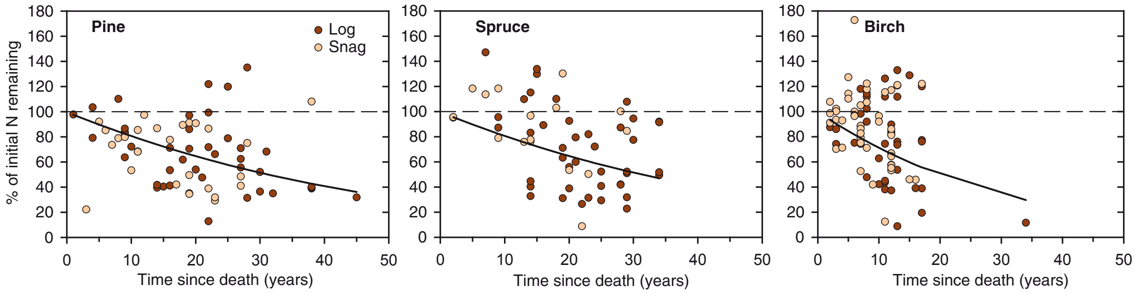

Fig. 1. The N content, expressed as a percentage of initial N remaining, in Scots pine, Norway spruce and birch logs and snags after various periods of decomposition. Experimental data are presented by dots and model results by continuous line.

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Nitrous oxide emissions from a cotton field in North East China

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The global increases in atmospheric CH_4 and N_2O are primarily due to agriculture (IPCC, 2007). Although CO_2, CH_4 and N_2O emissions from terrestrial ecosystems have been relatively much studied during the last two decades, uncertainties in emission estimates are very large, particularly with respect to N_2O. China is one of large agricultural countries in the world. It contains 12% of world's total crop harvest area where 25% of the global synthetic nitrogen was consumed in 2003 (FAO, http://apps.fao.org). One of the key challenges in the future is to lower the uncertainties in the N_2O emission inventories by better quantifying the N_2O emissions in the intensively cropped agricultural areas in China. As the N_2O emissions mainly occurs in short pulses, continuous and automated measurements are needed to capture the temporal variability in the emissions.

To overcome the shortage of continuous greenhouse gas (GHG) flux measurements in Chinese croplands, we organized an intensive field measurement campaign in Yunchen, southern Shanxi province, Northern China. Common practices in the area are intensive fertilization and irrigation of crops with groundwater. Cotton cultivation is increasingly popular, however, the information on GHG fluxes of cotton cultivation in China is poorly understood. During this 12-month campaign in 2009 the fluxes of N_2O and CO_2 are continuously measured by micrometeorological eddy covariance (EC) method and automatic chambers (AC). In addition, supporting measurements include crop growth dynamics, soil moisture and temperature, air temperature, soil ammonium and nitrate content, ground water table, atmospheric nitrogen deposition, laboratory estimated potential rates of N_2 emission from denitrification, and gross nitrification and gross denitrification rates.

Here we will present results of the first part of the measurement period in January-June 2009. We will concentrate on the measurements of N_2O fluxes by chamber and micrometeorological methods, and related these emissions to the soil and meteorological measurements.

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Comparison of static chambers to measure N_2O and CH_4 fluxes from soils

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Soil fluxes of the greenhouse gases (GHG) nitrous oxide (N_2O) and methane (CH_4) are often measured by closed static chambers. Chamber type and measurement protocol substantially affect the flux of the target gas. In general, most chamber types tend to underestimate trace gas fluxes from soils by slowing down the gas diffusion from the soil to the chamber headspace during the measurement.

To test different types of static chambers for N_2O and CH_4 fluxes a chamber calibration campaign was organized at Hyytiälä Forestry Field Station in Southern Finland during August-October 2008. The overall aims of the campaign were to quantitatively assess the uncertainties and errors related to static chamber measurements, and to bring together and discuss these problems with researchers working in the field of GHG fluxes. Overall 15 different static chambers were tested for 5 different N_2O and CH_4 flux levels with 3 different soil conditions (moisture and porosity) in a calibration tank described by Pumpanen et al. (2004). Gas concentrations in the calibration tank and in the headspace of soil chambers were monitored with a gas chromatograph (GC) for N_2O and automatic gas analyzers for CH_4.

Preliminary results show that most of the static chambers that were tested either over- or underestimated the N_2O and CH_4 fluxes, and the magnitude of over- or underestimation remained constant regardless of flux level for each of the chambers. Chamber designs differed from each other and the sampling protocol strongly influenced the gas concentrations inside the chambers. After a thorough data-analysis the results of the campaign will provide with quantitative information on the level of under- or overestimations of the fluxes, as well as provide guidelines of ideal chamber designs for N_2O and CH_4 emission measurements.

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Denitrification versus nitrogen loadings in shallow riverine wetlands in the Po River Plain (Northern Italy)

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Dissolved oxygen, dissolved inorganic carbon (DIC) and nitrogen fluxes, and denitrification rates (isotope pairing technique, Nielsen, 1992) were measured in winter and summer 2007 in 22 shallow riverine wetlands located in the Po River Plain (Northern Italy). Sampled sites were eutrophic to hypereutrophic with fluffy and organic sediments. The different degree of connectivity with the adjacent rivers resulted in variable nitrate concentrations (from <5 to 1133 μM).

Oxygen demand (from 0.29±0.05 to 6.51±0.32 mmol $m^{-2}h^{-1}$)and DIC release (from 0.41±0.93 to 16.70±1.05 mmol $m^{-2}h^{-1}$) resulted in respiratory quotients generally > 1. NH_4^+ was mostly released from sediments into the water column, with rates up to 2670±307 μmol $m^{-2}h^{-1}$ in summer. Concurrently, $NO_3^- + NO_2^-$ uptake rates up to -4062±1121 μmol $m^{-2}h^{-1}$ were measured. Denitrification rates (2÷1888 μmol $m^{-2}h^{-1}$) appeared to be regulated mostly by nitrate concentration in the water column (DW), with DW accounting for more than 60% of total denitrification (DT). Nitrification coupled denitrificatio (DN) was probably limited by oxygen availability in organic rich anoxic sediments.

Laboratory incubations of sediment cores demonstrated that nitrate additions resulted in prompt increase of denitrification rates, meaning that potential denitrification was elevated at all sampled sites. Overall, at sites connected with the main rivers, denitrification was an important pathway for nitrogen removal and organic matter oxidation; whilst in isolated sites ammonium regeneration prevailed over denitrification. The main conclusion of this study is that hydraulic connectivity of wetlands with the main river bed is critical for the maintenance of important biogeochemical functions, as nitrogen removal with denitrification.

Denitrification rates in the considered wetlands were also discussed with respect to mass balances of nitrogen in the surrounding agricultural soils. Nitrogen budgets were calculated as differences between nitrogen inputs (animal manure, chemical fertilizers, atmospheric depositions, biological fixation, irrigation) and outputs (crop uptake, ammonia volatilization, denitrification) according to Oenema *et al*. (2003). Despite measured denitrification rates were among the highest reported in the literature, the annual nitrogen removal with denitrification was several times lower than the annual N surplus in the agricultural soils. Unbalanced N supply and N removal is to a large extent responsible of freshwater and groundwater contamination by nitrate in the Plain of Po River.

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N-cycling in a large eutrophic river, Canada: sources and processes

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Agricultural runoff and wastewater effluent contribute large quantities of nitrogen (N) pollution to water bodies of heavily populated catchments. Nitrate (NO_3^-) and ammonium (NH_4^+) are toxic to humans and wildlife at high concentration and degrade freshwater habitat through eutrophication. Microbial processes such as nitrification and denitrification produce nitrous oxide (N_2O), a potent greenhouse gas that aids the destruction of stratospheric ozone (Zafiriou 1990). Three major knowledge gaps in freshwater N studies are: 1) the global significance of N_2O emissions from rivers (Kroetze *et al*. 2005), 2) N-cycling dynamics in systems with strong diel oxygen cycling, and 3) the potential for natural abundance stable isotope analysis of inorganic N-species ($\delta^{15}N$, $\delta^{18}O$) as a tracer of N_2O sources and production pathways. Concentration and stable isotopic ratios of NO_3^-, NH_4^+, N_2O and DO were collected from the Grand River, Ontario, Canada, a seventh order stream receiving both agricultural and urban N-pollution. Biweekly and summer diel sampling were completed at sites upstream and downstream of two municipal wastewater treatment plants (WWTPs). Two whole-river surveys were also conducted and WWTP effluent and plume samples were taken.

Concentration data indicated that areas downstream of WWTPs had rapid N-cycling and N_2O production during summer, tightly coupled with large diel DO variability. Whole-river surveys indicated that N_2O emissions are positive but low in areas receiving primarily agricultural N. Weighted annual N_2O emissions from 2006–2008 were calculated, with highest N_2O emissions below WWTPs, when nightly oxygen minima were below 2 mg/L in summer. Emissions were higher in warm, dry years when macrophyte growth was high but were below estimations using Intergovernmental Panel on Climate Change (IPCC) empirical equations. Stable isotopic values of N_2O produced were modelled taking gas exchange into account and were found to be significantly different above and below WWTPs.

The significance of different N-cycling processes and sources vary diurnally, seasonally and spatially along the Grand River. Stable isotopic enrichment factors (ε) for N_2O production are necessary to correctly interpret isotopic field data, but there are currently no published values for freshwater systems. ε values for denitrification, were determined in sediment and water incubations and compared to those determined from field data and modelling. The effects of acetylene (C_2H_2) inhibition, N_2O production rate and temporal and spatial variability in N_2O stable isotopic composition and ε were examined.

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New insights on N transformations by ^{15}N tracing techniques

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In recent years the understanding of the nitrogen (N) cycling in soil experienced great changes due to the discovery of a variety of new processes or underpinning the importance of alternative processes, including anaerobic ammonium oxidation (anammox), archaeal nitrification, fungal denitrification and co-denitrification, heterotrophic nitrification and nitrifier denitrification (Francis *et al*., 2007; Hayatsu *et al*., 2008). A widely used method to investigate N cycling are ^{15}N tracing studies where one or more soil N pools are labelled with ^{15}N and subsequently the concentrations and ^{15}N enrichments are followed over a period of time. The main objective of these studies is to quantify the simultaneously occurring gross N transformations. Recent progress in ^{15}N tracing models (Müller *et al*., 2007) enables us to perform more comprehensive process-specific analyses of the N cycle and investigate the ecological importance of previously ignored processes such as heterotrophic nitrification and dissimilatory nitrate reduction to ammonium (DNRA) (Rütting *et al*., 2008).

Here we present results from several ^{15}N labelling studies in temperate grassland and forest ecosystems from the northern and southern hemisphere. In these ecosystems DNRA is the dominant, sometimes exclusive pathway of NO_3^- consumption. The main advantage of DNRA over other NO_3^- consumption processes is that N is transferred into NH_4^+, another plant available N form, which is not prone to N losses. Therefore DNRA leads to conservation of mineral N in soils.

Due to the method of data-analysis we are able to identify correlations between several N transformations. These correlations provide evidence of the existence of “functional links” which we hypothesize to be adaptations of the microbial community to the prevailing conditions and are optimized for N retention. In our studies functional links were observed between: DNRA and heterotrophic nitrification, NH_4^+ oxidation and NO_2^- reduction rather than oxidation to NO_3^- as well as between mineralization and NH_4^+ immobilization.

Autotrophic nitrification and denitrification are considered to be the main N_2O producing processes in soils. We developed a ^{15}N tracing model to differentiate total N_2O emission into process-related quantities. Four processes of N_2O production are considered, namely autotrophic nitrification, denitrification, reduction of NO_2^- derived from oxidation of organic N and a hybrid-reaction for N_2O production whereby one atom of the N_2O is derived from an enriched NO_2^- pool and another from organic N at natural abundance (i.e. co-denitrification). Our findings indicate that heterotrophic processes using organic N as substrate are primarily responsible for N_2O emissions and are more important in (semi-)natural temperate ecosystems than previously thought.

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Rhizosphere soils versus bare soils: responsiveness of nitrifying populations to vegetation cover

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Microbial activity related to the cycling of nutrients needed for plant growth is expected to be intensified in rhizosphere soils, because the release of exudates and the accumulation of organic compounds lead to a major microbial concentration. However, this general pattern deserves much more study. *Lolium* grasses are fast growing and highly N-demanding species and have contents of phenolic acids that make them potentially allelopathic. In consequence, its particular nature may change the conventional thought of the rapid cycling of nitrogen in rhizosphere soils. We studied the effect of a mixture of two phenolic compounds (ferulic and p-coumaric acids 50:50) and an aqueous extract of *Lolium multiflorum* (50 g of fresh weight/L) on the nitrification potential (NP) and the microbial biomass (MB) of a a) bare soil and b) a soil sown with *Lolium multiflorum* . Soils were wet shieved, 500 mg placed in polyethilene bags and sprayed with 10 ml of the following treatments: 1) low concentration of phenolic mixture (2 µg/g soil), 2) high concentration of phenolic mixture (0.2 mg/g soil), 3) *Lolium aqueous* extract and 4) distilled water. After 24 h of incubation at room temperature, 10 g were subsampled for the NP analysis (shaken soil-slurry method) and 40 g for the MB (chloroform fumigation/direct extraction method). Nitrate determinations were performed with an autoanalyser (Braun+Luebbe) and statistically analysed using a general lineal model procedure (SPSS 15.0). Regarding soil covering, bare soils displayed much higher NP rates than *Lolium* soils (F=121.16, p=0.000, Fig. 1a) despite there were no significant differences on MB between bare and *Lolium* soils (F= 1.130, p=0.294, Fig. 1b). Regarding phenolic additions, NP rates tended to slow down with high concentrations of phenolics and *Lolium* extracts (F= 10.79, p=0.000). On the contrary, MB was increased by these treatments (F= 8.70, p=0.000). Results reflect a different composition of soil microbial communities of rizosphere versus bare soils, since both had the same microbial N biomass, despite rizosphere soils showed a drastic drop of nitrifying populations. However, both soils displayed the same response pattern to phenolic additions: an increase of MB at high concentrations, but a trend to decrease NP rates, which also reflects a shift in soil microbial communities. It is known that phenolic compounds may decrease soil N availability through changes in microbial populations (Castells 2008). This experiment highlights the complexity of the pattern when plant-microbial competition is included in the study and reveals that rhizosphere soils may not offer the best conditions for nitrification when strong plant competitors are present here-in.

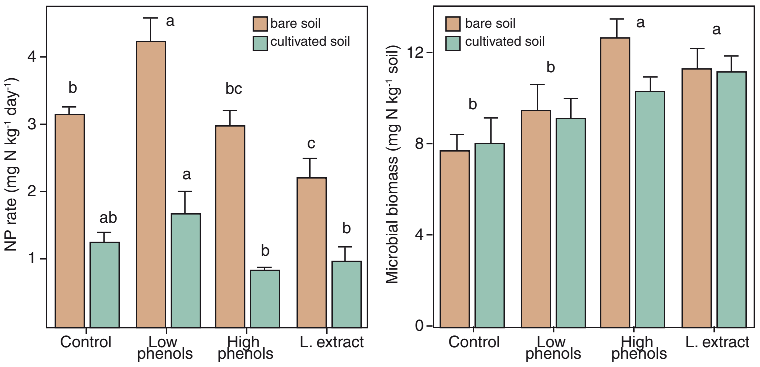

Fig 1. Nitrification potential rates and microbial biomass N of bare and *Lolium* soils amended with phenolic compounds. Different letters mean significant differences (LSD p<0.05) within bars of the same colour

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Microbial N transformations in N loaded spruce forest soils: fluxes and pools

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Nitrogen (N) leaching persists in Central European mountain forests even after ~40% reduction in deposition of inorganic N (IN) compared to the 1980s. We hypothesize that this leaching is closely linked to biochemical N transformations, among which microbial N immobilization plays crucial role. The aims of the study are to estimate (i) the effect of temperature on biochemical N transformations and (ii) N fluxes and pools in the soil profile of N-saturated, mountain spruce forest.

The study sites were situated in the Bohemian Forest (Czech Republic). The effect of temperature on net nitrification, ammonification, and microbial N immobilization were measured in a short term incubation experiments without substrate addition. N pools were calculated from the concentrations of N forms in the soil and soil pool weights, while daily N fluxes were calculated from net rates of processes and soil pool weights.

The results showed that N transformation occurred mostly in the upper part of the soil profile (litter, humus, and 0–10 cm of mineral soil layer) and over the whole year (even at temperature close to freezing point). Relationships between temperature and net nitrification, net ammonification, and microbial N immobilization did not follow the Arrhenius type equation; all processes were active close to 0 °C. Microbial N immobilization flux was always greater than mineral N ($NH_4 + NO_3$) flux. Averaged for study sites, daily microbial N immobilization fluxes in the measured part of soil profile were 162 mg N m^{-2} d^{-1} and 234 mg N m^{-2} d^{-1} at 0 °C and 10 °C, respectively, and the corresponding daily mineral N fluxes of 35.7 mg N m^{-2} d^{-1} and 37.7 mg N m-2 d^{-1} at the same temperatures, respectively. The microbial N pool was much larger than mineral N pool (10.9 g N m^{-2} against 2.5 g N m^{-2} in the studied part of the soil profile). Balance of the available N pools (microbial and mineral pools) in the upper part of the soil profile showed that organic layers contributed more than 70% to the available N in the soil profile. The daily N fluxes were related to corresponding N pools. On average, N fluxes represented a relative daily mineral and microbial N pool change of 1.14 ± 0.9% and 1.95 ± 0.9%, respectively.

Microbial N immobilization was by far the most important biochemical N flux throughout the soil profile indicating that microbial N flux can strongly affect the ability of soil to retain N. In addition, experiments with ^{15}N labeling revealed that microbes could use organic and mineral N (both NO_3 and NH_4) forms simultaneously, but mineral N was built into microbial biomass less effectively (Tahovská, Šantrůčková 2009). It suggests that any, even a relatively small, decrease of microbial N immobilization either due to microbial growth limitation or due to mineral N consumption might result in a decrease of mineral N immobilization resulting in excess of mineral N in the soil and, therefore, an N leaching hazard.

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Evaluation of the contribution of agricultural activity to nitrogen concentrations in several small lakes in the Khorezm region of Uzbekistan

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Cotton, rice, and wheat are grown extensively in the Khorezm province of western Uzbekistan, fed by water from the Amu Darya River. Approximately 150–300 kilograms of nitrogen per hectare (kgN/ha) are applied annually to these crops, although it is estimated that only about 30 percent of this amount is utilized by the plants (Scheer *et al*. 2008). Runoff from fertilized fields and seepage from shallow groundwater provide water for over 450 shallow lakes distributed across this arid region. Monthly water quality data were collected from 13 lakes from 2006 to 2008 and compared to land use data for the area within 500 meters of each lake's perimeter to evaluate temporal variations between fertilizer loads to agricultural fields and nitrogen levels in the lake water column. Zooplankton samples were periodically collected and prepared for stable isotope analysis to examine effects of land use on aquatic food webs.

Land use data show that the majority of fields within 500 meters of the lakes were planted with cotton and rice, for which fertilizer is normally applied between May and August. In contrast, measured water column dissolved inorganic nitrogen concentrations were highest in all lakes during the winter months, and peaked in March. Ammonium was the most abundant constituent of nitrogen concentrations in all lakes, with concentrations up to 3.0 milligrams of nitrogen per litre (mgN/L). Based on these results, we hypothesize that although fertilizer is applied to surrounding fields during the summer growing season, excess agricultural nitrogen does not have a noticeable impact on lake water quality until the following spring (March), when fields are flooded with water to leach high salt concentrations from the soil in preparation for planting. Zooplankton stable isotope results generally support this hypothesis, with nitrogen isotope values in several lakes increasing by as much as 2.6 per mil between June and October. An understanding of the effects of local agriculture on lake water quality is useful as local farmers consider implementing aquaculture in these lakes to supplement family income.

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Nitrogen dynamics in contrasting forest ecosystems exposed to enhanced atmospheric N deposition

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Despite chronically enhanced nitrogen (N) deposition to forest ecosystems in Europe and NE America, considerable N retention by forests has been observed. It is still unclear which factors determine N retention in forest soils. However, this knowledge is crucial to assess the impact of changing anthropogenic N emissions on future N cycling and N loss of forests. For coniferous and deciduous forest stands at comparable sites, it is known that both N deposition to the forest floor as well as N loss by leaching below the rooting zone are significantly higher in coniferous stands (De Schrijver *et al*., 2007). In addition, the N loss in coniferous stands is often more enhanced than can be explained by the higher N input only, which suggests lower N retention by coniferous stands and may be related to differences in litter quality, microbial activity, and N uptake by plant roots. To test this hypothesis, we studied the effect of forest type on N retention. N dynamics were examined for two adjacent forest stands (pedunculate oak (*Quercus robur* L.) and Scots pine (*Pinus sylvestris* L.)) on a well-drained soil type and with a similar stand history, which are located in a region with high N deposition (Belgium). Firstly, input-output N budgets were established by quantifying atmospheric deposition and leaching, which confirmed the above finding of higher N deposition and disproportionately higher N loss by the pine stand than the oak stand. Secondly, the fate of inorganic N within the ecosystems was studied by spraying dissolved ^{15}N onto the forest floor, both as ammonium (NH_4^+) and nitrate (NO_3^-). The ^{15}N recovery over time in organic and mineral soil layers, tree roots, water leaching, ferns, foliage, and stem wood was compared between the two forest stands and N treatments. Thirdly, *in situ* gross N transformation rates in undisturbed mineral forest soils were determined via a ^{15}N tracing approach (Müller *et al*., 2007). Meaningful differences between the two forest stands were found for the rates of mineralisation, heterotrophic and autotrophic nitrification, and NH_4^+ and NO_3^- immobilisation. Unexpectedly, dissimilatory NO_3^- reduction to NH_4^+ (DNRA) was detected in the oak soil. This process has mainly been described for unpolluted soils (e.g., Huygens *et al*., 2008), and to the best of our knowledge, this is the first report of DNRA under field conditions in a temperate forest soil under high N deposition.

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Microbial N transformations in N loaded spruce forest soils: immobilization of different ^{15}N forms into microbial biomass

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Soil microbes can immobilize a wide range of N compounds. However, detailed information about microbial immobilization of different N forms in N loaded acid soils is still poorly known and data are scarce. It appears that microorganisms have high capacity to incorporate N and that microbial N immobilization plays crucial role in N turnover in spruce forest soils in the Bohemian Forest (Czech Republic; Šantrůčková *et al*. 2009). The main goal of this study was to estimate immobilization of different ^{15}N forms into microbial biomass and determine their partitioning in other soil N pools.

Microbial N immobilization in organic soils from N loaded spruce forest ecosystems (Bohemian Forest, CR) was investigated in laboratory ^{15}N-tracer experiment. Soil was labelled either with ^{15}N – N-NO_3, ^{15}N-NH_4 or ^{15}Nglycine (all N sources added together, only one of them enriched) and incubated for 0.5, 2, 6, 18 and 48h. At each sampling time distribution of tracer-derived ^{15}N was determined (elemental analyzer connected to IR-MS) in following soil N pools: microbial biomass (^{15}Nmic; CFEM); soluble N (non-fumigated extract, ^{15}Nsol), chloroform non-labile microbial residues (^{15}Nres) and ammonium ($^{15}NH_4$; diffusion technique). ^{15}N in nitrate (^{15}Ni) and dissolved organic N (^{15}DON) pools was calculated as a difference between ^{15}Nsol and ^{15}N-NH_4, because the amount of Ni in Nsol was to low to use the diffusion technique. Production of N_2O was measured at each sampling time (GC), but it was insignificant (lower than 0.1ppm). In separate experiment abiotic N immobilization of all N forms in sterile soil was measured and taken into account in calculations (35% N-NH_4, 26% N-NO_3, 0% glycine abiotically immobilized).

Microbial N immobilization of all ^{15}N sources was fast; from 28% to 81% of added ^{15}N was immobilized into microbial cells and non-labile residues (^{15}Nmic + ^{15}Nres) within 30 minutes after addition (Table 1). In this time, ^{15}N-NH_4 pool significantly increased in ^{15}N-Gly treatment, indicating rapid N mineralization. Generally ^{15}N – Gly was used primarily (^{15}Nmic + ^{15}Nres; ~80%), while high proportion of mineral ^{15}N (~40 to 70%) were found in soluble ^{15}N pools ($^{15}NH4$ +15Ni + ^{15}DON) in ^{15}N-NO_3 and ^{15}N-NH_4 treatments (Table 1). It appears that mineral N is built into microbial biomass less effectively than organic N and higher proportion of them remains (persists) in soluble N pool. However, all offered N sources were immobilized simultaneously.

Table 1. Mean ^{15}N distribution among soil N pools after 0.5 and 48 hours after labelling. The distribution was corrected for abiotic N immobilization (means ± s.d; n=4).

treatment	N pool	^{15}Nmic	^{15}Nres	^{15}N-NH_4	^{15}DON+^{15}Ni
	time (h)			%	
^{15}N-NO_3	0	29±13	19±10	0±0.1	52±3
	48	22±8	39±14	1±1	38±7
^{15}N-NH_4	0	6±3	22±13	58±10	14±5
	48	10±7	48±12	23±8	19±11
^{15}N-Gly	0	45±6	36±1	17±5	2±1
	48	21±8	61±6	17±2	1±0.4

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Soil N dynamics changes along stand age in a forest ecosystem in central Japan

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Stream NO_3^- concentration is a good index for nitrogen (N) cycling of the watershed (Aber *et al*. 1998). It is well known that disturbance causes NO_3^- leaching loss through the change of nutrient cycling change by decreasing vegetation uptake (ex. Likens1969, Vitousek 1982). After a few decades NO_3^- leaching decreases and returns to the level of pre-disturbance (Fukushima and Tokuchi 2008). At that time it is considered that N cycling also returns to the pattern of pre-disturbance. However, it is still unknown whether the pattern of N cycling is same as the pre-disturbance. The purpose of this study is to examine the pattern of N cycling with stand development.

Soil nitrogen transformation, soil N availability and soil microbial biomass were measured along the stand age to examine soil N dynamics with forest development. Ecosystem properties such as N budget changed with stand development. It indicates that the N cycling changed from open cycle to closed cycle. Soil microbial biomass (SMB) N was the dominant available N pool irrespective of stand age and SMB increased with stand development. It is consistent with Gonza´lez-Prieto & Villar 2003. Net N transformations rates was significantly different between the stands in 7 and 32 years old and 90 years old stand, while gross N transformation rate was different among 7, 32 and 90 years old stand. However, it is shown that the bacterial diversity in soil haven't related to stand ages using Terminal restriction fragment lenght polymorphism (T-RFLP) analysis based on 16SrRNA. These results show that N cycling changes from small pool and fast turnover to large pool and slow turnover in this study site. Also gross N transformation indicates N cycling changes not only quantitatively, but also qualitatively with stand development in this study site.

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Biological nitrogen fixation by biological soil crusts in arid dune ecosystems

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In arid and semi-arid regions water is be considered to be the controlling factor for productivity and the vegetation pattern. Several investigations emphasised that nutrients are critical for the productivity in arid lands. The main N input pathways into the ecosystems are atmospheric deposition in wet, dry and gaseous forms, and the biological fixation of atmospheric nitrogen N_2. In most drylands a biological soil crust build up by cyanobacteria, green algae, soil lichens and mosses covering the first millimetres of the top soil (Veste *et al*. 2001). Nitrogen-fixing cyanobacteria of the genera *Nostoc, Microcoleus, Chroococcus* and *Calothrix* and soil lichens with cyanobacterial phytobionts are common in such soil crusts. The importance of biological N fixation by soil crusts is emphasised by several authors, although determining N-fixation under field conditions has several methodological problems. In this paper we present field measurements of biological N fixation (BNF) obtained by the natural ^{15}N abundance method and use them to estimate the annual nitrogen input by the soil crusts into desert sand dunes of the north-western Negev. We perform a novel approach of the natural ^{15}N abundance technique by using the non-N_2-fixing lichens as a reference in order to determine N_2–fixation by the biological crust *in situ*.

Biological fixation by cyanobacterial biological crusts and *Collema tenax* lichens of 9–12 kg N ha^{-1}yr^{-1} and of about 43kg N ha-1yr^{-1}, respectively are very important nitrogen input pathways (Table 1). N input by dust at just 2–4 kg N ha^{-1} yr^{-1} (Littmann 1997) and by the shrub *Retama raetam* (Fabaceae) at just 0.11 kg N ha^{-1} yr^{-1} can be considered as minor pathways into the sand dune of the north-western Negev.

Table 1. Biological N_2 fixation (BNF) by biological soil crusts and soil lichens in arid sand dunes of the NW Negev, Israel (ID interdune, NWS north-west-facing slope). *Fulgensia fulgens* contaminated by free living N-fixing cyanobacteria.

Crust type (location)	N stock g N m^{-2}	NdfA %	N growth g N m^{-2} yr^{-1}	Abs. BNF g N m^{-2} yr^{-1}
Fulgensia fulgens (ID) (lichens)	17.7	68	2.5	1.7
Collema tenax (ID) (lichens)	34.0	88	4.9	4.3
Cyanobacterial biologicalcrust (ID)	5.4	91	1.4	1.2
Cyanobacterial biologicalcrust (NWS)	6.5	84	1.1	0.9

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Quantification of nitrogen cycling functional gene abundance in soil of variably-retained stands of Douglas-fir (*Pseudotsuga menziesii* ssp. *menziesii* (Mirb.) Franco)

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Nitrogen (N) is a limiting nutrient in most Douglas-fir (*Pseudotsuga menziesii* ssp. *menziesii* [Mirb.] Franco) forest ecosystems. Understanding the links between forest management and forest ecosystem function, including the cycling of N, is of paramount importance to researchers and forest managers. Clear-cutting reduces available soil N and alters the community structure of N-cycling microorganisms. It is not yet apparent how clear-cutting or variable tree retention affects the abundance of N-cycling microorganisms. In this study, we used real-time PCR assays to quantify the abundance of functional gene targets for diazotrophic (universal *nifH* and *Azotobacter* sp.-specific *nifH*-g1), ammonium-oxidizing (*amoA*) and denitrifying (*nirK* and *nirS*) microorganisms in Douglas-fir stands on eastern Vancouver Island in British Columbia, Canada. Field sampling was conducted at four sampling dates over one year, comprising nine samples of both the organic soil layer (with leaf-litter) and 9 samples of the mineral layer, within each of three plots of un-thinned control plots (100% tree retention), thinned plots (10% and 70% tree-retention), and clear-cut plots. The organic samples were pooled together, as were the mineral samples. Soil samples were analyzed for total carbon (C), loss on ignition (LOI) C, total N, NH_4^+ and NO_3^-. Standard curves were developed for all gene targets using DNA extracted from pure cultures. Tree retention of 70% significantly ($P = 0.033$) increased *nifH*-g1 abundance. Sampling date and site location significantly ($P < 0.001$) affected universal-*nifH* and *nirK* abundance. Significant correlations between *nifH*-g1 and total C, total N and NH_4 in the organic layer were calculated following linear regression. Significant ($P < 0.001$) positive correlations between *nirK* and *nirS* abundance were also observed. Correlations observed in this study demonstrate the functional relationship between gene abundance and soil nutrient status. The retention of the soil organic leaf-litter layer (after thinning), where the majority of nutrient cycling events take place in forest soil ecosystems, contributes greatly to the preservation of a functioning soil ecosystem.

The multi-annual nitrogen budget of a peat-covered catchment – constraining carbon budgets and N_20 fluxes

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This study considers the multi- annual nitrogen budget of an upland peat catchment in northern England. The study site site has been monitored since 1993 and the monitoring considered: wet and dry deposition; soil porewater and streamwater ammonia, nitrate and DON concentrations. By consideration of these inputs and outputs it is possible to reconstruct the nitrogen fluxes as water leaves the peat profile as opposed to assessing fluxes from the streamwater. The atmospheric input of Total N to the site varied from 0.64 to 4.03 g $N/cm^2/yr$, the streamwater flux of Total N varied from 0.14 to 0.81 g $N/cm^2/yr$; and the flux of Total N as water leaves the peat profile varies from 0.41 to 1.85 g $N/cm^2/yr$. These simple input flux measurements were augmented by a consideration of the C/N contents of each of area's vegetation, litter layer and peat profile to at least 90cm depth. These fluxes would imply that the peat soil is moving from a net sink of nitrogen to being a net source of nitrogen and that there is extensive release of nitrogen from the decomposition and humification process and in this way the peat is acting to release nitrogen built up under historic high levels of N deposition rather than present levels of deposition.

Long term fate of litter ^{15}N in forest soils: mineralization vs. stabilization

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In beech forests between 20 to 40 kg N ha^{-1} yr^{-1} are restituted to the forest floor by the annual litterfall. Plant residues contain N mainly as proteins and peptides. During litter decomposition and mineralization, N undergoes a partitioning into different organic and inorganic forms. *In situ* labeling techniques using ^{15}N enriched fertilizers or litter demonstrated the use of organic or inorganic N sources by plants and soil microbes and made progress in tracking the fate of deposited N or litter N in forest soils However, there is a lack of information about the precise mechanisms which control the balance between mineralization and stabilization and their combined effects on N turnover in soils. We have identified two main reasons for this lack of information. First, we find that only very few experiments have been conducted on the time scales pertinent for stabilization mechanisms (i.e. decadal and longer). Second, there is a major constraint on the ^{15}N labeling technique: the large stock of N in soil dilutes the ^{15}N signal and requires very high initial ^{15}N enrichment to obtain significant information from the ^{15}N signal that remains after several years.

One decade ago we performed a ^{15}N-labeled litter experiment designed to provide a strong ^{15}N signal to a forest ecosystem, allowing us to study it over decades. Highly ^{15}N-labelled beech litter (2.2 atom % excess) was deposited in a young beech stand at Ebrach (Germany) in February 1996. Nine 15-year-old trees with similar height and diameter were selected. A circular plot (1 m^2) was isolated from the surrounding trees by a solid plastic barrier forced deeply into the soil, then 250 g of labeled litter were applied and fixed on the forest floor by a net (mesh 2 cm). Annual litterfall was collected from each tree, labeled litter, organic and mineral soil was collected. Repartition of the litter ^{15}N in the mineral N, microbial N and among the particle size fractions was regularly determined.

Uptake of litter-released ^{15}N by the trees increased continuously from 1996 to 2001 and then decreased until 2008. The ^{15}N enrichment of mineral N ($NO_3^- + NH_4^-$) was slightly higher than that of the leaves, but followed the trend observed for leaf ^{15}N. In 1999, 2004 and 2007, the recovery of the applied ^{15}N in the forest floor, mineral soil and the tree was 90.6%, 82.3% and 80.1% respectively. The vertical distribution of litter ^{15}N in the soil profile showed an accumulation of ^{15}N in the upper 2.5 cm (35%), about 28% of litter-released ^{15}N was incorporated into the above (15.7%) and below ground (3.8%) tree biomass and a total of 8.6% (33% incorporated ^{15}N) were lost as litter during the period 1996–2004.

Minerlization rate of litter-released ^{15}N was significantly higher in 1999 (0.2 µg ^{15}N kg^{-1} day^{-1}) than in 2004 (0.1 µg ^{15}N kg^{-1} day^{-1}). In 1999, mineralization of soil organic ^{15}N was much higher than mineralization of bulk soil organic N which indicates a preferential mineralization of N from fresh litter. Five years later, both bulk soil N mineralization rate and ^{15}N mineralization rate had converged to near identical values, indicating that the ^{15}N introduced with the added litter had become become less disposed to undergo mineralization.

From 1996 to 2007, the particle size distribution and the amount of particulate organic matter in each size class did not vary in the most enriched topsoil layer (0–2.5 cm depth). Within this time frame, the distribution of litter 15N among the particle size fractions approached the distribution of total N except in the smallest fraction (0–50 µm), which showed an enrichment in 15N. This means that N has moved into organo-mineral associations on a decadal time scale (within 8 and 12 years). This observation gives rise to the insight that organo-mineral associations may be more dynamic components of the soil system then previously thought.

Quantifying the peatland carbon budget – the CEH Carbon Catchments

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Whilst the perception that northern hemisphere peatlands act as a major sink for carbon is largely based on flux tower measurements, recent research has highlighted the importance of the aquatic carbon flux in peatland systems. Eddy covariance measurements show inter-annual variability in sink strength and data from Finland, Canada and the UK confirm the long-term drawdown of CO_2 from the atmosphere to the peatland surface. Peatlands, however, lose carbon continuously throughout the year via the aquatic pathway, the magnitude of carbon loss being strongly linked to peatland hydrology and the degree of "connectivity" between the peatland carbon pool and the drainage system. Clearly modifying hydrological connectivity and rainfall-runoff regime will have a significant impact on peatland carbon fluxes.

The Centre for Ecology and Hydrology (CEH) has recently developed a network of four peatland sites across the UK which aims to quantify the peatland carbon balance by measuring or estimating all the flux terms. The Carbon Catchments Initiative aims to combine measurements of the land-atmosphere carbon flux (using eddy covariance and chamber methods) to the downstream fluxes of POC, DOC, DIC and gaseous forms of carbon. The four peatland sites are at Forsinard (N Scotland), Auchencorth Moss (Central Scotland), Moor House (N England) and the Upper Conwy (N Wales).

The CEH Carbon Catchments also provide a framework or a "platform" for other related research now and in the future. For example, the site at Moor House is the focus of a collaborative study on the role of peatland "pipes" in the transport of various forms of carbon to the steam system. The site in the Upper Conwy is the headwater water region of a "catchment to coast" study of carbon and nutrient transport within in the River Conwy catchment. The Forsinard site (part of the Flows National Nature Research) aims to measure the impact of peatland management (drainage, drain blocking) on carbon fluxes.

One of the main aims of the CEH Carbon Catchments is to reduce uncertainty in the peatland carbon budget and to integrate and link flux terms, which in the past have been measured independently by atmospheric scientists and hydrochemists. Data is presented to show the significance of this linkage in terms of the overall peatland carbon budget.

Impact of small-scale changes in soil moisture on redox dynamics and trace gas emissions in mesocosms of alpine fen and northern bog peat

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We analyzed the effects of short term changes in soil moisture, as they occur during summer months, on the redox dynamics and trace gas emissions from peatland mesoscosms. Using peat from an ombrotrophic northern bog in Canada and a minerotrophic, alpine fen in the Rocky Mountains, we determined water contents using the FDR technique, analyzed pore water chemistry in the unsaturated and saturated zone, and quantified fluxes of CO_2 and CH_4 using the static chamber technique. In situ production and consumption of acetate, CO_2, CH_4 and terminal electron acceptors was quantified by mass balance. Concentrations and turnover of CO_2, CH_4 and electron acceptors were higher in the fen than in the bog peat, resulting in 4 times higher CO_2 and 10 times higher CH_4 emissions. Acetate partly accumulated to millimolar concentrations and fermentation processes were thus partly decoupled from terminal respiration. Diffferences in hydrologic properties of the peats had a strong impact on redox dynamics. Reducing conditions prevailed up to 5 cm above the water table in the fen peat whereas such conditions were limited to the saturated zone in the bog peat. Drought periods resulted in a much stronger response of water table position in the fen peat, but had less impact on redox processes. Methane was mostly produced near the water table in the fen peat (> 150 nmol $cm^{-3}d^{-1}$) and was fairly insensitive to drought in comparison to the bog peat. After irrigation, methanogenesis restarted in both peats without appreciable time-lag. Methane emission was reduced during water table fluctuations in the fen peat and too low to be analyzed in the bog peat. CO_2 production was dominated by the unsaturated zone that was enlarged due to water table fluctuations; but increased production rates did not result in altered fluxes. The results of the study suggest that short-term fluctuations in water table and soil moisture strongly alter redox process patterns, depending on hydrologic properties of the peat, but that trace gas fluxes are quite resilient in comparison.

Seasonal nutrient partitioning between microbes and plants in peat bogs

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Soil microbes play a key role in nutrient biogeochemistry, particularly in nutrient-poor ecosystems where they are supposed to have the biggest impact on ecosystem functioning and structure (Bardgett et al. 2005). Ombrotrophic peatlands are nutrient-poor ecosystems that can potentially be a good model for a better understanding of nutrient partitioning between microbes and plants. Here, we investigate the seasonal dynamic of microbial activity in four Swiss bogs along an altitudinal gradient from about 600 m up to 1900 m a.s.l. To this aim, peat microbial biomass carbon (C) and nitrogen (N), fluorescein diacetate activity (FDA), total dissolved nitrogen (TN) and organic carbon (DOC) in pore water as well as total exchangeable N in peat were periodically assessed from the snow melt until the beginning of autumn 2008.

We report a sharp decline of peat microbial biomass C early in the growing season with a concomitant release of N in pore water. Lower values of C/N quotient in microbial biomass were found at the beginning and at the end of the growing season. This trend of the microbial C/N quotient seems to indicate that microbes act as N sinks outside the plant growing season and as N sources during summer months (Hu et al. 2001). Along the study period, the amount of exchangeable N in peat was negatively correlated to vascular plant production so suggesting an effective competitive ability of vascular plants in absorbing N compared to microbes (Schimel & Bennet 2004). On the other hand, the positive relationship between vascular plant production and DOC concentration in pore-water seems to indicate a primary role of root exudates in affecting DOC concentrations (Fenner et al. 2007). The hydrolytic activity of FDA was uncorrelated to microbial biomass, but primarily related to the peat water content with a reduction of FDA activity when peat water content was higher than 95%. A sustained FDA activity along the study period highlights the important role of mineral stabilized enzymes for the mineralization of organic matter under suitable peat moisture conditions. Our preliminary data suggest the presence of important aboveground-belowground feedback mechanisms in terms of nutrient biogeochemistry. How these mechanisms act in front of a changing climate is a topic that deserves further research to predict the future of peat bogs.

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Relationships between vegetation and hydrochemistry in drained and restored mires in the Sumava National Park (Czech Republic)

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Large proportion of peatlands in the Sumava Mts. (Czech Republic) have been influenced by drainage in the past. In 1999, a *Programme of Peatland Restoration* started to be implemented in the area with the aim to restore disturbed hydrology and to stop mire degradation caused by drainage. Main restoration technique used was blocking of drainage ditches by set of board dams. In 2005, both drained and intact mires were selected in the area to study degradation changes induced by disturbed hydrology and to evaluate the success of restoration. Restoration of monitored sites was performed in summer and autumn 2008.

Five small catchments with different level of disturbance (control, drained and heavy drained) and including a large proportion of mires have been studied. The mire habitats under the program of monitoring are ombrotrophic peatbogs (*Leuco-Scheuchzerion palustris, Oxycocco-Ericion, Sphagnion medii*) and waterlogged spruce forests (*Mastigobryo-Piceetum*). Permanent plots (71) with associated water wells were established to characterise microtopographical, vegetation and drainage patterns of the different sites. Position of water table was measured by piezometers in plastic boreholes. Water samples from boreholes, ditches and streams were taken monthly for a detailed hydrochemical analysis, including content of main cations and anions (SO_4, NO_3, NH_4, PO_4, Ca, Mg, Al, Fe), pH, conductivity and DOC. Runoff from drained catchments as well as amount of precipitation were measured continualy. Vegetation was sampled in 1x1m permanent plots around each borehole. Percentage cover values for all vascular plants and bryophytes present on the permanent plots were estimated visually.

Three year of pre-restoration monitoring shows that water table was maintained in a lower position than a natural system and exhibited higher fluctuations in direct relation to the amount of precipitation received on drained sites. Water table was maintained in lower position especially on dryer dwarf shrub sites (somewhere with expanding trees) prevailing on drained bogs. During first post-restoration phase in the autumn 2008, water table in drained bog sites rised up to a position comparable with intact bogs and exhibited low fluctuation. The effect of restoration on position of water table was still less marked or none in spruce forest sites.

Conductivity of groundwater had higher values in general on drained bogs. DOC was higher in groundwater of heavy drained sites and in ditches and much lower in runoff water from drained catchments. Concentrations of SO_4 and NH_4 were higher on drained bogs with the highest SO_4 values in runoff surface water from drained catchment. Concentration of SO_4 exhibited a decreasing trend in runoff surface water after restoration. Al concentrations had higher values in groundwater of drained mires with highest concentrations in groundwater and ditches of drained waterlogged spruce forest.

Changes in abiotic environment of drained mires are well mirrored by their vegetation. Degradation changes include considerable recession of hollow vegetation (all. *Leuco-Scheuchzerion palustris*) and *Trichophorum caespitosum* lawns. Drainage also caused expansion of moss and lichen species adapted to lower water table (e.g. *Pleurosium schreberi, Dicranum scoparium, Polytrichum strictum, Cladonia rangiferina*) and expansion of well competitive graminoids (mostly *Molinia caerulea*). In drained sites, expansion of dwarf shrubs with high proportion of *Vaccinium myrtillus* at the expense of *Vaccinium uliginosum* was recorded. Intensively drained bogs are characterised by expansion of trees (*Picea abies, Betula pubescens*) into the bog expanse.

Mapping peat vulnerability to climate change to inform policy in the UK

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Observed changes in UK soil carbon stocks (Bellamy et al., 2005) and dissolved organic carbon in freshwater (Evans et al., 2005) have stimulated policy interest in conserving and restoring soil carbon reserves. Particular attention has been given to peat soils, which contain around 50% of the UK terrestrial carbon store, as most have been degraded to some degree by a long history of agricultural use, forestry and acid deposition. However, restoration is time consuming and costly. Attempts to restore degraded peat back to active peat accumulation may be in vain if future climate change makes peat formation at certain sites unviable. Current climate scenarios for the UK suggest an increase in temperatures and change in the pattern of rainfall, which could shift the net water balance at some sites from positive to negative (i.e. precipitation/in flow becoming less than evapotranspiration). This in turn could stimulate increased decomposition leading to peat loss rather than accumulation (Freeman et al., 2001).

Policy makers and land managers have an immediate need to know if climate change poses a risk to peat formation in the UK, and where that risk is greatest. To help inform decisions making, we produced maps of peat vulnerability to climate change across the UK. Our approach was to develop a bioclimatic envelope model for current peat distribution based on global data (‘top down approach’) (Gallego-Sala et al., 2008) and national scale data (‘bottom-up approach’). We then future climate scenarios for the UK to these models to estimate future vulnerability. Output from these empirical spatial models was then compared to output form available dynamic peat accumulation models run for specific sites where long-term data were also available. The resulting maps represent our current ‘best estimate’ of peat vulnerability to climate change. The maps are part of wider assessment of how other pressures, such as atmospheric pollution, will impact on vital ecosystem services such as the provision of good water quality in the future.

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Long-term trends in absorbance-dissolved organic carbon relationships from 2 moorland streams

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In surface waters, dissolved organic carbon (DOC) occurs in many forms from simple hydrophilic molecules to larger hydrophobic (aromatic, more recalcitrant) structures such as humic and fulvic acids. The relationship between UV absorbance and DOC concentration is a useful tool for assessing hydrophobic properties and hence biodegradability of DOC (Marschner & Kalbitz, 2003; Weisharr et al., 2003). Long-term changes in this relationship may indicate fundamental changes in decomposition processes occurring within the terrestrial environment and/or exported organic carbon.

This study shows that a significant change in the relationship between absorbance and DOC has occurred across a period of 21 years at 2 moorland catchments in Scotland, UK. Previous studies have shown that similar absorbance-DOC relationships (expressed as Specific Ultra Violet Absorbance - SUVA, the UV absorbance per mass of carbon) can result from a range of DOC compounds when taken from different aquatic environments. However, comparisons of UV absorbance within the same watershed over time, will be intrinsically related to DOC composition (compounds contributing to aromaticity) and reactivity, provided no major land-use changes have occurred (Watts et al., 2001; Weisharr et al., 2003)).

A statistical mixed-modeling approach indicated that the UV absorbance-DOC relationship had changed significantly over time. For a given DOC concentration, absorbance (at 250 nm) measurements (and consequently SUVA) had decreased. Of the potentially mechanistic variables that were tested, only annual non-marine sulphate loads were significant in explaining this long-term change. No other climate or surface water chemistry parameters that were included in the analysis were significant in explaining observed trends. Notable short-term perturbations in overall patterns of change were observed following major drought years. Although not significant within the current analysis, it appears that hydrological dynamics may explain additional variability in the UV absorbance-DOC relationship and hence DOC composition.

Ultimately, this study suggests that although DOC concentrations may be increasing in these upland streams (Dawson et al., 2008) the proportion that is hydrophobic has been decreasing over the past 2 decades. Moreover, this is the first dataset that provides a possible mechanistic explanation (decreasing sulphate-driven acid load) controlling solubilisation of organic matter and increasing DOC concentrations with changes in DOC composition in upland streams. These trends will have impacts on both freshwater biota as well as the biodegradability of less recalcitrant material in terms of carbon cycling.

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Carbon and GHG budgets of an ombrotrophic peatland – importance of surface drainage water as a flux pathway

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Peatlands represent a major store of soil carbon and as such play an important role in global atmospheric CO_2 and CH_4 cycling. Much previous peatland research has focussed primarily on land-atmosphere fluxes. Where aquatic fluxes have been considered, they are often in isolation from the rest of the catchment and usually focus on downstream losses, ignoring evasion (degassing) from the water surface. However, as peatland streams have been repeatedly shown to be highly supersaturated in both CO_2 and CH_4 with respect to the atmosphere, they potentially represent an important pathway for catchment greenhouse gas (GHG) losses. The primary aims of this study were: a) to create a complete GHG (CO_2, CH_4, N_2O) and carbon budget for Auchencorth Moss, an ombrotrophic peatland in south east Scotland, and in doing so identify the relative importance of aquatic fluxes and b) to understand what controls aquatic fluxes in order to predict how they will respond to changes in both land management practices and future climate scenarios.

Using both empirical modelling and the examination of streamwater CO_2 concentration-discharge hysteresis loops, a number of distinct CO_2 sources were identified within the catchment. These included the input of deep peat/ground water containing high concentrations of dissolved CO_2, through-flow from the shallow peat, and water originating from an area of deep peat/peat extraction upstream of the study site. Temporal variability in both CO_2 and CH_4 could be well modelled using discharge and temperature data alongside the inclusion of an antecedent rainfall variable, indicating the importance of flow path in controlling the source of catchment derived gaseous carbon.

The catchment functioned as a net sink for GHGs (212 g CO_2-eq m^{-2} yr^{-1}) and carbon (30.7 g C m^{-2} yr^{-1}) (Fig. 1) . The greatest flux in both the GHG and C budget was net ecosystem exchange (NEE). Terrestrial emissions of CH_4 and N_2O combined returned only 1.6% of CO_2-equivalents captured by NEE to the atmosphere, whereas evasion of GHGs from the stream surface returned 13%. DOC represented a loss of 38% of NEE carbon uptake, which if processed and evaded downstream, outside of the catchment, may lead to a significant underestimation of the actual catchment derived GHG losses. The budgets clearly show the importance of aquatic fluxes at Auchencorth Moss and highlight a significant "disconnect" in the interpretation of GHG and C budgets

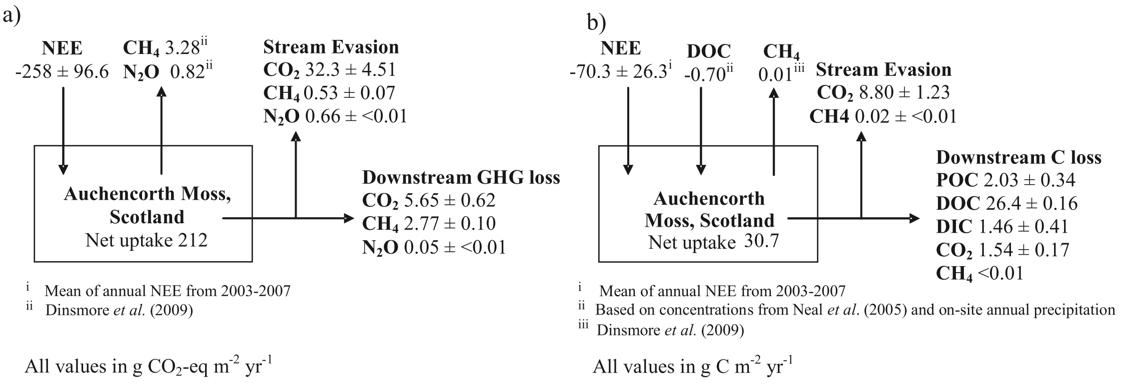

Fig. 1. a) GHG and b) C budget for Auchencorth Moss

PEATBOG: Pollution, Precipitation and Temperature Impacts on Peatland Biodiversity and Biogeochemistry

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PEATBOG is a new research consortium within the European Research Association BiodivERsA programme, funded under the European Union 6th Framework.

The aims of PEATBOG are to understand how the biodiversity and ecosystem functioning of peatlands across Europe are impacted by nitrogen pollution and climate change, and to develop meaningful indicators of risk to these impacts. On a national and European scale, we intend to identify the peatlands that are most vulnerable to combined deposition and climate stressors, and critically evaluate current conservation and air pollution control policies from this perspective.

The project will integrate regional surveys, field manipulation, biogeochemical/microbial investigations, and model development under five objectives:

1. Through surveys across northern Europe, determine the relationships between peatland vegetation diversity and the deposition of reactive nitrogen, considering all other major drivers on biodiversity.
2. Conduct field manipulation experiments to quantify the nature of interactions between nitrogen pollution, soil hydrology and temperature on peatland biodiversity and biogeochemistry.
3. Using isotopic tracer techniques and controlled mesocosm experiments, investigate the mechanisms that link peatland biodiversity to nitrogen cycling, carbon sequestration, and C and N exchange with the atmosphere, and how these are impacted by chronic N deposition.
4. Determine how the composition and function of the microbial community reacts to enhanced atmospheric nitrogen deposition, warming and drought, and relate these responses to above-ground vegetation diversity.
5. Develop meaningful indicators, at scales appropriate to the user, of the risk to peatland ecological and functional integrity of elevated nitrogen deposition and climate change.

By investigating at a range of scales from regional gradient studies to detailed mesocosm experiments, and by integrating this knowledge into both process-based models and simple transfer functions, PEATBOG directly links a co-ordinated research programme with the practical needs of resource managers and policymakers. To this end, the project has a Core Advisory Group encompassing the relevant European policy and conservation arenas, and a wider Stakeholder / Scientists Group with representatives from science, policy, management and the public. The three-year project began in Spring 2009.

Release of carbon and GHGs from peatland catchments in Eastern Finland during the spring snowmelt event

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One of the most important controls on carbon and greenhouse gas (GHG) release from streams and lakes associated with northern peatlands is the frequency of extreme hydrological events. In temperate and boreal peatlands associated with an extensive period of snow cover, the spring snowmelt period may lead to 30–50% of the annual runoff occurring within a 2–4 week period. Quantifying the concentrations, fluxes and forms of C released at this time of year is not only important in terms of annual fluxes, but also for understanding the processes that control C and GHG release from peatlands. Longer term changes to the extent, timing and intensity of the spring snowmelt event may have a significant impact on annual fluxes.

The aim of this study was to investigate the temporal changes in hydrochemistry of two streams draining small (86 and 113 ha) forested peatland catchments in the North Karelia Region of Eastern Finland during the 2008 spring snowmelt event, and to quantify the fluxes of various forms of carbon released. In addition to dissolved concentrations of the greenhouse gases CO_2 and CH_4, we also measured N_2O. Carbon fluxes during this 2 month period were then compared to the long-term (1979–2008) flux of TOC from both catchments, one of which is undrained (the control) the other partially drained. The study is based both on a routine 2 month spot sampling programme and the deployment of continuous sensors. In particular, the study used both in-stream and in-soil CO_2 sensors to collect high resolution data on small-scale temporal events. Our data therefore shows how the biogeochemistry of the two streams changes during the transition from a largely frozen winter peatland to a more biological active system.

Both the pristine (Välipuro) and drained (Suopuro) catchments showed a significant decrease in DOC and CO_2 concentrations during the flood event which lasted for ~10 days. Evasion of CO_2 from the streamwater to the atmosphere peaked before peak discharge, on the rising limb of the flood event. Both POC and DIC concentrations were unaffected by the snowmelt event. Methane concentrations peaked in the drained catchment at the time of highest flow, but no comparable effect was observed in the pristine catchment. N_2O concentrations were low throughout the 2 month sampling period, with no significant change during the snowmelt period.

Fluxes are presented for the various streamwater C components during the spring 2008 snowmelt event and these are compared to the annual long term TOC fluxes in the two catchments. In addition, our data are used to compare fluxes from the pristine and the drained catchments, and the results discussed in terms of the impact of drainage on peatland C fluxes during the spring snowmelt event.

Impact of drying and rewetting on carbon cycling in a northern fen

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Peatlands are quantitatively important carbon-storing terrestrial ecosystems (Gorham 1991) where peat develops due to the rate of C input (organic matter as litter) surpassing that of C output (gas efflux and leaching) during biomass decomposition. High water contents are an important factor controlling such equilibrium in these soils since water does not become limiting for plant growth while keeping peat in a highly reduced state and thus lowering peat degradation rate. A predicted effect of current climate change is the potential alteration in the hydrological regime due to extreme rain events and extended dry periods. Thus, greater fluctuations in the water table levels may be expected to influence redox processes and carbon cycling in peatlands.

We investigated respiration and transport processes in peat during manipulation of water table level at ecosystem scale in a small iron-rich fen located in a forested area of North Bavaria (Germany). The experimental design consists of three treatment (dry-rewetting) and three control plots where spatially high resolved peat profiles (2.5, 5, 7.5, 10, 12.5, 15, 17.5, 20, 25, 30, 45 and 55 cm depth) were weekly followed up during 6-7 months. An approach combining gas (for CO_2, CH_4 and O_2 analysis) and pore-water sampling allowed gaining insight into spatio-temporal gradients and linking those to water table fluctuations. Soil moisture, temperature and CO_2 concentrations were also investigated at discrete time resolution by installing sensors in the upper peat layer (Δ=5 cm up to 20 cm) to obtain data series during the investigated period.

A seasonal drying event naturally occurred in the control plots during summer. The drying effect was thus reinforced (greater intensity and duration) in the treatment plots. The main terminal electron accepting process was Fe(III)-reduction as suggested by high reduced iron and nearly undetected hydrogen sulphide concentrations. Water table manipulation affected redox processes in the peat with progressive suppression of Fe(III)-reduction during the drying period and recover of reduced iron concentrations following the rewetting event. Spatial gradients were observed in terms of dissolved gas concentrations along the whole experimental period; oxygen concentration decreased, methane concentration increased and carbon dioxide concentration increased with depth. Drying period effects included cessation of methane production in the whole investigated profile and decrease of carbon dioxide concentration. Water table level rapidly rose during the artificial rewetting event from -80 cm to about -15 cm (data from only one plot). Concomitant response of dissolved gases concentrations occurred with a sudden drop of oxygen in upper peat layers and a steep increase of carbon dioxide in the middle layers. Methane concentrations only recovered in the deepest peat layer showing a lag after the rewetting as elsewhere reported (Hughes, Dowrick et al. 1999). Although the water table level dropped to -80 cm, anoxic conditions were kept in peat at -50 cm suggesting that the water content was high enough to reduce permeability for oxygen which likely was rapidly consumed. Such a difference becomes relevant when considering carbon fluxes as air filled porosity physically controls gas transport across peat profile.

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DOC from source to sea: where does it come from, and where does it go?

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Increasing concentrations of DOC have been documented in surface waters in large areas of Northern Europe and Northeast North America (Monteith et al., 2007). Although often associated with peatlands, these increases have also been observed in catchments draining organo-mineral and mineral soils. DOC export represents a significant terrestrial C loss pathway, but in greenhouse gas (GHG) terms its importance ultimately depends on whether it is mineralised to CO_2, or transferred to long-term storage in freshwater or marine sediments. Based on an integrated, intensive and extensive monitoring programme, we attempt to identify key sources and potential loss pathways for DOM within the 250 km^2 Conwy catchment, North Wales, a typical UK mixed upland area of blanket bog, mountain grassland, conifer plantation and improved pasture. Samples from representative headwaters indicate that DOC concentrations are greatest in streams draining peat catchments, but that concentrations are also high in streams draining farmland. Large qualitative differences are observed, however, with farmland-derived DOM characterised by much lower DOC/DON and absorbance/DOC ratios. These observations suggest that peat-derived DOM is likely to be more susceptible to photodegradation, and farmland-derived DOM to biodegradation. We identify three potential hotspots for DOM processing within the catchment: 1) long residence time lakes, which intercept approximately 10% of drainage in the catchment, mainly in upland areas; 2) headwater streams, which comprise a large part of the overall channel length and stable surface area (Battin et al., 2008); and 3) the estuary, in which freshwater/saltwater mixing may enhance physical and/or biological DOM removal. An initial assessment indicates that headwater lakes are locally important as DOM sinks but (because of their limited overall extent) can account for only a small fraction of the total DOC budget. The role of headwater streams is difficult to quantify based on monitoring alone, but high-frequency DOC and fluorescence measurements in peat streams show clear diurnal cycles, suggesting that at least a proportion of peat-derived DOM may be actively processesed within the stream channel. This appears to occur under both baseflow and high flow conditions (Austnes et al., submitted). In the estuary, we do not find clear evidence of DOM removal through the freshwater/saltwater interface, with DOC concentrations exhibiting conservative mixing relative to salinity, and terrestrially-derived DOM observed at the mouth of the estuary. A spatial DOM model has been developed, which will be applied for several large (60 site) snapshot surveys, and used to test alternative assumptions regarding in-stream and in-lake processing. A first catchment-scale budget of DOC sources and sinks will be derived, and the implications of rising DOC inputs to fluvial networks considered in terms of aquatic ecological impacts and terrestrial GHG balances.

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Diurnal temperature effects on the production of trace gases in peatland soil

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Peatland soils are important reservoirs in the global carbon cycle and there is much interest in characterising the response of their carbon stores to temperature perturbations. Peatlands are notable also because of their dual function as carbon capacitors and amplifiers in the Earth System, sequestering CO_2 into soil organic matter, but also producing CH_4, a greenhouse gas more potent than CO_2. Cycling of H_2 in both aerobic and anaerobic soils is poorly characterised despite accounting for ~80% of the annual atmospheric H_2 sink (Rahn *et al.*, 2003). Our study adapted a novel heating and cooling instrument, the Metz Syn^{10}, typically used for process chemistry, as a new form of soil incubator. The instrument is capable of generating cyclical and ramped temperature regimes and this feature was exploited to simulate real-time diurnal soil temperature variations while measuring concentrations of CH_4, CO_2 and H_2 at a temporal resolution of every six minutes. The incubated samples were obtained from the acrotelm and catotelm of a raised bog (Cors Caron) and a transition fen (Crymlyn Bog) both located in Wales, UK. The peat samples were subjected to three different temperature regimes: constant stepped, cyclical and ramped. The concentration data collected were used to calculate production rates, F-ratios (ratio of CH_4 production to $CH_4 + CO_2$ production), Q_{10} factors, activation energy and Gibbs free energy values for specific microbial and enzymatic processes, namely hydrogenotrophic methanogenesis and CO_2 and H_2 production. Determinations of these parameters from the cyclic temperature regimes were compared to values from conventional stepped temperature incubations which are presently used in most models of anaerobic carbon mineralization in peatland soils. Lower rates of methanogenesis occurred in cyclical versus constant temperature incubations; however, the effect existed only in acrotelm peat from the fen. Temperature sensitivity of anaerobic CO_2 production in peat soils also was linked positively to nutrient status. Rates of H_2 production were similar for all temperature regimes and responded rapidly to variations in temperature, driving similar but delayed changes in rates of methanogenesis. Ramped temperature incubations allowed for the determination of optimal temperature of the methanogenic communities present in each sample. Gradual and continuous ramping of temperature (0.6°C h^{-1}) in the incubations enabled the determination of the optimal temperature for methanogenesis in peat from the acrotelm and catotelm of the ombrotrophic and minerotrophic peatlands as well as the impact of cessation of terminal anaerobic carbon mineralization at higher temperatures on the cycling of CO_2 and H_2. Nutrient status of a peatland appears to influence the ability of microbial communities responsible for carbon turnover to respond to changes in temperature. Q_{10} values for fens determined from conventional temperature-stepped incubations may overestimate the response of methanogenesis to variations in temperature. Methane production in peat from ombrotrophic peatlands responds similarly to both stepped and cyclical temperature regimes.

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Bioclimatic envelope modelling of the present global distribution of boreal peatlands

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Natural wetlands cover ~8-10 million km^2 of the earth's surface (Lehner and Doll 2004) and approximately 20% of the world's soil carbon is stored in boreal and subarctic peatlands where it has been accumulating gradually under wet and cool climatic conditions since the end of the last ice age . It has been suggested that global warming will increase the extent of northern peatlands (Shindell et al. 2004). The large area of peatlands currently under permafrost is particularly susceptible to climate change since warming has been predicted to be most pronounced at high latitudes. Thawing of the permafrost in arctic and boreal peatlands favours carbon accumulation due to an increase of net ecosystem production (Turetsky et al. 2007). However, peatland ecosystems at lower latitudes may not be well adapted to survive the more frequent extreme heat waves predicted as part of global warming (Bragazza 2008) and low boreal peatlands may migrate northwards as a result of elevated temperatures and drought (Gignac et al. 1998). Bioclimatic envelope modelling is an appropriate technique to study the current distribution of peatlands and to project the potential changes under future climate scenarios. Regional distribution of peatlands have successfully been mapped in Canada (Gignac et al. 2000) and Fennoscandia (Parviainen and Luoto 2007) using various bioclimatic models. We plan to study the zonation of peatlands at a global scale using STASH, a model that attempts to find the most meaningful bioclimatic variables that characterize the physiological limits of a given ecosystem or species (Sykes et al. 1996). The predictor bioclimatic variables will be specifically chosen to best differentiate between each observed mire complex type so that changes in peatland zonation under future climates can be predicted.

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Does invasion of a *Sphagnum*-peatland by *Betula sp* and *Molinia caerulea* impact carbon dynamics?

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Peatlands are important CO_2 sink and CH_4 source at the same time. As such they play a major role in the regulation of the global carbon cycle and the climate of the earth. However, under the global changes produced by human activities, their functioning may switch from sink to source of carbon. Invasion of peatlands by trees and grasses is a natural process that may be accelerated by global and/or local changes (i.e. drainage, nutrient input). The new species through their root system and their litter input may affect the accumulated organic matter (OM) composition as well as the soil conditions and thus, may reduce the capacity of the peatland to store carbon. The aim of the study is to assess the effect of a recent (for 30 years with an acceleration in the last decade) invasion of a French peatland by *Betula verrucosa*, *Betula pubescens* and *Molinia caerulea* on the soil organic matter dynamics. This site has been selected to be part of a program which aimed to monitor CH_4 and N_2O emissions in anthropogenic and natural ecosystems. The results presented here concern the bulk biogeochemical characteristics of peat from different area of the peatland (treed and treeless areas).

Depending on water table level, 2 areas within the peatland were being considered: a southern part of the peatland as a wet area and a northern part as a dry area. Within each of these areas, 2 plots of $4m^2$ surface were chosen depending on vegetation: 2 open plots (treeless) and 2 close plots (with trees and Molinia). In June 2008, 4 cores (50 cm) were collected in the 4 plots. Each 5 cm, bulk density, OM content, pyrophosphate index (PPI), CNS content and Rock Eval pyrolysis parameters were measured. At each depth, a MANOVA was conducted to assess how different were each area in terms of bulk biochemical composition.

Along the peat profiles, MANOVAs showed a high variability between plots at the deepest depths (from 47.5 to 27.5cm). From 27.5cm to 7.5cm, the variability of peat chemical composition decreased steadily. At 7.5 cm depth, no significant differences between plots ($P>0.05$) were observed. At the surface (2.5 cm), bulk chemical composition was different between plots ($P<0.05$). Although no dating had been carried out yet on the peat profiles, the results could be interpreted in terms of variability of plant sources and ecosystem processes: the homogenisation of peat chemical composition observed from 27.5cm to 7.5cm may be due to a homogenisation of source materials, i.e. vegetation tending to be similar between plots with time, and/or to soil conditions, i.e. decomposition tending to become similar everywhere in the peatland. However, at the surface, this way to homogeneity was broken. PPI and OM content results showed that the peat in invaded plots was more decomposed and OM content was less than in the peat from treeless zones (Fig 1). The results suggested that invasion of the peatland by *Betula sp* and *Molinia caerulea* has already affected the accumulated peat chemistry and that was probably accompanied by an increased level of OM decay. Experiments based on mixed litter bags are being conducted on invasive *vs* autochthonous plant species from the peatland. This will allow us to assess decomposition kinetics of the plants and the effect of their mixing litters, and thus to better understand the carbon cycle of peatlands invaded by trees and grass.

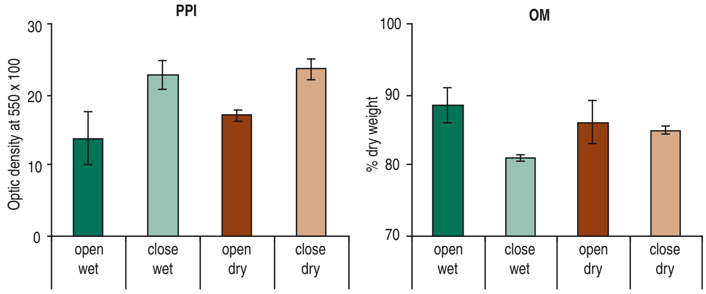

Figure 1. Pyrophosphate index (PPI, optic density at 550 x 100) and organic matter (OM, % of dry weight) content of peat from open and close vegetation plots *vs* wet and dry situation in La Guette peatland.

The function of ombrotrophic bogs as active carbon sequesters under different environmental conditions

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In recent years it has been questioned if ombrotrophic bogs presently works as active carbon sequesters (Malmer & Wallén 1999, Franzén 2006, Gunnarsson et al. 2008). High levels of nitrogen deposition and changed climatic conditions are thought to be the main ecological drivers of the change in ecosystem function resulting in reduced carbon sequestering rates. However, studies of carbon flow with eddy covariance towers show that bogs are still working as carbon sequesters (i.e. Lund et al. 2008). Can a spatial differentiation in carbon sequestration explain the contrasting views on the function of bogs as active carbon sinks? In order to answer this question we sampled peat cores from several bogs in southern Sweden and dated them with the pine method (Ohlson & Økland 1998) to estimate the recent carbon sequestration rates (i.e. the last 40 years). We modelled the carbon input rates (annual primary biomass productivity and decomposition rates) for the different sites and related it to climatic parameters as average temperatures and precipitation and the nitrogen decomposition rates.

Preliminary data analysis shows a strong correlation between carbon input rates and the amount of precipitation for the studied sites. Sites with the largest amount of precipitation had the largest input rates. It is the decomposition rates rather than the annual biomass production that has the strongest influence on the carbon input. The amount of nitrogen deposition is, however, strongly correlated with the precipitation in the region and is therefore also highest (about 12 kg ha^{-1} yr^{-1}) in the sites with the highest precipitation. From this result we can conclude that nitrogen *per se* is not the most important factor regulating carbon uptake from ombrotrophic temperate peatlands as long as the climatic conditions are strongly humid. To have high carbon sequestration rates it seems to be important to have a high ground water table, which makes the produced peat quickly inundated in the catotelm, where the decomposition rates will be much slower.

This study show that the spatial variation of the carbon sequestration rates in ombrotrophic bogs in south-western Sweden is important. The climatic impact of especially the precipitation is a main driver for the bogs function as carbon sequesters.

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Dissolved organic carbon and nitrogen in peat with different N levels during four temperature sum treatments

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Soil organic matter and its quality are key factors influencing microbial population and the release of nutrients. In peat, which consists almost entirely of plant residues in different stages of decomposition, the transformation of organic to inorganic compounds is important for ground vegetation and tree stand growth.

Nitrogen (N) is critical for tree growth on drained peatland forests. Almost all of the peat N is in insoluble organic forms, which cannot be utilized by trees and ground vegetation. In peat with low pH, the major forms of N are ammonium, NH_4^+ and dissolved organic nitrogen (DON). In this paper we show how soil temperature and the total N content of peat affects the microbial activity and subsequent changes in DOC and DON organic compounds. The experiment was made in controlled laboratory conditions. The initial amounts of N in the peat samples (0-10 cm) are denoted as $Peat_1$ (mean peat N amount 35 g m^{-2}, SD ± 8.9), $Peat_2$ (139 g m^{-2}, SD ± 31.2) and $Peat_3$ (147 g m^{-2}, SD ± 30.1). The experiment had a split-plot design with four replicates for each N level and temperature sum (3 N levels x 4 temperature sums x 4 replicates).

The peat samples were placed in growth chambers that were programmed to run different temperature sums in peat (749d.d., 924d.d., 1085d.d. and 1309d.d. at the end of the experiment, the threshold value was 0 °C) for a period of 17 weeks. Unlike other studied components (CO_2, NH_4, microbial C and N) there was only a weak response to the temperature treatments of the DOC ($p = 0.029$, $F = 3.1$, $n= 192$) and none of the DON ($p = 0.347$, $F = 1.1$) concentrations. However, the initial peat total N had a significant effect on both the DOC ($p = 0.000$, $F = 60.5$) and DON ($p = 0.000$, $F = 121.9$). In the $Peat_1$ samples with the lowest peat N the DOC and DON concentrations were smaller than the corresponding concentrations in $Peat_2$ and $Peat_3$ that had about the same DOC and DON levels throughout the experiment. When comparing all the samples the DOC and DON concentrations correlated well ($r = 0.74$, $n = 192$), but when broken down into the different treatments there occurred some differences in the peat N and temperature treatments (see Fig. 1)

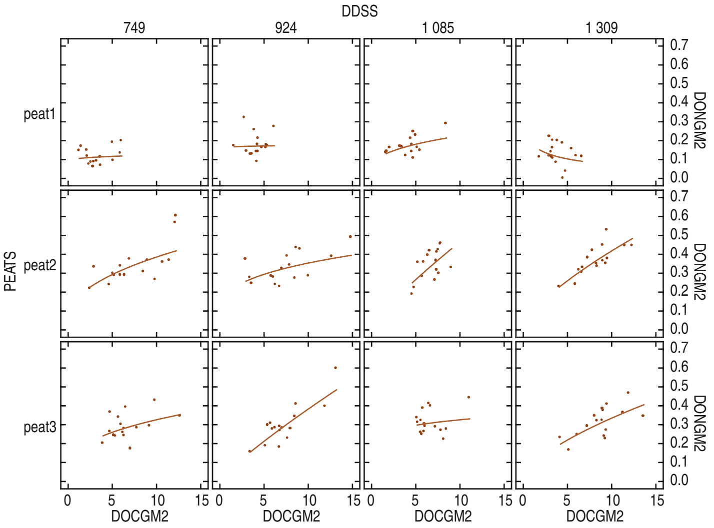

Fig. 1. Relationships between DOC and DON concentrations for the different temperature sum treatments at the three peat total N levels.

Spatial variation of water and peat chemistry in relation to water level and vegetation gradient in a calcareous fen (North Estonia)

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Calcareous species-rich fens are one of the most endangered wetland types in the world. Estonian fens have been drained and turned into pastures, hayfields and cropfields since the middle of the 19th century. The area of calcareous rich fens has decreased from about 80 500 ha in the 1950s to some 5000–8000 ha at the present time. We studied the plant cover and environmental conditions of a calcareous fen, which is the habitat for 13 rare and protected vascular and moss plant species. The main aim of the study was to relate the calcareous fen vegetation to microtopography and content of selected chemical elements in mire water and peat soil.

The composition of vascular (70 species) and moss (44 species) plant species, depth to water level (DWL), microtopography (proportion and mean height of tussocks), chemical composition (Ca, Mg, Fe, Na, K, S, total N, total P), bulk density and ash content of the topmost peat layer (0–10 and 10–20 cm), also chemical composition (Ca, Mg, Fe, Na, K), pH and electric conductivity of mire water were analysed in 23 plots on the open part (ca 40 ha) of the Parapõllu calcareous fen (230 ha) in North Estonia. The site can be divided into recharge and discharge (because of moderate drainage) parts with Carex panicea–C. davalliana–Schoenus ferrugineus and Molinia caerulea communities, respectively.

The Mantel test confirms no significant relationship between field and surface layers. Microtopography is strongly related to DWL and the amplitude of its seasonal fluctuation (standardized Mantel statistic r=0.41, t= 3.7, p=0.0002). Ordination by Nonmetric Multidimensional Scaling demonstrates that variations in the species composition of the field layer mainly correlate with DWL and the contents of Ca, Mg, Na, Fe in water and the N content in the topmost peat layer. The moss species distribution is well related to Ca and Mg in water, and N, S, K, Na and Mg contents in peat. Depth to water level and its seasonal amplitude are in significant negative correlation with peat ash and Ca but positively related to the N content of peat. The total phosphorus content of peat is very low. The coverage of Molinia caerulea, which rapidly responds to increased N availability under limited P conditions (Tomassen et al. 2003), rises with increasing DWL. In N-enriched and deep summer water level conditions M. caerulea outcompetes Schoenus ferrugineus. As the proportion of Molinia tussocks exceeds the 30% level, many calcareous fen specialist species dissappear. The tussock-rich environment favours the spreading of Sphagnum, other moss and dwarf-shrub species common to poor fens and bogs and also contributes to the afforestation of the site with Betula pubescens, Picea abies and Pinus sylvestris.

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Emissions of nitrous oxide from a natural wetland ecosystem coupled to seasonal variations in subsurface oxygen availability, soil moisture and groundwater level

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Nitrous oxide (N_2O) is recognized as one of the more important trace gases contributing to the greenhouse effect. Microbial transformations of inorganic nitrogen compounds by nitrification and denitrification processes are the main sources of nitrous oxide from soils. Recent research has been directed towards a better understanding of the relative contributions of two processes indicating that both production and consumption of N_2O in soils as well as net emissions of N_2O from soils to a large degree are controlled by subsurface soil water content and below ground oxygen availability. Movement of N_2O in subsoil takes place primarily through diffusion. The effective diffusivity of the soil is strongly influenced by the soil water content where high soil water contents may lead to entrapment of N_2O which may be released to the atmosphere by ebullition. The diffusion of N_2O in subsoil may also be influenced by various biogeochemical processes as well as the anaerobicity of the soil and soil air which may influence the potential for further reduction of N_2O to N_2. Emissions of N_2O from soil have traditionally been measured by manual static non-flow through non-steady state closed chamber methods over relatively limited time where gas samples have been drawn at a predefined time intervals for later laboratory analysis and flux calculations. The methodology has proven to be reliable and cost effective but has the inherent drawback of low temporal resolution that manual measurements on a non-continuous basis entails.

The current study investigates the potential of achieving an improved insight into more high temporal resolution dynamics of N_2O effluxes coupled to soil water content, groundwater level and subsurface oxygen availability from a natural wetland ecosystem by measuring N_2O effluxes on a continuous basis using automated non-flow through non-steady state closed chambers with *in situ* measurements and real-time analyses of N_2O by an infrared field gas analyzer whereas subsurface concentrations of both gaseous and dissolved oxygen, soil water content and soil temperature are obtained by use of permanently installed thermistors, soil moisture sensors and oxygen optodes.

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Carbon balance of UK peatlands

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Peatlands represent the largest store of carbon in UK ecosystems, with Scottish peats alone holding an estimated 4523 Mt of carbon, which amounts to 46% of the total soil carbon in the UK (Milne & Brown 1997). UK peatlands have been subjected to a significant amount of disturbance during the previous century, including nitrogen deposition, land management practices such as afforestation, drainage, grazing and burning and more recently the effects of climate change. These peatlands have the potential to act as a major source or sink for carbon, but their current status is unknown as significantly less research has been conducted in the UK compared to other peatland areas such as Northern America and Europe.

This PhD studentship has been funded by the Centre of Ecology & Hydrology in order to improve the understanding of the status and key processes of UK peatlands. CEH has developed a network of peatland sites within the UK as part of the Carbon Catchments project, at which the land-atmosphere exchange will be measured using eddy covariance and flux chamber methods as well as carbon loss from the sites in surface water. These measurements will help determine the carbon balance of these peatlands.

In addition to quantifying the carbon balance the effect of some of the disturbances peatlands have experienced is being investigated. The four sites chosen to quantify the carbon balance are located across the length of the UK and will have been exposed to different levels of nitrogen deposition. In addition to this a long running nitrogen deposition manipulation experiment exists at Whim Moss, south of Edinburgh. This site is to be used to examine the effect of nitrogen deposition on the carbon fluxes there. The burning and drainage of peatlands has been commonplace in the UK for sport and agricultural reasons, but not much is known about the effect this has on the ability of the peat to store carbon. Most studies have focused on only one aspect of carbon exchange when examining the effect of these land management practices, whereas the effects of the management on all parts of the carbon exchange are to be examined by this project.

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Controls on long-term increases in TOC concentrations and fluxes in peatland catchments in northern Minnesota, USA

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Numerous recent studies have reported long-term increases of dissolved organic carbon (DOC) concentrations in streams and lakes of northeastern North America, the U.K., and northern Europe (e.g. Monteith et al. 2007). A number of mechanisms have been proposed that may explain increases in DOC concentrations. Changes in land use or forest cover as a result of harvesting or fire have been shown to influence DOC concentrations (France, 2000), although increases are also found where there have been no changes in cover. Higher temperatures resulting from climate change have been proposed as controls on DOC concentration trends (Freeman et al. 2001), however, this result is not consistent with other studies in which temperature alone cannot explain increased stream DOC concentrations (Worrall and Burt 2007). A CO_2 fertilization effect has also been proposed that could lead to elevated DOC in water because of higher overall aquatic or terrestrial productivity (Fenner et al. 2007). Others have speculated on hydroclimatic controls such as streamflow variability (Erlandsson et al. 2008) and severe drought (Clark et al. 2006) that may cause higher DOC concentrations in surface waters. Still others have shown that pH and DOC solubility increase in response to long-term recovery from acid anion deposition, largely due to sulfur emission controls (Monteith et al. 2007). At the Marcell Experimental Forest (MEF) in northern Minnesota we have measured long-term increases in unfiltered total organic carbon (TOC) concentrations from upland/peatland catchments. Since 1986, mean air temperature and stream pH has increased, sulfate in wet deposition has decreased and stream TOC concentrations have more than doubled at two catchments (Fig. 1). One catchment (S2) is a control watershed where no manipulations have occurred over the past 100 years. The second catchment (S6) has had two manipulations over the past 30 years. In the early 1980s the upland part of the S6 catchment was clearcut and converted from a deciduous to a conifer forest. Also, starting in 2002 and continuing through 2008, the ambient sulfate wet deposition has been increased by 4x across one half of the bog in the S6 catchment to mimic past deposition levels. Despite similar increases in TOC concentrations (Fig. 1), stream TOC export has increased at S2 and not at S6. The combination of treatments in the S6 watershed allows us to tease apart the reasons for these differences and sheds light on the importance of different hypothesized controls on stream TOC trends. In addition, we compare TOC trends to dissolved N and P trends to further explore responses of TOC to changes that affect forested ecosystems.

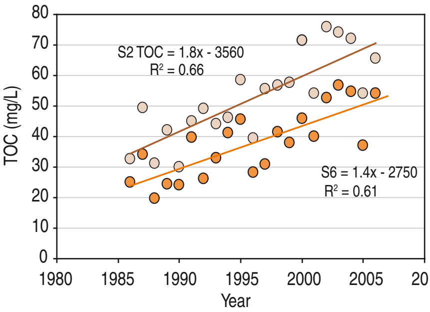

Fig. 1. Volume-weighted stream TOC concentrations from the S2 and S6 watersheds.

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Mire margin forest vegetation structure and diversity in Finland since1950s and the role in carbon cycling today

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Compared to the early 1950s in southern and central Finland only c.a. 20% of the area of forested mire margin sites have remained undrained (Eurola et al. 1991, Hökkä et al. 2002). In their undrained condition these forested mire margin habitats have retained a relatively natural stand structure and ground vegetation, although they have been often subjected to some degree of silvicultural management. Thus, on the community and species level, they are assumed to be important for local and regional biodiversity (Korpela 2004).

Most of the mire margin forests represent, even in 1950s, the intermediate (e.g.*Vaccinium myrtillus* -type spruce swamps) and lower nutrient level (paludified pine forests and spruce-pine mires) sites characterized with hummock dwarf shrub vegetation.

The changes in structure of understorey vegetation of mire margin forests in southern and central Finland was evaluated according to four Nation wide vegetation surveys from year 2006 as far as 1950s. Their role in carbon cycling today was evaluated according to a smaller set of forested mire margin sample plots gathered in 2006.

The common feature for all drained sites is the general decrease in the abundance of sedges and mire dwarf shrubs in the so-called last phase after drainage (after 15–50 years). Most drastic change take place in the ground layer: The decrease of *Sphagnum* species and their replacement by forest bryophyte species such as *Pleurozium schreberi* is clearly evident. These changes reflected the change towards mineral soil forest vegetation in the understorey vegetation (e.g. Korpela 2004, 2008).

The most striking feature in the 1980s and 1990s compared to the 1950s was, in addition to the small number of drained sample plots in 1950s, the large number of sample plots of the pristine, most nutrient- and herb-rich, (meso-eutrophic) sites (e.g. Korpela 2004). After comparison to the data of the survey of year 2006 the overall lower abundance of understorey vegetation, especially the cover of field layer species, and especially the lower cover of sedges also in undrained sites was obvious**.**

Distribution of the understorey vegetation biomass and carbon sequestration followed quite well the percentage cover estimations.

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Sphagnum growth processes and their interlinks

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Sphagnum mosses are widespread in both southern and especially in northern hemisphere; they are common in all areas where mires exists. While *Sphagnum* mosses cover almost 2% of earth's surface they potentially store more carbon than is captured in photosynthetic assimilation by all terrestrial vegetation in one year, and therefore constitute a major carbon sink (Clymo et al. 1982). However, different growth processes of *Sphagnum* mosses and how they relate are still poorly understood.

We measured growth in biomass and length, CO_2 assimilation and chlorophyll fluorescence from five different *Sphagnum* species typical of different mire habitats. The mires, from which the samples were collected, are located in Siikajoki, Finland (64°45´N, 24°42´), and form a successional gradient from a wet meadow through fens to a *S. fuscum* bog. Typical hollow, lawn and hummock species, common in these mires, were included in this study (namely *S. balticum, S. fimbriatum, S. fuscum, S. majus* and *S. papillosum*).

CO_2 assimilation (A) and chlorophyll fluorescence (quantum yield of PSII, Fv/Fm) measurements were conducted for several samples of each of the *Sphagnum* species. Measurements were made on the day of sampling using a portable gas exchange fluorescence system (GFS-3000, Walz, Germany). Measurements of A and quantum yield of PSII were made at eight different levels of photosynthetically active radiation (PAR) between 0 and 2000 µmol m^{-1} s^{-1}. Otherwise cuvette conditions were maintained at a constant level. Fv/Fm was measured from the same samples after 10 and 20 minute darkening of the sample.

We found significant between species differences in all measured variables. We measured the lowest growth in biomass and length from the bog species *S. fuscum* (Section Acutifolia) (Table 1). *S. fimbriatum*, a species from the same section, but from the opposite end of the successional gradient, had the highest biomass and length increase. In addition, it had the highest CO_2 assimilation and respiration rates (Table 1). On the other hand, this species had the lowest quantum yield of PSII and Fv/Fm. Quantum yield of PSII and Fv/Fm were highest in the hollow species *S. majus* (Table 1).

Table 1. Growth in biomass (g) and length (mm), CO_2 assimilation (A) (µmol g^{-1} (fresh weight) s^{-1}) at PAR 1000 and 0 µmol m^{-2} s^{-1}, quantum yield of PSII and Fv/Fm, for each *Sphagnum* species. Standard errors are included in brackets.

Species	Biomass	Length	A @ PAR 1000	A @ PAR 0	Quantum yield of PSII	Fv/Fm
S. balticum	1.9 (0.5)	28.2 (1.8)	9.6 (0.9)	-2.5 (0.3)	0.25 (0.02)	0.58 (0.2)
S. fimbriatum	2.8 (0.2)	51.2 (2.0)	13.3 (0.9)	-6.7 (0.2)	0.17 (0.01)	0.55 (0.1)
S. fuscum	1.0 (0.2)	8.1 (0.4)	12.5 (0.9)	-4.5 (0.3)	0.24 (0.02)	0.60 (0.1)
S. majus	1.5 (0.2)	28.2 (1.2)	11.4 (1.1)	-2.5 (0.3)	0.25 (0.04)	0.71 (0.2)
S. papillosum	1.1 (0.2)	18.3 (1.0)	10.5 (0.8)	-3.1 (0.2)	0.21 (0.02)	0.65 (0.1)

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The restoration of minerotrophic peatlands based on biogeochemical insights

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The restoration of wetlands has, at least for a long time, been based on a trial and error approach. By presenting research on the restoration of minerotrophic peatlands, we will show how vital biogeochemical knowledge at different spatial scales, from microbiology to landscape hydrology and biogeochemistry, is for optimal ecological management.

In combination with correlative field studies, experimental research (in the field and under more controlled conditions) is essential. This type of information provides insight into the actual causal relationships between environmental changes and ecosystem responses including those related to the coupling of C-, N-, S- and P-cycling, nutrient availability, and phytotoxicity. In addition, it indicates the target processes for wetland restoration, and thereby enables scientists, water managers and nature managers to choose between different measures and to predict restoration prospects for locations that differ with respect to their initial conditions.

The present paper reviews the major environmental problems in aquatic and semi-terrestrial fens related to biogeochemical issues: desiccation, eutrophication (including increased internal nutrient mobilization), acidification, and intoxication. It strongly focuses at the biogeochemical processes and factors responsible for the deterioration of minerotrophic peatlands, and for ecosystem recovery. Only with the knowledge of these key processes and factors are optimal restoration and management measures possible.

Role of *Sphagnum* mosses in methane cycling of a boreal mire

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It has lately been shown that *Sphagnum cuspidatum* Hoffm. shows methane (CH_4) oxidation capacity due to inhabiting methanotrophic bacteria (Raghoebarsing et al. 2005). This is an interesting finding as peatlands are a major natural source of the strong greenhouse gas CH_4 into the atmosphere. Emissions from *Sphagnum* dominated mires are lower than those from *Carex* dominated ones. One reason for this could be the CH_4 oxidation associated to these mosses. Methanotrophs harbouring the hyaline cells of *Sphagnum* leaves and stem, methanotrophs produce carbon dioxide (CO_2) from CH_4 derived from decaying plants. The moss fixes the produced CO_2 in its photosynthesis and releases oxygen for the methanotrophs. Therefore, carbon released in decomposition would be efficiently recycled within the ecosystem and the moss layer would limit the release of greenhouse gases CH_4 and CO_2 to the atmosphere.

In Finland 41 different *Sphagnum* species are found with the majority occurring on peatlands. The 50 ha large Lakkasuo peatland inhabits 23 different *Sphagnum* species. The following questions were addressed:

1. Which *Sphagnum* species show CH_4 oxidation and thus harbour methanotrophic bacteria?
2. Can the responsible methanotroph be identified?
3. What are the key environmental controls of methanotrophy in *Sphagnum*?
4. Is CH_4 a significant carbon source for *Sphagnum* on an ecosystem scale?

To answer the questions 1–3 we sampled from Lakkasuo systematically all *Sphagnum* species and tested their ability to oxidize CH_4. We investigated the existing vegetation plots in every 100 m for their *Sphagnum* species and sampled each dominant species from 5 plots. Species occurring on less than 5 plots were sampled from every location found. With this approach we detected *Sphagna* with narrow and broad ecological tolerance. From each plot also water table was recorded. To answer the question 4, we analyzed the ^{13}C signal from both CH_4 and CO_2 dissolved in water and the *Sphagna*.

All 23 *Sphagnum* species support methanotrophs. When individuals showing no CH_4 oxidation activity were transplanted to an environment where the same species, or species belonging to a same section had CH_4 oxidation activity the transplants became CH_4 oxidizers. The active transplants hosted a *Methylocystis* sequence which they did not have before transplantation. Water level was the key environmental control of methanotrophy in *Sphagnum*. In *Sphagnum* 10–30% of carbon potentially originates from CO_2 derived from CH_4 oxidation.

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How atmospheric N deposition affects peatland vegetation composition, production and *Sphagnum* N concentration: an analysis of 30 fertilization studies across the Northern Hemisphere

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Since the industrial revolution, the increase in anthropogenic N pollution has resulted in high levels of atmospheric N deposition across extensive areas of Europe, Asia and North America. As N is a limiting nutrient for plant productivity in many ecosystems, these increases have had dramatic consequences for productivity and biodiversity. *Sphagnum* dominated peatlands are considered to be one of the ecosystems most vulnerable to elevated N deposition, as their only input of N comes from the atmosphere. Although modest increases in N deposition rates seem to stimulate moss productivity, higher rates generally lead to a shift from *Sphagnum* moss dominated to vascular plant dominated vegetation. As *Sphagnum* performs key functions in both the hydrology and C-sequestration of peatlands, the above is a cause for much concern and has resulted in an impressive number of fertilization studies.

In this presentation we combine data in a meta-analysis from the majority of published fertilization studies as well as some unpublished sources to better quantify N deposition effects across a wider spatial and time scale than is possible for the separate studies. Apart from quantifying effects, this analysis allows us to test the current theoretical framework regarding N deposition effects and the time-lags involved with ecosystem responses to deposition changes. In the presentation we try to answer the following questions

- Is the response of *Sphagnum* (and or) *Sphagnum* dominated vegetation equal across geographic regions and/or climate?
- To what extent is the response to fertilization affected by background N deposition, P availability, exposure time to fertilization, vascular plant cover, water table and peatland type?
- Does the type of experiment (field fertilization or greenhouse experiment) matter?

Large annual CO_2 uptake in a drained peatland forest

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In Finland, forestry is the most important form of land-use in peatlands. More than half of the original peatland area has been drained, and over 90% of that are forestry-drained peatlands. There is still controversy on the carbon (C) balance of this land-use, some studies showing loss of C from the soil into the atmosphere, some others showing decreasing CO_2 sink or even increasing sink. It has been suggested that the nutrient status of the peat soil may strongly affect the C balance of such ecosystems, nutrient-rich sites being potentially sources of C, whereas drainage could even increase the potential for CO_2 uptake at nutrient-poor sites. We have measured the CO_2 exchange with the micrometeorological eddy covariance method on a forestry-drained peatland since 2004. The site, Kalevansuo, is a nutrient-poor dwarf-shrub pine bog, and it is located in southern Finland. The results show that the forest is a large CO_2 sink annually, fixing about the same amount of C annually than a similar pine forest growing on upland soil about 50 km's away from Kalevansuo. The interannual variation in CO_2 fluxes and balances during for years will be analyzed and the controlling factors and possible explanations for the unexpectedly high CO_2 sink will be discussed.

Mitigation of nutrient leaching from active forestry land by retention in peatlands

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Forest land is extensive in the Nordic-Baltic countries and contributes considerably to element and nutrient leaching to the inland and coastal waters. Peatlands exert crucial functions for aquatic ecosystems in forest landscapes. Forestry operations add to outflows and in a situation with increasing biomass harvesting, enhanced pressures on water courses occur. The importance of retention areas such as buffer zones attracts attention in water turnover and chemical element balances. Investigations on mires as protection areas were carried out in central Sweden over the 16 year period 1992–2007.

In the Bälgsjön lake catchment forest land use impacts on discharge and element leaching were studied. A number of sub-catchments, joining in a sedge fen, formed a joint outflow from the fen to one stream inflow to the lake being a drinking surface water supply. Water quality had deteriorated over several years. The only activity inside the catchment was forestry with clear-felling, drainage and scarification. The conclusion regarding the changed water quality was that forestry measures caused the effects. The importance of the peatland mitigating capacities for water and element budgets, including about 20 elements, was determined providing results on the fen function as buffer area.

In relation to a surface water supply lake in central Sweden investigations of a fen were carried out with results for many elements showing mainly retention, especially for the eutrophication compounds nitrate (34%) and phosphate (5%). However, organically bound elements, such as metals, had a tendency to be released as well as organic carbon and hydrogen furnishing slightly acid water with high water colour. An increase of the colour from 144 mgPt L^{-1} to 158 mgPt L^{-1} was observed. In the forest land use, considerations on preserving riparian sites in the near stream zone for surface water formation are important and should be considered in a careful way.

Spatial variation in CO_2 exchange at a northern aapa mire

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Northern mires have an important role in the global carbon budget. In order to understand their feedbacks to current climate change, it is necessary to know the functional diversity within the ecosystem and the mechanisms governing mire carbon exchange dynamics. We compared CO_2 exchange and its controls in different plant communities in a northern aapa mire. The study was carried out in Kaamanen fen in northern Finland (69º08'N, 27º17'E, 155 m a.s.l.). The mire is composed of wet flarks and dry, ca. 1m high strings, which is a typical pattern for a northern aapa mire.

Based on a systematic vegetation inventory and ordination analysis, we chose four plant community types for the study: *Ericales-Pleurozium* string tops, *Betula-Sphagnum* string margins, *Trichophorum tussock* flarks and *Carex-Scorpidium* wet flarks. During the growing season 2007, CO_2 exchange measurements with closed chambers were carried out weekly or biweekly. Based on the measurements, we created nonlinear gross photosynthesis (PG) and ecosystem respiration (RECO) regression models using air temperature, photosynthetic photon flux density, peat temperatures at different depths, water level and vascular plant green area (VGA) as independent variables. Based on CO_2 exchange responses to environmental factors, we distinguished two functional components in the mire: an ombrotrophic component (*Ericales-Pleurozium* string tops) and a minerotrophic component (other plant community types). We constructed separate PG and RECO models for these ecosystem components. With the models we simulated PG, RECO and net ecosystem exchange (NEE) half-hourly over the growing season using continuous environmental variable data. To validate the models, we did a second set of measurements in the early summer 2008.

For the minerotrophic mire component, variation in VGA was the main control for PG while for the ombrotrophic component, temperature and possibly moisture factors were more important. RECO was controlled by water level and VGA, but the responses differed between the ombrotrophic and minerotrophic mire components. Trichophorum tussock flarks were the most efficient CO_2 sink: their PG was efficient due to large VGA but RECO was low due to small aerobic peat volume (Table 1). In the drier *Ericales-Pleurozium* and *Betula-Sphagnum* types, PG and RECO were both large while in the wet *Carex-Scorpidium* type they were both low. The study demonstrates that the fen/bog functional dichotomy can exist also within one mire and that wet minerotrophic communities can act as effective carbon sinks within northern mires.

Table 1. Comparison of the four plant communities. Water level range relative to moss surface, average VGA on July 21 (growing season peak), growing season NEE, and within-type variation in NEE (SE).

Plant community type	Water level, cm	VGA, m^2m^{-2}	NEE, g CO_2 m^{-2}	SE (NEE), n=4
Ericales-Pleurozium	-86 – -45	1.26	-41.6	39.7
Betula-Sphagnum	-26 – 0	0.68	52.7	27.5
Trichophorum	-9 – 3	0.58	154.4	17.0
Carex-Scorpidium	0 – 18	0.22	84.4	19.8

Emissions of N_2O, CH_4 and CO_2 from undisturbed and drained peatlands in Estonia

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This paper aims to estimate emissions of greenhouse gases (GHG) N_2O, CH_4, and CO_2 in Estonian transitional fens and ombrotrophic bogs according to their disturbance due to drainage. The analysis has been performed mainly on the basis of the literature data from boreal regions of Fennoscandia and North America, which are comparable to Estonian conditions considering biophysical factors, mire types and flora (Salm et al 2009). The database of the ISI Web of Science was searched using the following keywords: peatland, wetland, greenhouse gases, N_2O, CH_4, CO_2, budget of greenhouse gases, sequestering of carbon in peatlands/wetlands. The following cartographic sources were used to estimate the total area of transitional fens and raised bogs: (1) Digital land cover database created by the CORINE Land Cover project covering the whole of Estonia (1997), scale 1:100,000. The following land cover types were considered: (a) Open fens and transitional fens, (b) Raised bogs, (c) Transitional woodland/scrub on mire (Paal 1997); (2) Landscape maps, scale 1:100,000; (3) Map layer for drained areas, scale 1:100,000 (Estonian Agricultural Registers and Information Board and the Estonian Environmental Information Centre 2007). The database includes 59, 165, 89 calculated fluxes of N_2O, CH_4, and CO_2, respectively. Most of the data used had a non-normal distribution pattern. Also, we used preliminary data of our field investigations (closed chamber method, gas-chromatograph analysis (Hutchinson & Livingston 1993), 3 sites in each area, 5 replicates per site, since June 2008) from 6 field study sites of undisturbed and altered mire types in Kuresoo, Valgeraba (both Soomaa National Park), Sangla, and peat mining areas of Ida-Virumaa (Puhatu, Kasesoo, and Hiiesoo).

The annual emission of CO_2, CH_4 and N_2O in Estonia is estimated to be 779,740 t CO_2 eq, of which CO_2 makes up 403,390 CO_2 eq (403,390 t CO_2 yr^1), CH_4 359,692 CO_2 eq (17,128 t CH_4 yr^1) and N_2O 16,659 CO_2 eq (56 t N_2O yr^1). The annual efflux from the drained area is 647,796 CO_2 eq, and 131,944 t CO_2 eq from the undrained area.

Comparing GHG emissions (CO_2 eq) from the areas under drainage (15% of the total area) with undisturbed areas (85%), the former contribute 83% of total emissions, whereas the reduction of CH_4 efflux due to drainage does not compensate the increase in CO_2 emissions. Due to drainage, Estonian fens, transitional fens and ombrotrophic bogs have turned from sinks to sources of GHG. Theoretically, without drainage the natural mires would be potential to bind 253,565 t CO_2 annually and release 19,293 t CH_4. Thus, the GWP of CO_2, CH_4 and N_2O from these mires would be 5 times lower.

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Atmospheric impact of nitrogen turnover processes in northern peatlands

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The large amount of carbon in northern peatlands has induced an intensive research to evaluate the possible changes in this C storage associated with global warming and various land-use activities. The northern peatlands store not only carbon but also huge amount of nitrogen in their organic matter. Therefore, changes in nitrogen turnover processes in peat soils have atmospheric importance. In fact, organic soils are the most potential ones to produce and emit nitrous oxide (N_2O), an effective greenhouse gas. Here an overview is given of the biogeochemistry of nitrogen/N_2O in northern peatlands and how anthropogenic activities and global warming would affect the N_2O dynamics in these ecosystems.

In general, N_2O emissions from natural peatlands are low. A key reason for this is that the high water content in peat limits oxygen diffusion into the soil resulting in low nitrogen mineralization and nitrification rates. Also, low availability of nitrate in peat highly limits denitrification, the most potential microbial process for N_2O production. Therefore, it is more important to predict changes in hydrology than the direct temperature effects on biological processes when considering the possible changes in N_2O fluxes in boreal peatlands with global warming.

Use of peatlands, e.g. for forestry and agriculture, generally, requires lowering of water table. This and soil preparation measures can highly induce the N_2O production and emissions. In addition to oxygen availability, peat characteristics regulate microbial processes behind N_2O production and release. Carbon to nitrogen ratio, particularly, has been shown to be important in peat soils. In the soils of the boreal region, the N_2O production is high even at soil temperatures below 0 °C. Therefore, cold seasons contribute significantly to the annual N_2O emissions from these soils.

An important issue in the land-use and climate policy is how to mitigate the high N_2O emissions from managed boreal peat soils. Unfortunately, the mitigation of N_2O emissions from managed peat soils has been proven to be difficult. For example, N_2O emissions from organic agricultural soils can remain high for decades after afforestation.

Arctic peatlands are not under such an intensive management activities compared to the boreal peatlands and N_2O emissions from the Arctic peatlands are believed to be low. However, a recent study shows that the nitrogen dynamics in the Arctic peatlands differs from that in the boreal peatlands. In the Arctic the permafrost related physical processes can highly change the chemical and biological characteristics of peat soils resulting in extremely high N_2O emissions. Therefore, the warming as such would thus have greater effects on the N_2O emissions from Arctic peatlands than in the boreal region.

Biomass, carbon and nitrogen accumulation during mire primary succession

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Under changing climate there is an acute demand for knowledge on the stability of carbon accumulation rate in mires. In this study, we determined accumulation profiles and accumulation rates of organic matter, carbon (C) and nitrogen (N) along a mire chronosequence to evaluate the predictability of accumulation pattern based on time since mire initiation. The sampling was based on a *ca.*8-km long chronosequence of mire ecosystems located in Siikajoki, on the land-uplift coast of Finland (Merilä et al. 2006). The chronosequence consisted of five peatland sites (core sites 1–5) with approximate terrestrial ages of 180, 210, 700, 1070 and 2500 years, respectively. To complement the sampling, three additional hydrologically independent mire sites in each mire age class (classes 1–5) were selected from a distance <1000 m of the core sites, resulting in a sample of 20 mires. A transect of 6–10 sample plots was established in each site to cover the moisture variation characteristic to each site. A peat or peat/soil profile from each sample plot within each site was sampled, cut into 10 cm slices, and determined for bulk density, loss on ignition and C and N concentration by means of LECO CHN analyzer. The terrestrial ages of the mires belonging to the age classes 1–3 were estimated by the quotient of the land elevation above sea level and land-uplift rate (Ekman 2001). The bottom ages of the peat layers in age classes 4 and 5 were ^{14}C dated.

We present the accumulation rates for organic matter, C, and N along the chronosequence and evaluate their predictability based on the linear regression models between the estimated site age and the accumulated amounts of organic matter, C, and N and on the accumulation profiles of organic matter, C and N within each site. Preliminary results show fairly large variation in accumulation rates especially in the mid-successional fen sites (age classes 3 and 4), indicating that accumulation rate of carbon is not constant along the chronosequence and may be influenced by factors such as nutrient availability and climate.

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Nitrogen and δ^{15}N in the Mer Bleue peatland, Canada

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The Mer Bleue peatland is a large (28 km^2) mire located 10 km east of Ottawa, Ontario Canada and comprises an ombrotrophic bog with hummock-lawn microtopography and sections of poor fen and beaver ponds at the margin. It has been the site of detailed biogeochemical and ecological studies, which have focused primarily on the C budget of the peatland (e.g. Roulet et al. 2007). In this paper, we present information on the concentration and mass of N in the ecosystem, the rates of N mineralization and denitrification and the δ^{15}N signature of the vegetation and the peat profile, as an indication of the processes of N cycling.

With the exception of some herbs and deciduous shrubs and trees, foliar N concentrations are small (0.8 to 1.2%) and show only minor seasonal variations, apart from the deciduous component, which shows a progressive seasonal decline. N mass in photosynthetically active tissues varies in response to plant species and microtopography, though the variation is not as large as the aboveground biomass. Estimated annual average N uptake by aboveground net primary productivity is ~ 3 g N m^{-2} a^{-1}. N concentrations in peat profiles range from 0.7 to 2.0 %, generally increasing with depth to reach C:N ratios of about 30:1 at the base of the peat profile. Long-term rates of N accumulation are 0.5 to 0.8 g N m^{-2} a^{-1} and short-term rates (derived from ^{210}Pb dating over last 50 to 150 years) are 1.6 to 2.6 g N m^{-2} a^{-1}.

Pore-water N concentrations range from1.8 to 8.0 mg L^{-1} with dissolved organic nitrogen (DON) dominating (14 to 82 % of the total N) over ammonium (17 to 85 %) and nitrate (2 to 9 %), the smaller percentages of DON occurring in the lower parts of the peat profile. Ion exchange resins confirm the paucity of available inorganic N in the system. In the bog section, nitrification rates ranged from -8 to +25 ng N g^{-1} peat d^{-1} while net mineralization rates ranged from -26 to 640 ng N g^{-1} peat d^{-1}. These rates were affected by a long-term NPK fertilization experiment.

δ^{15}N ranges from -6 to -10 ‰ in foliar shrub and tree samples to -2 to -3 ‰ in sedges, to 4 to -6 ‰ in mosses and -1 to +1 ‰ in *Smilacina* and *Typha*. There is a strong negative correlation between foliar N concentration and δ^{15}N, suggesting mycorhizzal fractionation of ^{15}N. Within the peat profile, δ^{15}N values range from -1 to -5 ‰ in the top 10 cm (reflecting the signature of the input litter), to 0 to +2 ‰ at a depth of 30 to40 cm and then remain close to 0 ‰ to the base of the profile.

A contemporary annual budget of N for the peatland suggests an import of ~ 1 g N m^{-2} a^{-1} from atmospheric deposition and an unknown contribution from N_2 fixation. Export comprises N_2O emission to the atmosphere, which is very small, probably < 0.01 g N m^{-2} a^{-1}, and aquatic export, tied mainly to dissolved organic matter, as DON, of ~ 0.4 g N m^{-2} a^{-1}.

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CH_4 Flux from the Mer Bleue Peatland, Canada

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The Mer Bleue peatland is a large (28 km^2) mire located 10 km east of Ottawa, Ontario Canada and comprises an ombrotrophic bog with hummock-lawn microtopography and sections of poor fen and beaver ponds at the margin. In this poster, we present information on CH_4 fluxes from the peatland.

Average growing-season (May – September) fluxes of CH_4 range from < 5 mg m^{-2} d^{-1} in 'dry' sections to > 100 mg m^{-2} d^{-1} in sections that are 'wet', such as hollows, beaver ponds and a *Typha* marsh. These average fluxes are closely related to the average position of the water table, explaining about half of the variation in flux (Fig.1). The overall relationship is similar to that observed in many other peatland regions in Canada and elsewhere (Fig. 2).

There is considerable variation in CH_4 flux in the middle part of the relationship, where water table position varies between -40 and -15 cm, which is the dominant frequency across the peatland. To better establish the controls on this variability, we measured CH_4 flux at approximately weekly intervals from April to November for 5 years (2004 - 2008) at 12 collars representing the water table and vegetation variations typical of the peatland. We show that over the sampling season peat temperature is the dominant control on CH_4 flux, and the difference among collars on a seasonal average is partially dependent on water table position. A third important control on CH_4 flux is vegetation, particularly the presence of *Eriophorum vaginatum*, which elevates CH_4 flux. There is also considerable inter-annual variation in fluxes, associated with varying peat thermal and water table regimes, suggesting the need to measure CH_4 flux from peatlands over several years to capture the important controls.

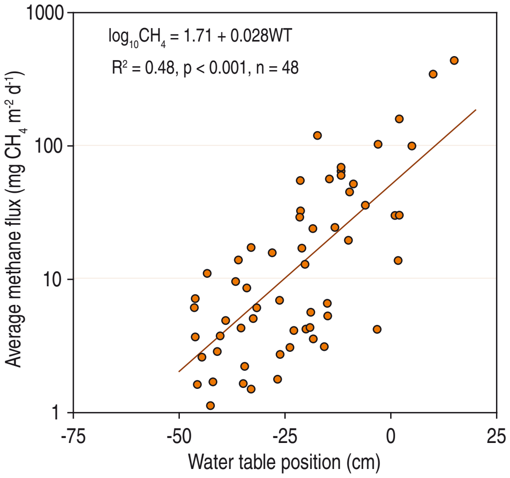

Fig. 1. Growing-season average CH4 flux and water table position in the Mer Bleue peatland.

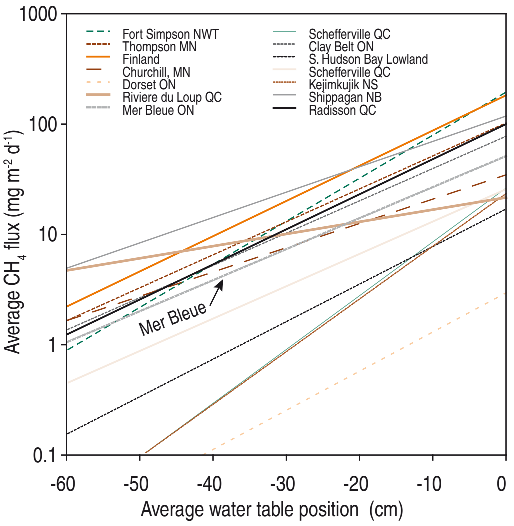

Fig. 2. Average CH4 flux: water table position relationships for northern peatlands.

Changes in Vegetation and Ecosystem CO_2 Fluxes Caused by Nutrient Addition in a Temperate Bog

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Nutrient addition, e.g. in the form of Atmospheric nitrogen (N) deposition, has the potential to alter the structure and functioning of ecosystems. It is important to quantify the effect of these changes on ecosystem carbon (C) sequestration in peatlands, which are globally important C storages. Many bogs are currently fertilized by atmospheric N deposition; but also climatic changes leading to accelerated mineralization may increase nutrient availability in otherwise nutrient poor bogs. Effects of nitrogen, phosphorous (P) and potassium (K) addition on the bog ecosystem have been studied at the temperate Mer Bleue bog, ON, Canada from the year 2000 to 2008. Three levels of N fertilization (from 1.6 to 6.4 g N $m^{-2}yr^{-1}$) are applied with or without phosphorus and potassium (PK) in triplicate plots. After the first 5-6 years of experimental fertilization, the results showed that high N deposition can change mixed *Sphagnum* moss and dwarf shrub dominated communities to dense dwarf shrub communities without moss cover. One interesting result was that those altered communities had lower net CO_2 uptake (Bubier et al. 2006).

The fertilization experiment has been continuing for 8–9 years, with the addition of new treatments started in the 2004. We conducted measurements during the summer 2008. Our aim was to follow changes in the ecosystem and specifically to quantify the relationship between the plant community structure and ecosystem CO_2 exchange. We measured light saturated net ecosystem CO_2 exchange (NEE), and its components ecosystem respiration and gross photosynthesis using clear and dark chambers (May-August). Vegetation characteristics were quantified by measuring foliage cover (leaf area index, LAI), amount of woody and foliar biomass, and abundance of moss species (point interception technique), moss growth (cranked wires) and green area of vascular leaves and moss.

The new treatments confirmed the earlier findings that moss cover, particularly *Sphagnum* species, start to decline even with the lowest N dose. Fertilization enhanced the growth of dwarf shrubs, measured as increased leaf area index, canopy height, and biomass. Woody to foliar biomass ratio increased under high N load. Exchange of CO_2 showed responses to accumulating N load (fertilization years times the annual dose). Ecosystem respiration increased with increasing N load. Also ecosystem gross photosynthesis increased with increasing N input, but the rate of change decreased with higher N accumulation. As a consequence, net ecosystem CO_2 uptake peaked at moderate N load to the system. We will examine the dependencies between the vegetation and net ecosystem CO_2 exchange, as well as component processes of respiration and photosynthesis, in order to understand the functioning of the changing environment.

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Controls on belowground vascular plant production in a bog in eastern Ontario, Canada

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Studies of plant production in peatlands have focused primarily on aboveground components, despite the fact that a significant portion of vascular plants are allocated belowground. We studied the relationships between belowground vascular plant production, water table, and aboveground biomass in a bog in southern Ontario, Canada to elucidate the possible controls on belowground production. We installed 80 in-growth bags for 17 months (June 2006 to November 2007) at Mer Bleue bog to a depth of 40 cm below the surface. During that time we monitored water table levels at wells at each core location and estimated aboveground biomass using a point-intersect method. Following the removal, bags were divided into 10 cm increments, and all roots were hand sorted from each depth increment. We used linear regression analysis to evaluate the role of water table depth and aboveground biomass in explaining the high variability in belowground production at the site. Mean fine root production over the 17 month period was 109.14 ± 71.36 g/m^2 with a coefficient of variation of 65%. Water table depth explained 65% of the variation in belowground production (df = 77, $p < 0.001$). Analysis of the relationships between aboveground biomass and belowground production indicated that leaf biomass was a better predictor of belowground production ($r^2 = 64\%$, df = 75, $p < 0.001$) than total aboveground biomass ($r^2 = 0.27$, df = 77, $p < 0.001$). Our results indicate that the variation in water table across the hummock and hollow microtopography at the site is the main driver of belowground production. Additionally, the strong relationship between leaf biomass and root production provides an important link between photosynthetic processes aboveground and nutrient and water absorption belowground and may be a time-saving and useful means of estimating the relative rates of belowground production across space and time.

Isotopic composition of carbon in *Sphagnum* peat in Central Europe during last Millennium

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Peat is one of the most important reservoirs for carbon storage in the Northern Hemisphere. Peat bogs may become carbon sinks for atmospheric carbon dioxide as well as a carbon source to the atmosphere, depending on climatic conditions. Raised peat bogs are very sensitive to the climatic changes and therefore may be valuable archives of climatic changes of the past. Unfortunately it is not easy to find undisturbed or even weakly exploited raised bogs in Central Europe. Recently, investigations of the isotopic composition of organic matter in peat have become more and more popular. However, the mechanisms which control isotopic composition of carbon in *Sphagnum*-peat are not yet well understood.

We present an attempt to find which climatic factors and natural processes control the isotopic composition of carbon in deposited *Sphagnum*. Two Baltic type bogs from northern Poland and additionally one ombrotrophic bog from Belgium were investigated. Two 1-m long cores were collected form Stazki bog (Poland), one from Slowinskie Blota bog (Poland) and one from Misten bog (Belgium). A Wardenaar corer was used to collect the peat profiles. Each core was sliced into 1-cm slices. *Sphagnum* stems were selected from each slice (if found). The isotopic composition of carbon was determined in the total organic matter of *Sphagnum* stems using an elemental analyser coupled to an isotopic ratio mass spectrometer. Polish cores were dated using $^{14}C/^{210}Pb$. Age-depth models were generated for dated peat profiles, which span more than one thousand years. An inter-comparison of the resulting dated datasets was undertaken in addition to comparisons with existing palaeoclimate data.

Evolution of organic carbon concentration and speciation during different stage of thermokarst lakes development in Western Siberia

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In order to understand the mechanisms of carbon mobilization and biodegradation during permafrost thawing and to establish the link between the organic carbon (OC) and other chemical and microbiological parameters in forming thermokarstic lakes, we performed a comparative multidisciplinary study on the biogeochemistry of OC and related elements in lakes that are being formed due to permafrost thawing in the northern part of Western Siberia. About 10 lakes and small ponds of various sizes and ages were sampled for dissolved and colloidal organic carbon and metals and total bacterial cell number. There is a clear chemical sequence of ecosystem stages during evolution from peat thawing and "palza" degradation in small ponds to large, km – size lakes subject to drainage and, finally, the "khasyrey" formation. At the beginning of permafrost thawing at the scale of several meter size ponds (stage 0 to 1), fast lixiviation of unaltered peat yields significant amount of OC, major and trace elements; the pH of these waters is acidic (3.5 to 4.0). At the intermediate stage of lake formation (2 to 4), consisting of fast growing ponds of 10 to 50 m in diameter, the lake water still preserves low pH, high DOC and trace element content. At the 5th stage of lake stabilization (500 to 2000 m in diameter), there is very weak primary production in the water column (< 0.01 mg C/L/day) but the bacterial mineralization intensity remains high, up to 0.3 mg C/L/day. At the 6th (final) stage, the remaining part of the lake located in the centre of the "khasyrei" exhibits the highest pH (5.5-6.0), presence of green algae and plants, very low conductivity (4–9 µS) and the lowest OC concentrations (Figure). In the chronosequence of lake formation, there is a clear decrease of the relative proportion of < 1 kDa organic carbon due to preferential use of small-size organic molecules by the bacterioplankton in growing lakes.

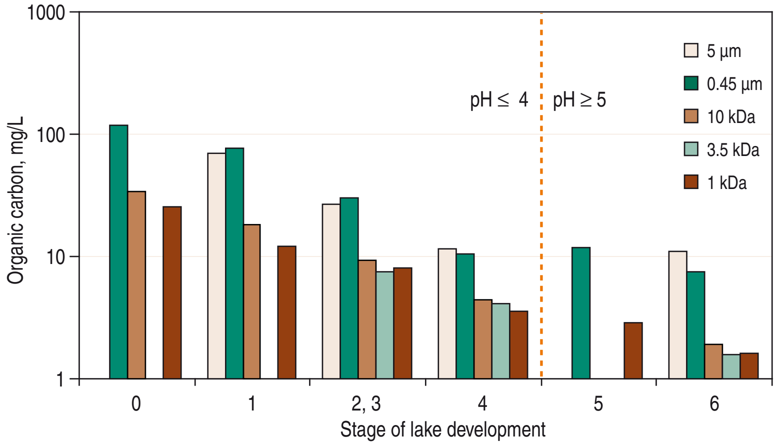

Figure. Organic carbon speciation in the thermokarst lakes at different stages of their development

The main conclusion drawn from this work is that there is a systematic decrease of both total (< 0.22 µm) and truly (< 1 kDa) dissolved organic carbon concentration in the sequence of thermokarst development. This evolution can be explained by the use of allochtonous organic matter and dissolved nutrients originated from the peat lixivation by microbial community until the steady-state concentration of bacterioplankton and DOC are established.

Modelling CH_4 emissions from wetlands for the MPI-Hamburg ESM

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Earth System Models (ESM) combine the knowledge about the atmosphere, the ocean, the cryosphere and the biosphere, and describe how the physical and biogeochemical processes in these components interact within the Earth system. ESMs are needed to understand past and future climate variations. The biosphere component in the ESM of the Max Planck Institute (MPI) of Hamburg does not currently include methane (CH_4) emissions from wetlands that, however, are the largest natural source of CH_4 in the atmosphere. The goal of our project is to incorporate wetlands into the MPI-Hamburg ESM. The present work concentrates specifically on constructing the model of CH_4 production and emission.

Our model is based on the CH_4 emission model of Wania (2007). CH_4 production occurs by anaerobic decomposition of organic matter. The production rate is determined by water table depth and the degree of anoxia in each soil layer. The produced CH_4 is transported into the atmosphere via aerenchymatous plants (e.g. sedges), diffusion and ebullition. On the way up, aerobic methanotrophic bacteria remove a fraction of the CH_4 by oxidizing it into carbon dioxide. The oxidized fraction depends on the amount of available oxygen. Oxygen is transported into the soil by diffusion and via the aerenchymatous plants.

The first prototype of the model will be validated using data collected on a boreal oligotrophic fen, Siikaneva, in southern Finland. Data sets of meteorological parameters, CH_4 profiles in the peat, and CH_4 fluxes measured by the eddy covariance method above the peatland are used for the validation. We will, for instance, test two different bubble formation models against the data. One (used in Wania 2007) is based on a threshold concentration above which a bubble is assumed to form and the other model bases on the nucleation theory. These models may produce different results because nucleation is controlled by pressure, i.e. mass of water above each soil layer, while in Wania's model the ebullition depends only on the CH_4 concentration.

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Organic and inorganic carbon concentrations and fluxes from managed and unmanaged boreal first order catchments

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Peatlands sequester significant amounts of carbon (C) globally and in the northern latitudes, streams provide a loss pathway for C via lateral transport downstream and degassing to the atmosphere. Recent studies have suggested that C loss via streams can make a significant contribution to the C budget of both peatland and upland areas dominated by organic soils (e.g. Dawson et al. 2001, Billett et al. 2004, Hope et al. 2004). However, the influence of the forest management is not known.

Seasonal and inter-catchment variation in losses of both organic and inorganic carbon via downstream transport and evasion were studied in 11 boreal first order catchments in eastern Finland dominated either by peatlands or upland soils. Out of these catchments 4 represent undrained peatlands, 4 drained peatlands, 2 unmanaged upland, and 1 managed (clear-cutting, ploughing) upland. Total organic carbon (TOC) and total inorganic carbon (TIC) concentrations of stream water were measured 7–11 times during year 2007 at the outlets of the catchments and the mean daily runoff was recorded by a V-notch weir and a water level recorder. CO_2 concentrations of the streams were calculated from measurements of TIC and pH with correction for water temperature.

Stream water TOC and TIC concentrations were highest in the undrained peatland dominated catchments, but the total range of concentrations between streams was much higher for TOC than for TIC. Annual downstream export of TIC was quite consistent between the catchments, but the export of TOC was highest in peatland dominated catchments. Consequently, highest lateral total carbon (TOC+TIC) exports were found from peatland catchments. TC exports were of the same magnitude from both drained and undrained peatlands, because in export calculations lower concentrations of TOC in drained peatlands were compensated by higher discharge rate. Partial pressure of CO_2 in streams was the highest in undrained peatland dominated catchments, whereas the estimated total annual evasion of CO_2 was also high in the drained peatlands presumably due to higher discharge rate and long drainage network. The estimated total annual evasion of CO_2 varied widely depending on calculation method, but was mainly larger than the lateral TIC export at the catchments. In mineral soil dominated catchments both downstream export of total carbon and evasion of CO_2 into the atmosphere were low.

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Dynamics of nitrate limitation on gaseous nitrogen exchanges from pristine peatlands

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Identifying the major regulatory dynamics of gaseous nitrogen fluxes from nutrient poor peatlands is crucial to assess the respective response to eutrophication. Respiratory denitrification is the main transformation process involved with gaseous nitrogen exchanges from natural peatlands, for which nitrate is the primary electron acceptor. Bio-availability of nitrate in soils is constrained by physico-chemical soil conditions and biotic interactions. The variance of nitrate limitation on gaseous nitrogen exchanges was studied in accordance to covariant soil anaerobiosis and resource competition[1] by comparing the responses of nitrous oxide (N_2O) and dinitrogen (N_2) fluxes to nitrate addition between distinct contrasts in plant growth at a pristine, hummocky peatland.

Two quantification techniques were applied parallel to soil core incubations in order to determine N_2O and N_2 fluxes. On the one hand a gas-flow core system was used for direct quantification of net N_2O and N_2 fluxes. Highly sensitive measurement of N_2 fluxes was enabled by reducing the N_2 concentration of the soil atmosphere to approx. 20 ppm before incubation. On the other hand a ^{15}N-N_2O dilution technique was applied to quantify the gross N_2O production and consumption of atmospheric N_2O to N_2 in peat soil. The headspace N_2O pool was increased with 0.03 ppm N_2O rendering an enrichment of ± 9.8 atom% ^{15}N-N_2O. Triplicate soil core samples were taken from two contrasting soil habitat in a hummocky, Carex dominated fen located in NE Poland (53° 07'N; 23°10'E). The hummocks had a gravimetric soil water content of 76.6 ± 2.2% and high root abundance, dissimilar to 83.4 ± 1.0% and absence of roots in the hollows. Singular nitrate addition, comparable to the atmospheric NO_Y-deposition, was applied two days in advance of flux measurement.

Actual net gaseous nitrogen fluxes and responses to nitrate addition were apparently different for both soil habitat (Table I). Hummock soil cores showed to be net sources of N_2O, while hollow soil cores were markedly net N_2O sinks. Net N_2 fluxes measured consistently higher from the hollows than the hummocks. Nitrate addition to the hummock habitat resulted in a small, non-significant increase of the net N_2O flux, while the hollow soil cores showed a drastic shift towards a net N_2O source upon nitrate addition. At higher nitrate availability both N_2:N_2O ratios and net N_2O fluxes clearly demonstrated that relatively more bio-available nitrogen is converted to N_2O by respiratory denitrification. Results of the stable isotope technique will confirm whether the consumption rate of atmospheric N_2O to N_2 agrees with the latter observation.

Higher root abundance associated with lower soil anaerobiosis and higher resource competition causes net N_2O fluxes to be positive, but mitigates the effect of nitrate addition. Lower root abundance associated with the higher soil anaerobiosis, causes natural peat soil to be net N_2O sinks, but lower resource competition attributes to higher eutrophication susceptibility. Inverse covariance of soil anaerobiosis and resource competition as a result of variance in plant growth indicated to be a major regulatory dynamic of gaseous nitrogen exchanges from natural peatland, by which the susceptibility to nitrate eutrophication is determined.

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Table I. Gaseous nitrogen fluxes per soil habitat and nitrate addition (øN = no addition, 0.1N = +0.1mg NO_3^--N).Characters indicate the significance of difference between nitrate additions of one soil habitat (n=3)

	Hummock		Hollow	
	øN	0.1N	øN	0.1N
Net N_2O flux (µg-N m^{-2} h^{-1})	2.08 ± 0.32a	2.16 ± 0.31a	-3.04 ± 0.12a	16.27 ± 2.87 b
Net N_2 flux (µg-N m^{-2} h^{-1})	1065.3 ± 139.2a	1249.2 ± 116.0a	2622.3 ± 106.3a	2689.7 ± 125.7a
N_2 : N_2O ratio	547.9 ± 50.8a	457.6 ± 16.5b	NA	159.1 ± 37.2

Organic-rich soils as a source of arsenic in the southern Pennines, UK

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Organic-rich peatland soils receiving mineralized groundwaters or atmospheric deposition are known to be important sinks of arsenic in the environment. In minerotrophic peat systems iron plays a major role in arsenic immobilisation (Blodau et al., 2008). In ombrotrophic peatlands iron is less abundant and fluctuations in water table may promote the release of previously deposited arsenic to fluvial systems (Rothwell et al., in press). The aim of this study was to investigate arsenic distributions across the Peak District National Park, Southern Pennines, UK, using the catchment characteristics approach. This area contains expanses of ombrotrophic peatlands that have been subjected to high levels of historical atmospheric contamination. Data from the national geochemical survey of the British Geological Survey (BGS) was used in this study. Stream water arsenic concentrations at eighty sites in the National Park were made available by the BGS. Arsenic concentrations across the region were highly variable, with values ranging from <0.2 to 2.41 $\mu g\ l^{-1}$. Within a Geographical Information Systems (GIS) framework, the catchment for each stream sampling point was described by morphological characteristics (area, slope and landscape position), land cover (wetland, heathland, grassland and arable) and hydrological properties (stream density, topographic wetness index and the hydrology of soil types). Empirical relationships between stream water arsenic concentrations and catchment characteristics were examined. Stepwise multiple linear regression revealed that arsenic concentrations were linked to combined wetland heathland cover, average slope and local relief. Arsenic concentrations in waters draining catchments dominated by peat soils were greater than those catchments dominated by mineral soils. The study also revealed that local topography exerts a control on stream water arsenic concentrations. In catchments with limited drainage or gully erosion, arsenic concentrations were low. In catchments with marked differences in local topography, arsenic concentrations were highly variable, suggesting that there are multiple controls on stream water arsenic concentrations. The results of the study suggest that peat soils are a source of arsenic in the drainage waters of the southern Pennines. Further work is needed to investigate arsenic dynamics in ombrotrophic peatlands, especially the role of geomorphology on arsenic retention and release mechanisms.

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The effects of burning on long term gaseous and fluvial carbon fluxes, and the use of fire and heather cutting as a carbon management techniques

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The carbon cycle from different upland management strategies has been of great importance with recent focus on whether these management schemes alter or indeed improve the carbon balance of peatlands. Fire is one of the most extensive management tools on upland peat soils in the UK with game keepers burning on a non-regulated burning rotation depending upon local knowledge and experience to produce different age heather stands with the aim of benefiting grouse production. Burning has been also used as a tool to reduce the risk of wildfire by reducing fuel load and creating firebreaks. Here we present a two year study on; carbon budgets, both gaseous and dissolved, and soil pore water chemistry from different fire management schemes including wildfire, managed burn, and a managed burn substitution option. The Goyt Valley in South Pennines (UK), has historically been managed by burning but no burning had been allowed for 5 years. Within this area permission was granted to conduct experimental burns and compare fresh burns with old burns; unburnt controls and an area of wildfire. As alternative to burning the experiment also considered the cutting of heather both with and without the lifting of the cut brash. On each experimental plot the study measured: gaseous carbon exchange, soil pore water and runoff chemistry; and water table depth.

Results show all the sites to be gaseous carbon sources, with the largest carbon sources being from the oldest heather stands whilst the smallest carbon source is from the wildfire site being a gaseous source of 63.4 Mg C km^{-2} yr^{-1}. The carbon losses from different heather stand ages show that there is a transitionary period between heather ages, i.e. the older the stand the greater the gaseous carbon released. Water table depths also show a similar pattern to the gaseous carbon fluxes with the sites with the deepest water table depths have the greatest carbon fluxes. After a managed burn water table depths become closer to the surface. The same is true of an alternative to managed burn which is heather cutting with the water table depths being comparable to the recent managed burn, and being much shallower than the degenerate heather site used as a control site. When DOC values are studied from the different sites a similar pattern is established with water table depth and gaseous CO_2 fluxes with the sites with the deepest water table depths and greatest gaseous fluxes have the greatest amount of DOC released.

The effectiveness of different restoration techniques on heavily eroded peatlands

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This study considers whether a peatlands can be restored to a net carbon sink or is restoration simply avoiding a loss of carbon? Further, what is the effectiveness of different restoration techniques?

Bleaklow in the Peak District (UK) has suffered severe and widespread pollution and wildfire events that in April 2003 resulted in a wildfire completly removing all vegetation from Km^2's of land on the summit exposing peat to erosion and degradation. Five different restoration techniques have been applied to different areas of bare peat in an effort to re-establish vegetation to stop the physical losses of peat surface via fluvial processes and reduce gaseous CO_2 fluxes. The first restoration technique is a natural re-vegetation study on bare peat. Results show that the gaseous carbon losses from a bare peat site are minimal with a carbon budget of 84.4 Mg C km^{-2}yr^{-1}, but there has been little natural vegetation regrowth with the percentage of bare peat measured still at 100% even after almost five years. The second restoration technique considered was seeding and liming. Liming raises the pH such that a nurse crop of lawn grass could establish a vegetation cover with subsequent promotion of natural regrowth of native species. The third restoration technique was seeding, liming and heather brash application. Heather brash acts as a mulch to preserve soil moisture and provide a seed bank of native species. The fourth approach was seeding, liming and geojute application where a hemp netting was rolled across the surface of the peat and fixed with biodegradable plastic pins. The hemp netting physically stabilised the slope and helped to maintain soil moisture. The fifth method is a grip blocking approach where a series of small dams were installed along a gully floor which retarded water flow and reduced particulate soil matter loss. Carbon budgets for the five sites were; bare peat 84.4 Mg C km^{-2}yr^{-1}; seeding/liming 83.6 Mg C km^{-2}yr^{-1}; seeding/liming and heather brash 90.6 Mg C km^{-2} yr^{-1}; geojute netting 59.7 Mg C km^{-2}yr^{-1} and gully blocking (results due for completion November 2008). For all sites a net gaseous carbon losses was observed which was compounded further by fluvial carbon losses. Soil pore water concentrations of DOC range from 0 to 293 mg C/l where the blocked grip site is losing the most DOC, on average 84 mg C/l, whilst the geojute site is loosing the least, on average 44.6 mg C/l. When all these sites are compared to a control site it can clearly be seen that restoration is only reducing the amount of carbon lost and as yet has had little success in re-creating a carbon sink. Using a predictive model it can be seen that the biggest effect on reducing gaseous carbon fluxes can be gained by reducing the depth to the water table.

Do we need buffer zones to bind the inorganic N load from the peatland forestry?

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Forest management in peatlands may result in an increased liberation of inorganic nitrogen (N). In order to prevent further leaching, buffer zones with sedimentation pools have been established. The wetland below receives the waters overflowing from the pool. The load of inorganic N and raised water table may both affect the vegetation and activity of microorganisms, and thereby immobilization of N or the release of gaseous N (N_2) and nitrous oxide (N_2O) by nitrification or denitrification.

Our site is a spruce swamp buffer constructed in 1997 below a peatland forest with loggings and soil preparation. In winter, N_2O fluxes were determined on the site using a snow gradient method and in summer using a static chamber. For denitrification potentials, peat profiles were cored during flooding in autumn and spring. Emissions of N_2O were measured in a laboratory by incubating the KNO_3 fertilized peat sections in N_2 atmosphere, conditions suitable for denitrification. Samples from the headspace were taken until the cessation of N_2O production. Also surface peat samples were taken for a fertilization experiment. The peat samples kept in open air were fertilized with 1.25, 2.5, 5.0, 10.0, 65.0 and 130.0 kg NH_4NO_3-N ha^{-1} apart from the controls. The N_2O emission was followed in 20°C in growth cabin conditions using static chamber until N_2O production returned to the level preceding the fertilization.

In the field measurements, N_2O emissions within the wetland were higher in the vicinity of surface water flows compared with those from less irrigated parts, but the flux rates did not correlate well with the distance from the water inlet. However, in laboratory there were clear differences. The N_2O production potentials were higher in samples taken near the water inlet than in more distant ones, and appeared highest at peat depths corresponding to the coring-time water table. Apart from the water table depth, the potentials were higher in samples originating from near peat surface layers than in those from deeper peat horizons.

The soil denitrification potential of the spruce swamp buffer was high. Furthermore, the high potential response of the peat profiles to produce N_2O after ammonium nitrate fertilization in laboratory suggests that similar high emissions could be expected also in the field if free NO_3- enters the buffer. Because very low N_2O flux rates were measured even near the principal water pathways, we can deduce that during the study period the buffer soil was only loaded with a very low amount of mineral nitrogen. There are several explanations to that. During growing period, mosses and vegetation can bind the free nitrate. It is also possible that nitrogen bypasses the buffer soil in surface water channels, or nitrification and denitrification already takes place in the upper parts of the catchment so that the potential load of inorganic N to the watercourses becomes very low. The latter is supported by the observed low concentrations of total nitrogen inflow and outflow, typical for humic waters. Buffers on organic soils may often have more importance in preventing the flows of solids than those of nitrogen or other nutrients.

Restoration as a disturbance in drained peatlands - water quality impacts in contrasting sites in southern Finland

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Less than 20% of the original mire area of southern Finland is still in natural state. Even many peatlands in today's nature conservation areas had been partly or totally drained before conservation. Until now, about 15 000 ha of peatlands have been restored in our nature reserves. Here we present data concerning changes in leaching due to restoration in two contrasting areas in southern Finland.

The peatlands in Seitseminen have originally been fairly open, growing stunted pine, and unfertile, either bogs or poor fens. The responses of tree stand to drainage in the 1960s were moderate, and the tree stand before restoration was about 50 m^3/ha, on average. The trees were partly harvested before filling in the ditches mainly in the years 1997–1999 .

The peatlands of Nuuksio are much more fertile than those in Seitseminen, and had greatly responded to drainage, which took place already in the 1930s and 1950s. The tree stand consisted mainly of spruce and exceeded 300 m^3/ha in large part of the area. The ditches were dammed in the autumn 2001 and the tree stand was left standing.

Runoff water quality was monitored in three basins in both areas. To obtain the leaching rates, we used areal simulated runoff data obtained from the Finnish Environment Institute, Hydrological Services Division. The responses in leaching were in the same direction in both cases. However, especially when calculated per restored hectare (Table 1), the responses were much stronger in the more fertile areas of Nuuksio for organic carbon and nitrogen, but not so much with phosphorus. The reasons for the greater responses in Nuuksio are partly hydrological. The mires of Nuuksio were originally minerogenic, catchment fed mires, and by restoration the peat layers regained their contact with the waters from the catchment. This was not the case with the bogs of Seitseminen and of less importance in the poor fens with a small catchment. Also biological reasons exist. The peat layers have changed much more in the fertile peatlands of Nuuksio. Moreover, the living biomass is much larger in Nuuksio, and due to restoration this biomass is inundated and consequently exposed to anaerobia. This has caused death of the forest species, release of bound nutrients, and, only gradually, colonization by mires species leading to renewed bounding of nutrients.

Restoration of drained peatlands is a positive action, but harmful water impacts should be avoided. This urges for hydrological knowledge in the planning and accomplishing phases.

Table 1. Annual long term unrestored leaching rates of organic carbon, nitrogen and phosphorus in the study sites, and increase in leaching as a sum of 6 post-restoration years, calculated per restored mire area.

Site	Unrestored leaching	Increase in leaching	Unrestored leaching	Increase in leaching	Unrestored leaching	Increase in leaching
	g C m^{-2} a^{-1}	g C m^{-2} $6a^{-1}$	g N m^{-2} a^{-1}	g N m^{-2} $6a^{-1}$	g P m^{-2} a^{-1}	g P m^{-2} $6a^{-1}$
Seitseminen	10.5	58	0.19	1.18	0.009	0.21
Nuuksio	5.3	107	0.13	2.54	0.004	0.18

The role of natural pipes in carbon transfer in northern peatlands

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Natural pipes are tunnels or conduits for water within soils and are often greater than 10 cm in diameter. Such natural pipes have been reported in most types of northern peatlands and have been observed to play an important role in water transfers within peat systems. However, until now no-one has studied carbon exports from natural pipe waters in deep peats. Pipes form complex undulating networks within the peat profile and may, under differing flow conditions, combine both water and carbon from various depths within the peat. Research has shown that environmental change in peatlands can lead to increased pipe formation (Holden et al., 2005). Pipes may therefore release greater amounts of carbon from deep within the peat to the aquatic and atmospheric systems in response to climate change.

We studied a blanket peatland in northern England where dissolved, gaseous and particulate carbon fluxes were monitored. The mean annual dissolved organic carbon (DOC) flux from the site is 218 kg ha^{-1} yr^{-1} (1993–2002, Clark et al. 2005). Of the 88 pipes found in this catchment, 8 representative pipes and the catchment outlet were monitored both routinely and during rainfall events. Pipe and stream waters were analysed for DOC, particulate organic carbon (POC), pH, conductivity, CO_2 and CH_4 with analysis of base cations and major anions on storm samples. Flow was also measured at these points. Deep and shallow pipes respond rapidly to rainfall inputs demonstrating strong connectivity with the peat surface. However, pipes also transported water from deeper layers of the peat. While many perennially flowing pipes respond quickly to rainfall events, pH and cation data show (e.g. Table 1) they also appear to obtain waters from deep peat layers and underlying mineral strata and thereby connect deep matrix and near-surface/overland flow. This mix of different sources of water results in highly variable concentrations of DOC and dissolved CO_2 and CH_4 within pipe water. Results to date show that 20 to 30% of the flow recorded at the catchment outlet can be accounted for by pipe flow, 53% of DOC and 200% of the exported POC in the stream is produced by the pipes (not all of the POC leaving the pipes makes its way to the stream, some of it is held in storage). Mean values of DOC for individual pipes range from 23.1 to 43.8 mg L^{-1} and mean POC concentrations vary from 0.64 to 6.38 mg L^{-1}. Episodic pulses of POC from pipe outlets are common during storm events suggesting failures of pipe walls and flushing of debris from the internal system. Mean CH_4 and CO_2 concentrations are shown in Table 1. Work that is underway to understand more about the sources of carbon being released from pipe networks will be outlined. Dual isotopic analyses (C^{14} and delta^{13}C) are to be used to further elucidate the proportions of pipe and streamwater "old" and "new" carbon.

Table 1. Variation in carbon species, pH and calcium at Cottage Hill Sike from January to July 2008 based on bi-weekly samples. P are pipe outlets and CHS is the catchment outlet. DOC, POC and Ca^{2+} are measured in mg L^{-1}, CO_2 measured as CO_2-C (mg L^{-1}) and CH_4 measured as CH_4-C (mg L^{-1})

	Site								
	CHS	P1	P3	P5	P6	P9	P32	P35	P39
Mean DOC	28.2	32.0	30.0	27.6	23.1	25.1	27.0	43.8	33.1
Mean POC	0.96	1.76	3.44	0.64	1.09	4.03	6.38	3.77	2.90
Mean CO_2	2.63	0.83	1.94	2.31	1.04	1.22	9.36	3.34	2.20
Mean CH_4	0.025	0.009	0.005	0.012	0.008	0.014	4.877	0.389	0.081
Mean pH	3.87	3.81	3.78	3.85	3.77	3.83	4.46	3.90	3.71
Mean Ca^{2+}	0.43	0.28	0.37	0.25	0.25	0.23	0.66	0.30	U

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Size and spatial variability of subsurface peatland methane stock

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Many recent studies have revealed the importance of subsurface methane (CH_4) stocks, particularly that stored as entrapped gas bubbles, for influencing peatland hydrology, ecology and carbon biogeochemistry (e.g. Strack *et al*., 2005; Rosenberry *et al*., 2006). However, there are still relatively few studies that have quantified the size of both the dissolved and bubble subsurface CH_4 pool and fewer still that have investigated how the size of these pools vary across and between peatlands. As both CH_4 production and entrapment of gas bubbles may be related to vegetation type via its controls of substrate availability and peat physical properties, it is expected that subsurface CH_4 stocks will vary between peatland microforms (hummocks and hollows) and peatland types as vegetation varies across these gradients. We collected depth profiles of pore water and entrapped gas within the upper 1 m of peat at triplicate hummocks and hollows at four Canadian peatlands. CH_4 content of the resulting samples was determined. The four study sites included a treed moderate-rich fen, two poor fens and an ombrotrophic bog. The degree of microtopographic development also varied between the study sites.

Entrapped bubble CH_4 was found at all peatlands and microforms and accounted for a large proportion of the total subsurface CH_4 stock. Subsurface CH_4 stocks varied between peatlands being lowest at the moderate-rich fen. CH_4 stock also varied between microforms with consistently higher values at hummocks compared to hollows. This is most likely linked to differences in peat structure between the microforms with hummocks consisting of denser, often woody peat that appears to be more conducive to trapping CH_4-containing bubbles. It is also likely that aerenchymatic vegetation present at hollows enhances CH_4 release and maintains lower CH_4 stock at this microform. Because of the importance of entrapped bubbles for controlling peatland hydraulic conductivity, hydraulic and chemical gradients and CH_4 efflux via ebullition, the observed variability in subsurface CH_4 stock may be important for controlling differences in ecohydrological properties between microforms. Understanding its role is important for improving our understanding of peatland ecohydrology and biogeochemistry. Future research is needed to better explain the controls on bubble entrapment in peat soil and to determine the magnitude and variability of subsurface peatland CH_4 stocks in other regions.

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Effect of experimental water table drawdown on vegetation and carbon dioxide exchange in a temperate ombrotrophic peatland

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Peatlands are important to the global carbon cycle storing accounting for an estimated one third of the global soil carbon stock and approximately 5% of global annual methane (CH_4) emissions. Carbon is stored in peatlands due to low rates of organic matter decomposition resulting from saturated soil conditions. However, it has been predicted that future climate change will result in increasing summer drought in northern peatlands resulting in water table drawdown. Water tables in northern peatlands are also increasingly being drawdown due to land-use change and resource development. This hydrologic change has the potential to increase decomposition rates and release stored soil carbon. Alternatively, increased soil aeration may enhance vegetation growth potentially increasing peat accumulation. It is also likely that the response will vary across ecohydrological gradients that naturally occur in many peatlands due to microtopography. To investigate the effect of water table drawdown on peatland carbon cycling, peak growing season vegetation cover, vascular plant aboveground biomass, and carbon dioxide (CO_2) exchange were determined at an ombrotrophic peatland with a natural water table position (N) in Quebec, Canada and compared it to neighboring sites experiencing water table drawdown for 5 (D-5) or 15 years (D-15). At each site measurements were made at triplicate hummocks and hollows to determine whether the response to water table drawdown varied between microforms.

Water table was similar at D-5 and D-15 where it was significantly deeper than N. Hummocks had significantly deeper water tables than hollows across all sites; however, microforms responded differently to the water table drawdown with very little change in water table position at hollows following drainage. Water table drawdown increased total aboveground vascular biomass primarily due to an increase in woody tissue at hummocks. Both ecosystem respiration (R_{TOT}) and gross ecosystem photosynthesis (GEP) were significantly higher at hummocks than hollows however drainage did not have a significant effect on net CO_2 exchange. This resulted because water table drawdown generally increased GEP at hollows but decreased GEP at hummocks (Table 1). Overall, larger differences in vegetation community and CO_2 cycling existed between microforms than could be induced by experimental water table drawdown. While the driest hummocks stored less CO_2 following drainage, net CO_2 uptake was enhanced at the wettest hollows resulting in little change in average net CO_2 uptake along the microtopographic gradient. These results are similar to those observed at a nearby poor fen (e.g. Strack *et al*., 2006) despite ecohydrological differences between the peatlands.

Table 1. Average (standard deviation) aboveground biomass, maximum GEP, maximum NEE and R_{TOT}*.

	N		D-5		D-15	
	Hummock	Hollow	Hummock	Hollow	Hummock	Hollow
Biomass	190 (104)	6.3 (5.0)	406 (112)	12.8 (4.2)	413 (235)	6.7 (3.0)
Max GEP	-24.0 (2.0)	-9.0 (6.6)	-18.9 (4.2)	-7.7 (3.1)	-14.4 (1.2)	-11.0 (0.2)
Max NEE	-8.3 (2.0)	-6.1 (6.6)	-4.4 (4.2)	-3.4 (3.1)	-2.6 (1.2)	-7.0 (0.2)
RTOT	15.7 (2.1)	2.9 (2.4)	14.5 (2.4)	4.3 (1.6)	11.8 (1.1)	4.0 (0.9)

* maximum GEP and maximum NEE were measured when photon flux density was greater than 1000 µmol m^{-2} s^{-1}. Units for biomass and CO_2 exchange are g C m^{-2} (assuming 50% of dry mass as carbon) and g CO_2 m^{-2} d^{-1}, respectively. Negative values indicate an uptake of CO_2 by the peatland.

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Vegetation composition, water and peat chemistry on spring, poor and rich fens in Estonia

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The distribution and nature of fen types are closely related to hydrology and nutrient condition and water sources. Species-rich fens are mainly found on the calcareous sub-surface in western islands and the western coastal part of the mainland, while poor fens are more common in the eastern part of the country. Spring fens are rather sparsely distributed over the country. The area of fens has decreased dramatically during the last centuries due to land use (Table 1), and drainage and cessation of mowing and/or grazing have changed vegetation on still existing fens.

Table. The area of fen types in Estonia in 1955 and in 1990

Fen type	Area in the 1930s–1950s, ha	Area in the 1990s, ha
Species-rich fens	80 500	5 000–8 000
Poor fens	152 000	16 000–17 000
Spring fens	1 500	250–500

The aim of our study was to find out differences in the relationships between the composition of vascular and moss plant species and peat and water chemistry in open spring, rich and poor fens in Estonia. We studied the species composition and coverage on 1 m × 1 m sample plots on 16 rich fen, 12 poor fen and 17 spring fen sites in July 2008. The height and coverage of tussocks and depth to water level were also found. Mire water and peat samples were taken near the vegetation plots. Water pH and electrical conductivity (EC) were measured, and N, P, Ca, Mg, Fe, Na and K contents of peat and water were analysed. We found that electric conductivity of mire water was significantly lower in poor fens than in rich and spring fens, 320±170, 450±160 and 460±45 $\mu S\ cm^{-1}$, respectively, but pH did not differ between the three fen types. In the presentation we shall discuss how the differences in electric conductivity are related to the chemical composition of the topmost peat layer and water and to the vascular and moss species composition of spring, poor and rich fens.

Effect of degraded peat soil re-wetting on nutrients mobilization and on carbon dioxide and methane production

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Peatlands are considered to be most well-preserved natural ecosystems in Sumava National Park (located in the southwest part of the Czech Republic in the Sumava Mts.), though 70% of these peatlands have been drained in the course of the intensification of forestry. Peat degradation and mineralization frequently cause high nitrate losses and higher CO_2 production due to the faster aerobic decomposition, while re-wetting may lead to the elevated phosphorus concentration in the pore water and higher methane production. The state of degradation and type of peatland are important factors affecting a success and rate of restoration, it is also affected by topography, climate and hydrological dynamics. Therefore the samples of peat were taken from pristine fen and from drained fen and bog in the Sumava Mts. The conditions of re-wetted or drained site were simulated by anaerobic or aerobic incubation of homogenized peat samples under laboratory conditions at the temperature 15°C for 135 days. Rates of CO_2 and CH_4 production were regularly measured during whole incubation. Soluble organic carbon and nitrogen, soluble reactive phosphorus, nitrates, ammonium and pH were measured at the start and at the end of incubation.

Rate of N mineralization and concentration of total soluble nitrogen (TSN) increased under aerobic conditions as compared to anaerobic ones, whereas concentration of soluble organic carbon (SOC) decreased. Re-wetting caused decrease of rate of N mineralization, concentration of TSN was 2 times lower and SOC decreased significantly under anaerobic conditions as compared to aerobic ones. In contrast, concentration of soluble reactive phosphorus (SRP) increased after rewetting. Rate of CO_2 production had downward trend under both aerobic and anaerobic conditions, but the rate of CO_2 production was more than 2 times lower for anaerobic incubation as compared with aerobic incubation. Rate of methane production was higher for the samples of pristine fen (up to 4 μl CH_4 g-1 h^{-1}), than the rate of production measured for the samples of drained fen and bog. Methane production was initiated after 65 days for the samples of drained fen (up to 0.7 μl CH_4 g^{-1} h^{-1}), and it was still negligible for the samples of drained bog after 135 days. pH value increased during anaerobic incubation except the bog samples.

It was concluded that restored water regime (elevation of water table) of drained peatland may lead to increase of SRP concentration in pore water and increase of rate of methane production. However, it should cause decrease of N mineralization rate and rate of carbon dioxide production within a period of few months after peatland restoration as compared to drained peatland.

Phosphorus is efficiently retained in peatland buffer zones

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Our current knowledge of the P retention efficiency of peatland buffer zone areas used to reduce sediment and nutrient leaching from forestry areas is insufficient. Especially the role of P sorption by soil in buffer zones needs closer examination as there is considerable variation in the efficiency of P retention. Six sites in southern Finland were chosen for the study. The buffer zone areas varied between 0.09–0.23 of the catchment area for the three small buffer zones and between 1.1–4.9% for the three large ones (Table 1). A total of 10 kg of solute PO_4–P was added to the inflow of the buffer zone areas during 5 consecutive days. Large 2 and 3 received the addition in two periods during two consecutive years. The concentrations of PO_4–P in inflow and outflow were measured for 2–4 years after the adding periods. P retention characteristics of the surface peat were determined with sorption-desorption isotherms before and after PO_4–P addition and the effective buffer zone area over which the added P was spread was determined from soil water samples.

P retention in the two largest buffer zone areas was complete (100% retention, Table 1), and the third largest buffer retained 94%. Retention in the three smallest buffer zones was 24%, 95% and 95% of the added P. As a result of P addition reduction in peat P retention capacity was detected in three out of four cases. The effective buffer zone area varied from 67% to 100% of the total buffer zone area. Factors contributing to efficient P retention were large buffer size and low hydrological load whereas high hydrological load combined with the formation of preferential flow paths, especially during early spring or late autumn was disadvantageous (Table 1). The study showed that peatland buffer zones are efficient in retaining added P and even relatively small buffer zone areas can significantly reduce P load.

Table 1. P retention in buffer zones (% of the added amount) and factors contributing to it: area, % of the catchment area, hydrological load during the adding period, time of addition, and soil P retention capacity before/after P addition. Figures for the two addition periods for Large 2 and 3 are separated with semicolon. - no data.

Buffer zone	P retention, %	Surface area, %	Hydrological load, mm d^{-1}	Time of addition, month	Soil P retention capacity
Small 1	24	0.23	84–152	V	Moderate/decreasing
Small 2	95	0.16	68–99	VI	Moderate/decreasing
Small 3	95	0.09	58–81	VII	Moderate/decreasing
Large 1	100	4.9	2	VII	Good/unchanged
Large 2	94	1.1	4; 60–96	VI; IX	Good/-
Large 3	100	2.5	3–12; 4–5	VI; VI	-/-

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Assessing global microbial methane oxidation in peat moss through biomarker analyses and compound specific isotope labelling

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Symbiotic methane oxidising bacteria (methanotrophs) in peat moss (*Sphagnum*) probably play an important role in the global carbon cycle, by reducing methane emissions from peat bogs and providing carbon dioxide to *Sphagnum* (Raghoebarsing et al., 2005), see Fig. 1. The significance of this symbiosis on a global scale is, however, yet unknown. Therefore, we collected different *Sphagnum* mosses from peatlands all over the world, including Patagonia, Great Britain, Sweden and Siberia. They were tested for methane oxidation activity and analysed for molecular methanotroph biomarkers. Additionally, we incubated selected mosses with 99% ^{13}C labelled methane to confirm the presence of methanotrophs.

Sphagnum mosses from all over the world showed methane oxidation activity, indicating the global occurrence of the methanotroph-*Sphagnum* symbiosis. This was further substantiated by increasing incorporation of methane-derived label into bacterial compounds (C32-ββ-homohopanol, liberated from tetrafunctionalised hopanoids) over time. Plant-derived sterol showed also label incorporation, confirming that methane-derived carbon dioxide provides an important carbon source for *Sphagnum*. Labelling experiments additionally showed that mono-unsaturated fatty acids, hopenes and hopanols (hop-17(21)ene, 2-methylhop-17(21)ene and C32-ββ-homohopanol) are the prevailing methanotroph lipids in *Sphagnum*. These compounds were found in all the samples analysed and are potential biomarkers for methanotrophs in ancient peat bogs. Overall, our results show that the symbiosis between methanotrophs and *Sphagnum* is an important worldwide phenomenon, with a crucial role in the carbon cycle in peat bogs.

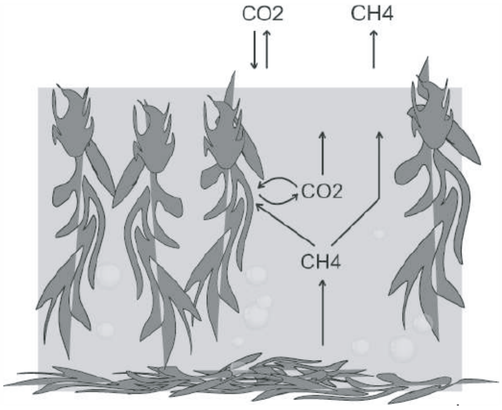

Fig. 1. Symbiotic methanotrophs oxidise CH_4 to CO_2, which is in turn assimilated by *Sphagnum*, efficiently recycling carbon.

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Vegetation composition change affects the quality and quantity of carbon inputs in peatlands following persistent water-level drawdown: Implications for carbon pools and fluxes

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Peatlands are ecosystems that accumulate organic matter due to an imbalance between net primary production and decomposition, with decomposition being slower than the production. The carbon (C) storage of a peatland is labile, and sensitive to variations in environmental conditions. Changes in peatland functions may be mediated through e.g. land-use change, or climatic warming. In both cases, drawdown of the water level is a key factor.

With respect to vegetation, a persistent change in the water level induces acclimation and adaptation, first within the existing community as changes in root:shoot ratios and species abundances, followed by slower but more drastic changes in vegetation composition when species better adapted to the new conditions gain dominance. Changes in both species abundances and species composition may be critical turning points for the C balance of a site. While pristine peatlands accumulate C mainly from plant litters of the ground vegetation (Sphagnum mosses and sedges), in drained peatlands the drastically increasing tree litter inputs may be more important.

The aim of this study was to examine how does the shift in vegetation composition following persistent water-level drawdown affect the quality and quantity (Fig. 1) of C inputs in peatland sites with different nutrient regimes. Including other components or mediators of the C cycle (decomposition rates, microbial activity) we estimate the impact of the changes in litter inputs on the C balance of peatlands. Understanding the factors that control the C fluxes in boreal peatland soils is essential for predicting their response to global change.

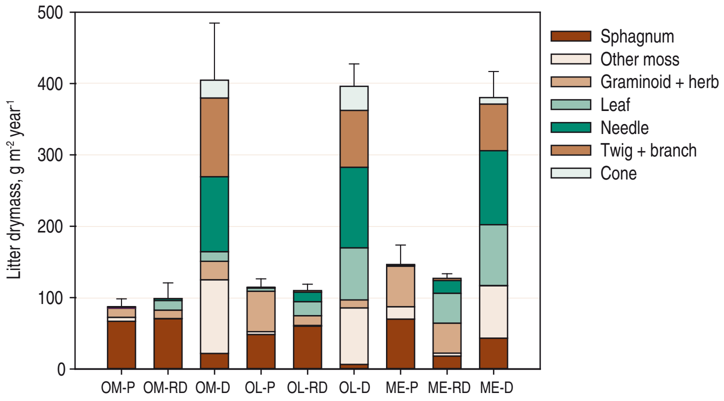

Fig. 1. Litter inputs per different peatland sites and water-level regimes. OM = bog (ombrotrophic); OL = oligotrophic fen (minerotrophic); ME = mesotrophic fen (minerotrophic); P = pristine; RD = drained ca. 4 years ago; D = drained ca. 40 years ago. The error bars show standard errors for the total litter production per plot.

Use of peatland buffer zone areas for nitrogen retention in forested catchments

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Nitrogen (N) and phosphorus (P) are the limiting factors for plant and microbial growth in most boreal waters (Pietiläinen & Räike 1999). Because of the growth-limiting effect, an excess of N and P in watercourses often enhances eutrophication that furthermore leads to cyanobacterial blooms, phosphorus release from the bottom sediment and water quality deterioration along with changes in flora and fauna (Pietiläinen & Räike 1999, Kauppila & Bäck 2001, Vesiensuojelun suuntaviivat...2007). As nutrient load in watercourses has been growing recently, the reduction of P and N in Finnish inland waters, coastal waters and groundwater has been one of the key interests in Finnish water protection policy (Vesiensuojelun suuntaviivat...2007). Because buffer zone areas have been shown to be an effective and sustainable means of buffering aquatic ecosystems against detrimental substances, their use is widely recommended (Ihme et al. 1991, Nieminen et al. 2005). However, very few studies have examined N retention in forested catchments, thus there is a great need to study the subject further. To address the gap of knowledge, we investigated nitrogen retention in buffer zones constructed on three pristine-like mires and three drained peatlands. The study was conducted by adding ammonium nitrate solution to the waters flowing into buffer zone areas during 1 or 2 addition periods. Water samples were collected before and after the addition, along with samples of peat, vegetation and N_2O+ N_2.

The main factors controlling the retention of N were the size of the buffer zone area and runoff volume. The largest mires retained the inorganic nitrogen almost completely, while small buffer size with considerable discharge during the addition period reduced the retention capacity to be even less than 15%. NH_4-N reduction was lower compared with NO_3-N at each study site. A significant amount of N added was released as N_2O and retained in vegetation. N_2O emissions increased immediately after the added nitrogen had found its way to gas sampling points. Thus, the emissions were dependent on runoff regimes after N addition. Biomass of vegetation increased slightly, and there was a clear trend in the increase of the field layer along with the decrease of the bottom layer. We suggest that a significant proportion of the N added has also been retained in microbial biomass and in the peat matrix.

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Peatland biogeochemistry in northern Alberta, Canada: processing of atmospheric deposition

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Increased industrial activity in the Athabasca Oil Sands Region of northern Alberta, Canada, has resulted in elevated emissions of S and N that pose a risk to the surrounding ecosystems. The existing emissions management framework for the region is dependent on both monitoring programs and model generated estimates of future soil and surface water chemistry. The spatial complexity of the landscape, owing to limited topography and extensive coverage of fens and bogs is currently an impediment to the application of dynamic hydrogeochemical models. At two intensively studied catchments of different hydrologic character, the spatial and temporal variability in soil, fen water and lake water chemistry have been studied to provide insight into key biogeochemical processes occurring in this landscape. This information is required for parameterization of the dynamic hydrogeochemical model MAGIC (Cosby et al. 1985) being used to support the management framework.

Surface water chemistry varies widely within the poor fen dominated peatlands. The data suggest that these peatlands can act as a significant sink for both sulphur (S) and chloride (Cl). At present S and Cl concentrations decrease in deeper (40 cm) fen waters and integration into the plant material may account for much of the observed retention. Further evidence from laboratory experiments indicates the potential for S retention on the exchange sites of organic soils under conditions of high acid deposition. Despite very low mineral weathering rates in upland soils, groundwater intrusions in the peatlands can act as a source of calcium and magnesium to the lakes. Additional observations using isotope hydrology (deuterium excess) are indicative of these localized groundwater sources to the fen complexes. This work reveals that the connection between upland draining and fen waters is minimal, thus these landscapes must be treated accordingly in dynamic model applications. Implications for applying a dynamic lumped-parameter catchment-scale model to predict changes in water chemistry of these heterogeneous watersheds in response to changing atmospheric deposition will be discussed.

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From microbes to hummocks: upscaling peatland carbon fluxes to the ecosystem level

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Reliable estimates of carbon fluxes to and from peatlands, as carbon dioxide (CO_2) and methane (CH_4), are vital for quantifying the feedbacks between climate change and the carbon cycle. However, peatland ecosystems are not included explicitly in global climate models (Limpens et al., 2008). The complex spatial and temporal variability of their carbon fluxes represents a key source of uncertainty. Consequently, greenhouse gas feedbacks from peatland carbon stocks are omitted from estimates of future climate change. Upscaling carbon fluxes from the microscale to the ecosystem scale is a way of resolving uncertainty, and crucial for the inclusion of peatland carbon feedbacks in models of future climate change.

Peatlands are highly heterogeneous environments, composed of a mosaic of microhabitats: hummocks, gullies, lawns, and pools, colonised by plants with different morphological and physiological attributes. Assemblages of plant species represent collections of Plant Functional Types (PFTs), which vary according to microhabitat (pools are dominated by sphagnum species, lawns by ericoids such as *Calluna vulgaris*, and hummocks and gullies by graminoids including *Eriophorum* sp.). Different PFTs have characteristic effects on inputs of carbon to the peat and outputs as autotrophic and heterotrophic respiration (De Deyn et al., 2008). Different plant species with particular functional traits that affect the quantity and quality of carbon inputs, as litter and root exudates, are important regulators of soil microbial communities responsible for aerobic and anaerobic decomposition (producing CO_2 and CH_4 respectively) (Bardgett et al., 2008).

Mapping PFTs provides an accessible means of modelling the spatial variability of potential carbon fluxes. Small-scale spatial heterogeneity can make an important contribution to carbon fluxes from peatlands at the ecosystem scale. For example, McNamara et al. (2008) used GIS to quantify the contribution of gully hotspots to ecosystem CH_4 fluxes. Increasing availability of high resolution remotely-sensed datasets such as QUICKBIRD and LiDAR, in addition to geostatistical techniques such as Kriging, now permit the mapping of factors and modelling of carbon fluxes from peatlands at the microscale. **This project aims to combine a GIS approach, incorporating LiDAR and extensive vegetation and peat depth survey data, with experimental work focussing on the influence of PFTs on soil microbial biodiversity and carbon fluxes.** Bulk density analysis of peat cores, combined with incubation experiments, will provide a basis for understanding variation in peatland carbon storage under a range of environmental conditions. Results from experimental work will be used to model peatland carbon fluxes based on PFTs and topographic characteristics at the microhabitat scale, which can be upscaled to provide more reliable estimates of ecosystem carbon fluxes. Here we present a novel methodology for upscaling microhabitat fluxes of CO_2 and CH_4 to the ecosystem scale, and provide a summary of initial conclusions derived from survey work conducted at Moorhouse National Nature Reserve, north Pennines, UK.

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Cosmogenic ^{10}Be as a potential dating tool in peat

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Ombrotrophic *Sphagnum* dominated peatlands receive inputs of water, nutrients, and pollutants solely via atmospheric deposition. Peat accumulates vertically as a result of the upward growth of Sphagnum mosses such that depth in the peat column reflects time. If materials remain immobile after deposition to the peat surface, dated peat profiles can reconstruct historical deposition patterns. Fine-scale temporal resolution of surface peat ages can be obtained using ^{210}Pb dating, but only over the past 150–200 years. Radiocarbon dating is problematic in young peat (<300 years). We suggest that atmospherically deposited cosmogenic ^{10}Be may provide a novel approach to peat dating. Immobility of deposited ^{10}Be, a requisite for its use as a dating technique was examined in the laboratory.

Eighteen peat cores were collected using PVC pipe (10 cm diameter, 50 40 cm tall) from a boreal bog near Calling Lake, Athabasca (55° 55’ N, 113° 40’ W). Surface vegetation in all cores consisted predominantly of *Sphagnum fuscum*. In the laboratory, six cores were randomly assigned to one of three water table position treatments: high (3 cm below the peat surface), low (15 cm below the peat surface), and fluctuating (alternating between high and low, with water table position changed weekly). Cores were watered every other day, applying 50 mL of synthetic rain water. For each water table position treatment, 2 cores received only synthetic rain water (controls) and 4 cores received synthetic rain water with added Be (4 mg of Be as $Be(NO_3)_2$ added in 20 simulated rainfall events over 40 days, followed by 18 simulated rainfall events without Be over an additional 36 day period (methods mirror those used of Vile et al. 1999).

Beryllium concentrations were below the limits of detection (5 $\mu g\ L^{-1}$ in digest solutions) in all sections of the control cores. For the cores that received Be additions, we recovered about 80 % of the added Be (3.2 out of 4 mg). The vertical distribution of Be (Fig. 1) indicates limited Be mobility. On average, 91, 85, and 99% of the recovered Be was located within the top 6 cm of the cores in the fluctuating, low, and high water table treatments. These results are quite similar to those of the Pb mobility study of Vile et al. (1999). Both Pb and Be are well retained and have limited mobility in ombrotrophic *Sphagnum* peat.

Using the 210Pb dates for the 3-6 cm depth section of a single ombrotrophic bog core (from Patuanak, Saskatchewan in 1999; Turetsky et al. 2007), we estimate a 10Be deposition rate of 13.7 (±1.4) x 109 atoms/m2/yr. Using this deposition rate, we find reasonable agreement between dates based on 210Pb and 10Be in the upper 39 cm of the peat core (depths below 39 cm were too old to be dated using 210Pb) (Fig. 2). We obtained three AMS 14C dates (48-51, 54-57, 60-63 cm). Results suggest that cosmogenic 10Be may serve as a new and valuable dating approach for ombrotrophic peat deposits.

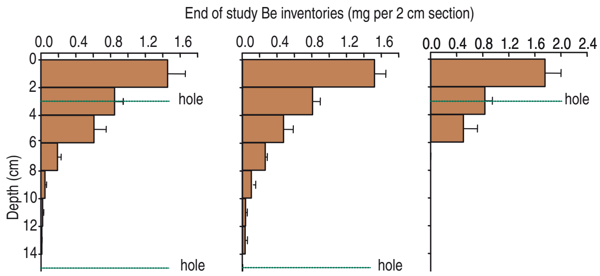

Fig. 1. Final distribution of added Be at the end of the laboratory Be mobility experiment.

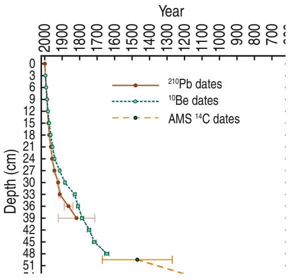

Fig. 2. Dates for a single peat core, as determinedby 10Pb, 10Be and 14C.

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Could managed burning of vegetation be good for peat soil C budgets?

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A common management strategy in UK uplands is the use of controlled burning to manage vegetation. In England, it has been estimated that 40% of moorland has received some burn management (Thomas et al., 2004, quoted in Yallop et al., 2005) with estimates of as much as 17% of English uplands having been burnt in the last 4 years (Yallop et al., 2006). A priori, the consequences of burning of heather or grass on peat soils is assumed to be detrimental for carbon storage, eg. Garnett et al. (2000). However, there is little or no evidence, other than anecdotal, that supports this view. The burning of vegetation produces char (black carbon) and char is a high carbon content material with a very low degradation potential in comparison to the normal litter produced by moorland vegetation – therefore production of black carbon locks up carbon relative to the normal litter produced by moorland vegetation. However, char is produced in low volumes in comparison to the annual litter production; it is only produced once in the burning cycle (eg. once every ten years); and the burning of vegetation means that litter production in the years after the burn is limited – therefore it might be considered that burning limits the normal peat accumulation process. The problem is that we do not know the balance of these effects. Kuhry (1994) have shown that peat accumulates slower where there are more frequent wildfires, and Garnett et al. (2000) have shown that peat accumulated slower under a 10-year managed burn than under no burn, but neither study actually measured carbon accumulation they measured depth of peat and assumed that all the peat had the same compostion. Firstly, this study reports simple modelling of carbon accumulation under regular burning and char production shows that it is theoretically possible that more carbon accumulates under regular "cool" burns and that it is possible that more carbon can accumulate under "cool" burns while leading to lower peat depth accumulation. Secondly, the modelling study was supported by a number of field surveys where loss of biomass during the burn was compared to production of black carbon and fate of the litter and soil layers. Thirdly, laboratory studies were conducted upon typical peatland vegetation in order to assess biomass fate and black carbon production acrossa range of burn temperatures and fire speeds. This study was able to quantify the fate of carbon across a managed burns and wildfires in not only the biomass butr also the litter and soil carbon pools. The study shows that the critical factors are: the degree to which a managed burn is "hot" i.e. the fire contacts the litter or soil layers; and the fire frequency in relation to the growth rate of the biomass.

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Modelling the present and future carbon budget of upland peat soils at the regional scale

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Upland peat soils represent a large terrestrial carbon store and as such have the potential to be either an ongoing net sink of carbon or a significant net source of carbon. In the UK many upland peats are managed for a range of purposes but these purposes have rarely included carbon stewardship. Firstly, it is important to understand the present state of theses heavily managed peatlands but also to assess their prognosis under climate change.

The sustainable uplands RELU project has developed a model for calculating carbon fluxes from peat soils that covers all carbon uptake and release pathways (eg. fluvial and gaseous pathways). The model has been developed so that the impact of common management options within UK upland peats can be considered. The model was run for a decade from 1997-2006 and applied to an area of 725 km^2 of upland peat soils. The study estimates that the region is presently a net sink of –62 Ktonnes C at an average areal export of – 136 tonnes CO_2 equivalent/km^2/yr. If management interventions were targeted across the area the total sink could increase to –160 Ktonnes CO_2 equivalent at an average export of– 219 tonnes CO_2 equivalent/km^2/yr. The study has considered the theoretical possibility of triple gain within peat ecosystems with respect to carbon storage, namely: avoided loss, transitionary sinks and perpetual gain and can demonstrate this approach by modelling the carbon budget of the peat soils of the Peak District National Park. Given present costs of restoration and value of carbon offsets the study suggests that of the (281/725) km^2 of the area where a carbon benefit was estimated by modelling 51% would show a profit from carbon trading within 30 years. This hindcasting of different management options shows that the most efficient approach to increasing greenhouse gas benefit in the region is to re-vegetate all bare soil areas and the least efficient is the blocking of drains and gullies where the increase in methane fluxes that would result threatens their carbon benefit. The modelling was then projected to 2030 and given climate change we see that all restoration would have to occur in a context of shrinking carbon storage in these already marginal peats.

The response of two peat bogs to predicted warming and drying

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Peatlands contain one third of total soil carbon and cover 4.10^6 km^2 of the word's land surface. Their response to predicted climate change is unknown. Peatlands are a sink of atmospheric carbon but there are fears they could become a net source of carbon-containing gases and accelerate further climate warming. Here, we present the results of a comparative study of how peat substrate will respond to predicted warmer and drier conditions during summers.

We collected 20 replicated peat cores from two European sites differing in mean annual temperature, Velké Dářko (Czech Republic; warmer; 7.2°C), and Stor Amyran (Sweden; colder; 4.0°C). For 8 months, the cores (10 cm ∅, 30 cm deep) were incubated in growth chambers with a ligth/dark cycle, and under controlled irrigation. At times 0, 4 and 8 months each peat core in a PVC cylinder was covered by a rubber end cap, flushed with oxygen-free nitrogen and kept at the room temperature over a period of two days. The concentration of headspace CO_2 and CH_4 were determined periodically using gas chromatography.

First, the effect of months-long temperature memory on gas emissions was studied using two different warming scenarios. The temperature increase was 5 and 6°C, the same as the predicted warming over the next century. Peat core replicates were kept at temperature regimes of 11°C versus 16°C and 16 versus 22°C. No temperature effects on CO_2 emissions were found. Under warming from 11 to 16°C we measured almost two-fold net production rate of CH_4, the production of CH_4 decreased due to warming from 16 to 22°C.

After an 8-month incubation, peat cores under drying conditions (decreasing water level by as much as 12 cm) were compared to samples with home-site water level. No effect on CO_2 emission in spite of 20 times decreasing CH_4 production was observed.

After four months of incubation, the combined effect of warming and drying conditions at temperatures of 16 and 22°C was studied. Despite no individual effect of warming or drying for CO_2, a three times higher CO_2 production was seen. Methane emissions decreased 70 times.

The warmer site Velké Dářko produced 7 times higher amounts of methane comparing to the colder site Stor Amyran. This was in agreement with the concept of greater peat accumulation under colder climate.

Site-specific behavior of peat substrate exposed to changing conditions was observed. Regardless of water table level, warming led to higher CO_2 production at the warmer site Velké Dářko. Moreover, drying conditions led to a steeper reduction in CH_4 production at Velké Dářko compared to Stor Amyran.

Our results show that methanogenesis is more temperature dependent than CH_4 consumption. A decreasing water table level will have a stronger effect on CH_4 production than the predicted higher temperature. The warmer site Velké Dářko responds more strongly to predicted climate change than the colder site Stor Amyran. CH_4 consumption is influenced by the combination of warming and drying. Considering the measured concentrations and the known relative contributions of CO_2 and CH_4 to the greenhouse effect, the combined effect of warming and drying at our sites would be a net decrease in the greenhouse effect (4 times lower direct contribution and 8 times lower indirect contribution). Thus, during dry and hot summers, the studied peatlands may reduce their contribution to an overall greenhouse effect.

Carbon exports and carbon character from catchments in a forest-wetland gradient in boreal Sweden

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Here we report result from 3 studies on dissolved organic carbon (DOC) exports and carbon character in a 68 km^2 boreal catchment in northern Sweden. The seasonal variation in DOC export was studied in 15 nested subcatchments within the Krycklan Catchment Study. The mean annual DOC exports from the 15 subcatchments (0.03–21.72 km^2) ranged from 14.8 to 99.1 kg ha^{-1} yr^{-1}. During winter base flow the spatial variation was linked to patterns in wetland coverage. During snowmelt in spring the spatial variation was connected to characteristics describing size and location of the catchment (i.e. median stream size, silty sediment distribution, stream order, altitude, and proportion of catchment above highest postglacial coastline HC). During the snow-free season the spatial variation in DOC exports was regulated by the amount of wetlands and forests, particularly forests made up of Norway spruce (*Picea abies*). An interesting result from this study was the effect of size implying that small headwaters may be the largest contributor to the terrestrial DOC export, per unit area (Ågren et al., 2007).

The character of DOC was studied in nine of the streams as well as in adjacent soils during two years, with focus on the spring snowmelt period. The streams selected for this study was small and covered a forest-wetland gradient, spanning from 0% to 69% wetland coverage. We found that wetland-derived DOC had higher average molecular weight than forest DOC (indicated by A_{254}/A_{365}), and the wetland runoff DOC was also more aromatic than DOC from forests (indicated by $SUVA_{254}$). The character also changed with flow and during low flow, the streams appeared to be dominated by wetland-derived DOC. During the spring snowmelt period, the character changed to lower molecular weight and more aliphatic DOC, particularly in streams with a high proportion of forest in the catchment. The forested soil solutions had higher molecular weight in the surface horizons that were hydrologically activated during the high flow events, while wetland soil solution had relatively low average molecular weight at all depths. Forest soils contributed more to stream DOC concentration during snowmelt that during winter low flow (Ågren et al., 2008b). The bioavailability of the carbon in the streams (measured as bacterial production during 7-day-dark bioassays) was found to be explained by both the amount and character (low-molecular weight fractions) of the carbon. The forest carbon had a higher bioavailability than the wetland carbon, and although mires had higher area-specific export of DOC, forests were found to be the main contributors of carbon supporting bacterial production in streams (Ågren et al., 2008a).

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Influence of plant residue quality on enzyme kinetics during early stages of decomposition in soil

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The process of decomposition of plant residue in soil is not only influenced by environmental variables such as humidity and temperature, but also by parameters such as intrinsic chemical characteristics of plant residues (Caddish and Giller, 1997; Bertrand et al., 2006; 2009) and the nature of micro-organisms involved in the decomposition process. In soil, the majority of biochemical reactions, including those related to the biodegradation of plant residues are catalyzed by enzymes. While it has already been shown that plant residue decomposition could be closely correlated to the activity of key enzymes (Sinsabaugh et al. 1992), few studies were performed to reveal the impact of the chemical quality of plant residues on their rate of decomposition via the analysis of enzyme activities.

The objective of this work is firstly to verify, whether contrasted kinetics of decomposition due to the nature of residues, will generate different enzyme kinetics. One of the main originality of this approach is to take into account 1) the presence or absence of endogenous micro-organisms on plant residue and 2) to measure enzyme activities in both the plant residue and soil, and their dynamics.

Incubations of plant residues corresponding to aerial parts (leaves) and underground parts (roots) of maize plants were performed. The role of endogenous micro-organisms in the process of decomposition was evaluated by using three different methods of plant residue sterilization i) unsterilized ii) partially sterilized by a surface treatment and iii) overall sterilized by gamma radiation. The incubations were conducted under controlled conditions for 40 days in which soil moisture was kept at a potential of -80kPa and temperature was maintained at 15 °C with nitrogen (N) as a non - limiting factor. In different steps, soil and plant extracts (leaf and root) were analyzed by measuring the activities of four different enzymes involved in the process of decomposition.

The results of these assays will be discussed in relation to the kinetics of mineralized C of maize leaves and roots. We are expecting on the basis of this combination 1) to identify the origin of enzymes involved in the process of decomposition and 2) the use of enzyme assays to show essential functions involved in the process of decomposition in relation to the nature of the hydrolyzed substrate.

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Soil biodegradation of maize roots: importance of chemical characteristics

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Roots remaining after crop harvests constitute one of the main sources of carbon entering the soil and contribute to build up the soil organic matter pool (Rasse, 2005). Unlike for plant above-ground parts, few studies relate in details the processes driving soil decomposition of roots. The chemical quality of crop residues is a well-known factor that influences their decomposition in soil and associated carbon and nitrogen fluxes. For instance, the proportion of the cell wall fraction and its composition are known to have a strong impact on crop residues decomposition (Bertrand et al., 2009). Roots are characterized by a high content in cell walls when compared to above-ground parts and most of these are strongly lignified. To assess the precise role of the chemical quality of cell wall components on the kinetics of carbon mineralization, roots of 16 different maize genotypes including “brown-midrib” mutants and normal maize were used. These lines were shown to have similar soluble and cell wall contents while they differ significantly in the cell wall composition despite root anatomy and tissue distribution did not vary.

Roots were sampled in the field and were separated, washed and dried pending analyses. Biochemical characterization consisted on classical determination such as C-to-N ratios and Van Soest extractions. In addition to these, cell wall composition was determined by measuring the amount and nature of neutral sugars by acid hydrolysis, of lignin by thioacidolysis (Lapierre et al., 1986), of phenolic acids following the method described by Beaugrand et al., (2004). Roots were then cut into small pieces (5–8 mm) and incubated in a loamy soil at 15 °C and -80 kPa for 800 days. Potassium nitrate was added to the initial N concentration of the soil to ensure that N would not limit decomposition (Henriksen and Breland, 1999). Carbon mineralization was measured in soil samples incubated in the presence of a CO_2 trap.

Carbon mineralization kinetics of maize roots differed markedly between the genotypes with the total amount of C mineralized ranging from 42% to 70% of the added C after 800 days incubation, thus confirming the importance of specific cell walls properties on carbon mineralization (Machinet et al. 2009).

The Roth C model represents the chemical quality of crop residue through two compartments: one labile DPM and one recalcitrant (RPR). This model was used to simulate the C kinetics and the results showed that standard parameters did not produce correct simulations. These results will be discussed in regard to i) their importance on C and N cycles and ii) the understanding of the relationships between crop chemical characteristics, the biodegradation processes and how to model it.

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Long-term trends of DOC in throughfall and soil solution of 22 temperate forests

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In many regions of the earth, DOC concentration has increased in rivers and lakes during recent decades. The DOC increase has been attributed to decreasing acid deposition (Evans et al. 2006) and some other factors such as increasing litter productivity (Roulet and Moore, 2006). Here we report long-term trends of DOC concentrations and fluxes in throughfall and soil solution below the organic layer and different mineral soil depths of 22 temperate forests in Bavaria, Germany. The forest sites are part of the European level II programme where DOC and other parameters have been monthly sampled and analyzed between 1995 and 2007. Soil water fluxes were modeled on daily basis with the same hydrological model for all 22 stands. The Seasonal Mann-Kendall test for auto-correlated data was used to detect monotonic trends in the time series (Hirsch and Slack, 1984). The magnitude of trend slopes was calculated with the Seasonal Kendall Slope Estimator (Hirsch et al., 1982).

In 12 of 22 sites, DOC concentration below the organic layer significantly increased by 0.4 to 3.0 mg C L^{-1} yr^{-1} from 1995 to 2007 whereas no significant trends were calculated for the other 10 sites and for throughfall in all sites. The increase in DOC concentration coincided with decreasing sulfate concentration, indicating that sulfate concentration is possibly an important driver of DOC release in the organic layer of these forest sites. Tree species, soil properties and annual litter production were not associated with the positive trend in DOC concentration. In contrast to the organic layer, DOC concentration below 30 cm mineral soil depth decreased by <0.1 to 0.4 mg C L^{-1} yr^{-1} at 9 sites. Opposite trends indicate that different processes dominate DOC turnover in the organic layer and mineral soil. Analyses of monthly DOC fluxes revealed no or no uniform trends during the study period. Our results suggest that not vertical leaching but surface runoff together with enhanced mobilization of DOC in the organic layer of forest soils contributed to the increase of DOC in surface waters. When sulfate concentration is a main driver, low level of sulfate input should limit the DOC mobilization in Central European forests in the near future.

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The effect of wood ants on carbon and nutrient fluxes in boreal forests

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Wood ants (*Formica rufa* group) are regarded as key-species in forest ecosystems, where they live in mutualistic relationships with canopy-dwelling aphids. These aphids excrete honeydew which the ants use as food, and as a trade-off the ants protect the aphids against predators. This mutualism between wood ants and aphids induces carbon (C) and nutrient fluxes from trees which can reduce their growth (Kilpeläinen et al. 2008). Additionally, the honeydew from aphids increases the amount of C added to the soil beneath the canopy as throughfall. Wood ants can have a significant impact on soil nutrient pools and fluxes in boreal ecosystems (Jurgensen et al. 2008). Here we report results of several recent or ongoing experiments conducted in boreal forests of Eastern Finland. Our aim was to quantify the role of wood ants in regard to nutrient pools and fluxes on the forest ecosystem level.

We found out that wood ant mounds do not represent significant C or nutrient pools in boreal coniferous forests (< 1% of the respective total forest soil pools), but by accumulating organic material into their mounds, wood ants increase the spatial heterogeneity of forest ecosystems (Kilpeläinen et al. 2007). The CO_2 efflux from ant mounds was many times higher than from the surrounding forest floor, but on ecosystem level, it corresponded only to 0.5–1% of the CO_2 efflux from the surrounding forest floor (Domisch et al. 2006). However, wood ants greatly affected fluxes from the tree canopy to the soil in the form of honeydew produced by aphids. When compared to the needle litter from conifers, which, like honeydew, represents a flux from the trees to the soil, honeydew transport represented a considerable flux. Compared to the fluxes in needle litter, the annual food input of C into wood ant mounds was rather small, 2–6%. However, the magnitude of the N and P input into ant mounds, as compared to fluxes in annual needle litter, was much higher, ranging from 12–33% for nitrogen and 27–58% for phosphorus. Presently, we are investigating the significance of the ant-aphid mutualism on throughfall water quality on the forest ecosystem level. Preliminary results will be presented.

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Controls on DOC fluxes in temperate grasslands

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Leaching of dissolved organic carbon (DOC) to the groundwater is thought to represent a significant C flux in temperate ecosystems which directly affects ecosystem C balance. However, quantifications of DOC fluxes in well drained agricultural soils are rare, often only DOC concentrations are reported.

DOC fluxes and their controlling factors were investigated on two grassland sites with similar climatic conditions but different soil types (Vertisol vs. Arenosol) for a 2.5-year period. Parts of both grasslands were disturbed by deep ploughing during afforestation. Contrary to what was expected, ploughing did not increase DOC export but surface soil DOC concentrations decreased by 28% (Vertisol) and 14% (Arenosol). DOC flux from the soil profile was negatively influences by the clay content of the soil with seven times larger DOC export in the clay-poor Arenosol (55 kg C ha^{-1} a^{-1}) than in the clay-rich Vertisol (8 kg C ha^{-1} a^{-1}). The possibility to upscale DOC fluxes from drained soils using texture maps will be discussed.

DOC export was not correlated with soil organic carbon stocks. Large differences in ^{14}C concentrations of 22–40 pMC between soil organic carbon and DOC in the subsoil indicated that both C pools are largely decoupled. We conclude that DOC export at both sites is controlled by physicochemical parameters such as the adsorption capacity of soil minerals and directly depends on the water balance of the ecosystem.

Conclusions on the importance of DOC fluxes for the C balance of temperate grasslands are drawn in the light of additional measurements of soil respiration, total ecosystem respiration and net and gross primary production determined with chamber measurements and an eddy covariance tower. Only in the acidic sandy Arenosol DOC export was a significant C flux of about 8% of net ecosystem production.

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Spatial and temporal patterns of soil-CO_2-efflux in a forested catchment in western Germany

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Soil, vegetation and the adjacent atmospheric boundary layer constitute key compartments, which are characterized by extremely complex inner patterns, structures and processes that act at different time and space scales. Within the scope of the Transregional Collaborative Research Centre 32 "Patterns in Soil-Vegetation-Atmosphere Systems: monitoring, modelling and data assimilation" this spatio-temporal variability of catchment properties and their effect on water, solute and CO_2 fluxes on a mesoscale is addressed. In this context special emphasis is placed on the investigation of spatio-temporal patterns of soil CO_2 effluxes and the follow-up application of a process-based model for simulating carbon related processes.

Weekly CO_2 soil respiration measurements using a closed dynamic chamber system have been carried out in *Picea abies* stands situated in the national park of the Eifel Mountains since 2006. Parallel measurements of temperature and soil moisture have been undertaken, too. The measurement setup is currently going to be extended. A long-term chamber will be installed to guarantee insight into variability of daily CO_2-efflux, furthermore the installation of a wireless soil moisture network will provide area-wide information on moisture conditions. For the necessary separation of microbial and rhizosphere respiration due to the different reaction of each to a change in environmental conditions (Boone et al., 1998), the method of trenching and root removal (Subke et al., 2006) has been applied. Future plans include the implementation of isotopic labelling as a more accurate method for discerning microbial and rhizosphere respiration (Subke et al., 2006).

In this presentation a focus is laid on a first evaluation of the results obtained from the ongoing measurement campaign with regard to spatial and temporal patterns of soil respiration. In accordance with literature (Buchmann, 2000), correlation of soil-CO_2-efflux with temperature is slightly better for temperatures in 5 cm depth compared to the correlation with temperatures in 11 cm depth. The general finding that temperature displays the most influencing factor on soil-CO_2-efflux (Buchmann, 2000; Subke et al., 2006) can be approved, since calculated coefficients of determination lay between 50–81%.

Temperature plays a major role in temporal variation, as resembled in the data. When looking at seasonal patterns the highest spatial variability can be found during summer months, while winter months generally show a lower spatial variability. Since spatial variability is mostly attributed to root growth and therefore root respiration (Subke et al., 2006) root growth in spring and winter months might be responsible for the observed high spatial variability. Temporal variability during one season in general was highest for spring and autumn, while winter showed comparably low temporal variability in CO_2-efflux. The greater temperature variation in spring and autumn might display a possible reason, whereas frost might play a role in the more or less constant CO_2-efflux during winter months.

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Decreasing soil carbon with latitude in Sweden explained by a gradient in N deposition

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Increasing temperatures and high N deposition are two factors which both may lead to changes in soil organic carbon (SOC) pools in forest ecosystems. In Scandinavia a trend with decreasing SOC stocks from south to north is well established. The trend is contrary to a global trend with increasing SOC with decreasing temperature. The gradient in SOC in Scandinavia coincides however approximately with both a gradient in climate and a gradient in N deposition and the effects of these factors are therefore difficult to separate. We have used data from the National Forest Soil Inventory in Sweden and analysed how temperature and N deposition are related to SOC stocks in the O horizon and mineral soils of podzols on glacial till. In order to overcome the problem of co-variation between the temperature and N gradient we divided the dataset into classes with similar N deposition or temperature sum. The relationships between temperature and N deposition with the SOC stock were thereafter analyzed with linear regression within each N deposition or temperature class. Our analysis showed that N deposition explained the south to north gradient in SOC stocks over Sweden significantly better than temperature. Temperature did not show a relationship with SOC stocks, alternatively had a tendency for a negative relationship. This implies that continued high N deposition may result in increasing SOC stocks, but that the projected increase in temperature probably will have small effects on SOC stocks in Sweden.

DOC dynamics at a boreal riparian zone: Implications of winter processes

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Dissolved organic carbon (DOC) dynamics is a defining feature of surface waters in the boreal region. Since DOC is mainly exported from the riparian soil, it is of great concern how the different soil processes influence the DOC dynamics in the riparian zone. One of the climate change implications in the future is alteration in extent, timing and duration of snow in the boreal region which may in turn affect the soil frost regime, below-ground temperature and frequency of freeze-thaw events (Mellander et al., 2007). In order to investigate how the snow cover extent and soil frost regime can affect the DOC dynamics, we have performed a field-scale soil frost manipulation experiment in a boreal riparian zone of a small first order stream in northern Sweden for six years. Three soil frost treatments (deep soil frost, shallow soil frost and control) are applied with three replicates each. The soil water samples are collected at five depths of soil profile (10, 25, 40, 60 and 80 cm) by means of suction lysimeters equipped with thermostat controlled heating system which made the sampling possible during the entire year by preventing the collected water from freezing while passing the frozen soil horizons. Sampling was more intensive during spring and summer. In addition, a laboratory experiment was conducted to study how DOC responds to the interaction of multi-factors. The experiment was based on a central composite face-centred (CCF) design and four factors were applied at three levels (see Table 1).

Table 1. Factors and levels of the factors in the CCF design

Factors	Temperature (°C)	Water content (WHC%)[a]	Freezing time (month)	Freeze-thaw cycles
Levels	0	30	2	1
	-6	60	4	4
	-12	90	6	7

[a] WHC: water holding capacity

The multi-year mean soil frost depth reached 48cm in the “deep soil frost” treatment, while it was 27cm and 4cm at the “control” and “shallow soil frost”, respectively. Elevated concentration of DOC was observed at the upper soil horizons of the “deep soil frost” treatment which was up to twice as much as the DOC concentration in the “shallow soil frost”, particularly during spring and summer. The laboratory experiment introduced temperature as the most important single factor, followed by water content. Combination of the lowest applied temperature and the highest water content as well as the longest freezing time and the largest number of freeze-thaw cycles resulted in the most pronounced increase in DOC concentration. DON (dissolved organic nitrogen) response to the laboratory treatment was quite similar to the DOC response.

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C and N in above- and belowground litter in stands of different tree species in northern Finland

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The belowground biomass of trees and understorey vegetation play an important role in the carbon and nitrogen dynamics of forest ecosystems (Helmisaari et al. 2007, 2009). However, there is insufficient information available about their contribution, in quantitative and qualitative terms, to C and N budgets. Especially, knowledge about carbon longevity in roots in relation to species, sites and climate, is needed for increasing the accuracy of estimations of the role of soils in the global carbon budget under scenarios of increasing atmospheric C. For this purpose, knowledge of root turnover and litter production are key factors.

The aim of our study was to determine both above- and belowground tree litter production and carbon and nitrogen inputs to soil in silver birch, Scots pine and Norway spruce stands. We hypothesize that 1) C and N inputs in fine root litter may be larger than the corresponding inputs in foliage litter. 2) Fine root litter differs qualitatively from the foliage litter, e.g. the C:N ratio and the share of organic compounds may differ. 3) Even if the major part of fine roots are in the soil organic layer, the relative contribution of fine root litter to soil C and N is largest in the mineral soil.

We determined the litter production of fine roots and foliage in a tree species experiment in northern Finland during three successive growing seasons. The study was made in the 70-year old stands of silver birch (*Betula pendula* Roth.), Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karst.*)* growing on originally similar soil on the *Hylocomium-myrtillus* site type (Smolander & Kitunen 2002, Kanerva et al. 2008). Biomass of fine roots was determined by soil coring, and turnover rate both by ingrowth cores and minirhizotrones. Tree aboveground litter was collected with litter traps. We also determined the decomposition rate of both fine roots and leaf/needle litter in a mesh bag study.

The annual means of leaf/needle litterfall were 1810, 1970 and 1940 kg ha^{-1} in silver birch, Scots pine and Norway spruce stands, respectively. Respective annual N inputs in foliage litter were 19, 9 and 15 kg ha^{-1}. The annual fine root litter production and respective C and N inputs of birch were smaller but those of pine and spruce as large or larger than in needle litterfall. Fine roots, however, decomposed during the first two years more slowly than needles and leaves: fine root mass loss was 20–30%, while foliage litter lost 40–60% of its weight. Spruce litter had the smallest mass loss, and birch litter the largest. The depthwise fine root litter production followed the fine root biomass as we did not find any significant root longevity differences with soil depth. We conclude that both above- and belowground litter affect soil fertility and soil C under different tree species in the long run, and should be considered in ecosystem C and N budgeting.

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Forest soil respiration: Identifying sources and controls

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Most of the respiration in forests comes from the soil. This flux is composed of two components, autotrophic and heterotrophic respiration. In a strict sense the former should be plant belowground respiration only, but the term is used here to denote respiration by roots, their mycorrhizal fungal symbionts and other closely associated organisms dependent on recent photosynthate. Heterotrophs are organisms using organic matter, chiefly above- and belowground litters, as substrate (i.e. substrates of in general much higher ecosystem age).

Because of the complexity of the plant-soil system, the component fluxes are difficult to study. I will discuss results of different approaches to partition soil respiratory components and to study their controls. The focus will be on northern boreal forests.

In these generally strongly nitrogen-limited forests, the autotrophic respiration equals or exceeds the heterotrophic component. The large autotrophic component reflects high plant allocation of C to roots and mycorrhizal fungi in response to the low soil N supply. A physiological manipulation, girdling, which stops the flow of photosynthates to roots, showed that autotrophic respiration could account for as much as 70% in N-limited forests, but only 40% in fertilized forests. Also using girdling, we could show that a shift to lower summertime temperature leads to a decrease in heterotrophic but not in autotrophic activity, suggesting substrate (photosynthate) limitation of the latter.

Physiological manipulations like girdling and trenching cannot be used to reveal the finer details of soil C dynamics. Natural abundance stable isotope (^{13}C) and ^{14}C approaches also have their limitations if a high resolution in terms of time, space and organism is required. A very high resolution can, of course, be obtained in studies of laboratory micro- or mesocosms, but the possibility to extend the interpretation of their results to the field may be questioned. In the CANIFLEX (CArbon NItrogen Forest Labelling Experiment) project, we use a short labelling period and highly enriched $^{13}CO_2$ to produce a traceable pulse through components of the system directly in the field. Thus, we have labelled 50 m^2 plots using 4–5 tall plastic chambers (i.e. 200–250 m^3) in a young Scots pine forest. Results of a pilot study in 2006 have been published (Högberg *et al*. 2008).

The CANIFLEX project has shown that traceable quantities of labelled C peak within a few days in ectomycorrhizal roots, microbial cytoplasm and soil respiratory efflux. In the two latter, the C had a half-life of 280 h and 35 h, respectively. Using higher tracer levels than in the pilot study, we have now successfully conducted stable isotope probing of specific groups of soil organisms at this large scale, finding ^{13}C tracer in PLFA (phospholipid fatty acid) biomarkers for fungi, but not in the majority of markers for bacteria. We are now into our second season of following the effects of additions of N on the belowground C dynamics using a combined ^{13}C (photosynthate) and ^{15}N (labelling of soil N) approach.

The physiological and labelling approaches are complementary, but need to be linked through modelling. This is a major challenge.

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Contribution of roots and litter layer on total soil respiration in a mixed pine-oak stand in central Korea

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The invasion of Korean pine (*Pinus koraiensis*) seedlings into mature natural deciduous oak forests from surrounding Korean pine plantation is commonly observed over the central and northern Korea nowadays. The establishment of bi-level stands of Korean pine seedlings and mature oak trees is normally caused by transportation of Korean pine seeds by rodents, especially red squirrels. In these forests the pine seedlings show higher levels of density and lower growth rates compared to those in planted Korean pine (Yi *et al*. 2007), suggesting different carbon cycling from that in pure Korean pine plantation. The goal of our study is, therefore, to clarify interacting effects of Korean pine seedling and mature oak trees on belowground carbon dynamics, especially on soil respiration that is one of the most important processes of forest carbon cycling. We conducted three different kinds of treatment (i.e. removal of Korean pine, oak and surface litter) in order to estimate contribution of roots and litter layer to total soil respiration in a mixed pine-oak forest in central Korea. We also investigated changes in soil temperature and its impacts on soil respiration simultaneously.

Experiments were conducted at the Kangwon National University Experimental Forest (37°49´N, 127°51´E) in central Korea. The mean annual precipitation for the period 1971–2000 in this area was approximately 1300 mm, nearly half of which concentrates between July and August. The mean annual air temperature is 10.9 °C. 12 m × 12 m experimental plots were established in a mixed pine-oak stand, where no treatment (C), removal of Korean pine seedlings (QL), removal of oak (*Quercus mongolica*) trees (PL), removal of surface litter (PQ) and removal of all above-ground trees (L) were conducted. Each treatment was 3 replicated and 15 experimental plots were made in total. Measurements of soil temperature (°C) and soil respiration (g CO_2 m^{-2} hr^{-1}) were carried out at 3 sampling points in each plot before (August, 2008) and after (October, 2008) the treatments.

The mean soil temperature and the mean soil respiration did not differ significantly among the treatment plots (ANOVA, $P > 0.05$) before the treatment. However, soil temperature and soil respiration changed significantly after the treatment (ANOVA, $P < 0.05$) (Table 1). Mean soil temperature was significantly lower in PQ sites compared to C sites. Mean soil respiration was significantly lower in PQ and L sites compared to the other sites. These results indicate that soil respiration in this forest is strongly affected by thick litter of oak leaves. Decrease of temperature caused by removal of litter layer might have partly caused the decrease in soil respiration. Decrease in root respiration caused by removal of pine seedlings or oak trees might have had little effect on total soil respiration. It is necessary, however, that long-term monitoring should be carried out in order to clarify the impact of belowground processes caused by pine, oak and their interaction on total soil respiration.

Table 1. Soil respiration (g CO_2 m^{-2} hr^{-1}) and soil temperature (°C) for treatment sites.

Date		C	QL	PL	PQ	L
08/08/21	mean soil temperature	18.0 aA*	17.9 aA	18.2 aA	18.0 aA	18.0 aA
	mean soil respiration	0.65 aA	0.67 aA	0.68 aA	0.67 aA	0.68 aA
08/10/30	mean soil temperature	10.0 aB	9.4 aB	9.3 aB	8.1 bB	9.6 aB
	mean soil respiration	0.23 aB	0.21 abB	0.22 abB	0.17 bB	0.17 bB

* Different small and capital letters indicate significant differences among the vegetation treatments, and between before and after the treatments at $P < 0.05$, respectively.

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The contribution of carbonaceous materials on the sorption of hydrophobic organic contaminants to the fluvially deposited subsurface soils of Korea

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Although the contents of carbonaceous materials in subsurface soils are generally not significant, carbonaceous materials in them dominate the sorption of hydrophobic organic contaminants (HOCs) such as trichloroethylene (TCE), tetrachloroethylene (PCE), etc. The condensed form of carbonaceous materials such as kerogen, char, etc. has high sorption capacities of HOCs compared to the soft form of carbonaceous materials such as fulvic acids, cellulose, etc. However, very few studies are carried out on the distribution and properties of carbonaceous materials in fluvially deposited subsurface soils in Kyungi and Kangwon province of Korea. The objectives of this study are to examine the physical and chemical properties of carbonaceous materials in fluvially deposited subsurface soils and its contribution on the sorption of HOCs to soils.

In order to characterize the type and amount of various carbonaceous materials, fluvially deposited subsurface soils were sampled from Paju in Kyungi Province and Wonju in Kangwon Province of Korea. Both sampling sites are located near Imjin River and Wonju Stream. Both of them are not contaminated by HOCs. The carbonaceous materials were separated from soils by various physical and chemical methods such as density separation and strong acid and base treatment. Separated carbonaceous materials were characterized by elemental composition (e.g., C, H, N, O) with combustion, functional groups with FT-IR and solid state ^{13}C-NMR, microscopic analysis using SEM with EDS. Mineral properties were analyzed with XRD. The bulk soil samples and separated carbonaceous materials were evaluated HOC sorption properties using TCE and phenanthrene. The fluvially deposited subsurface soils are mainly consist of sand and have some silty and clay layers. The mass ratios of light fractions (density < 1.6 g/cm^3) to bulk soils are less than 0.5%. The main carbonaceous materials of both light and heavy fractions are kerogen. Current experiments are focused on the characterization of carbonaceous materials in fluvially deposited subsurface soils.

Wintertime C-fluxes in a forest soil of the Swiss Jura: clues from a ^{13}C labeled litter experiment

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Recent studies in high-latitude ecosystems suggest that biological activity in winter can contribute considerably to annual soil carbon fluxes. However, similar studies are rare in the temperate zone, despite the predictions of a more distinct warming in wintertime. Since temperature sensitivity is particularly high at temperature close to 0°C and soil moisture is hardly limiting in the cold season, a small increase in winter temperature may alter soil organic carbon balance significantly.

To gain more insight into C fluxes in litter layer and mineral soils during wintertime, we performed a labeled litter experiment in a montane mixed forest in Switzerland. At the end of November 2007 we replaced native litter with ^{13}C labeled beech leaves (-40.7‰), which enabled us to trace the fate of ^{13}C in CO_2 as well as in leached dissolved organic carbon.

Considerable CO_2-fluxes (> 0.6 µmol CO_2 $m^{-2}s^{-1}$) were detected, even when the soil was frozen down to 5cm. CO_2-release from mineral soil was best described by a multiple regression model incorporating soil temperature in the deeper soil, signifying that the warmer subsoil contributed substantially to soil respiration when the topsoil was frozen. Altogether, five winter month contributed 20% to the annual heterotrophic CO_2-release. In contrast to the mineral soil, litter decomposition responded much faster to variation in air temperature. As a consequence, contribution of litter C to total soil respiration varied from 0 to 60%. We modeled litter respiration using air temperature and days after litter addition as independent variables. After five winter month, litter had lost 7.7% of its initial carbon content by respiration and 3.4% by DOC leaching. Only 5.6% of the DOC leached from the litter layer was recovered in the DOC of the mineral soil at 5cm depth, indicating that most of litter-derived DOC was retained in the mineral soil despite a low biological activity in winter.

Our results suggest that deeper soil horizons contributed considerably to heterotrophic soil respiration in the cold season. Moreover, the first stage of litter decomposition was completed at the end of the winter despite of a mean air temperature of only 1.9°C.

Temperature sensitivity of soil organic matter decomposition – implications for soil carbon storage in a warming climate

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Changes in soil carbon cycling and storage in response to climate warming will depend on the changes in C input and on the temperature sensitivity of decomposition of different soil carbon fractions. Current soil carbon models are based on the assumption that all soil C is equally sensitive to warming. This is unlikely to be true, and leads to significant uncertainties in the current model estimates. Most of the soil carbon is tens or hundreds of years old, and the temperature sensitivity of this older C is crucial for the soil carbon balance at timescales relevant for climate change adaptation and mitigation. According to the kinetic theory (Arrhenius equation), the temperature sensitivity of soil respiration should increase with decreasing carbon quality (increasing activation energy, Ea), but experimental evidence is controversial.

We studied the temperature sensitivity of labile and more recalcitrant soil C in two experiments using ^{13}C and ^{14}C measurements and short- or long-term laboratory incubations. The ^{14}C incubation approach enabled us to measure more directly than done before, the temperature sensitivity of the old, centennially cycling carbon compared to the younger fractions turning over on timescales from years to decades. Results from these two studies are consistent with each other, and also help to explain the apparently controversial conclusions from some earlier studies. In our ^{13}C study, we took soil samples from a field, where a C3 crop was replaced by maize (a C4 plant) cultivation 5 years ago, and from an adjacent control field with a C3 crop. We measured the ^{13}C/^{12}C -ratio (δ^{13}C ‰) of the respired CO_2 at different temperatures and calculated Q_{10} values for soil respiration originating from maize-derived SOM ($Q_{10}\approx2.4$) and from older C3-derived SOM ($Q_{10}\approx3.6$).

In the ^{14}C study, different layers of podzolic forest soils were incubated for 500 days in favorable decomposition conditions to let the most labile fractions decompose. At the end of the incubation, the ^{14}C activity of the produced CO_2 was measured at 8 and 25 °C. Based on these ^{14}C measurements and modeling, we calculated the contribution of older and younger C to soil respiration at 8 and 25 °C, and thus their temperature sensitivity. Measurements from the organic layers support the earlier result that the decomposition of the most labile C is not temperature sensitive ($Q_{10}<2$ for C with MRT 1–2 years), while the decomposition of the more recalcitrant C (MRT 9-16 years), was highly temperature sensitive (median Q_{10} 6.4 or 6.9). Soil organic matter with MRT's from years to decades was highly temperature sensitive also in the surface layers of the studied forest soils (median Q_{10} from 4.2 to 5.9), but less so in the deeper mineral soil layers (median Q_{10} from 3.1 to 3.7), which may reflect the lower amounts of labile C. The older, centennially cycling C was not especially temperature sensitive in any of the mineral soil layers (Q_{10} = 2.4–2.8), probably because stabilization with minerals limited its decomposition.

Our results imply that climate warming can induce higher carbon losses from the surface layers of both agricultural and forest soils than previously thought. Estimates based on the Q_{10} of total heterotrophic soil respiration underestimate the temperature sensitivity of the older, decadally cycling C fractions, because before pre-incubating the soils, soil respiration mostly comes from the most labile fractions. But similar estimates can overestimate long-term changes of carbon storage in the (deeper) mineral soil layer of forest soils, because the large pool of centennially cycling C is less temperature sensitive than the total respiration, and because availability of more labile C can also limit the decomposition of the temperature sensitive decadally cycling fractions.

Chemical and biological characterization of forest soil dissolved organic carbon and nitrogen divided into fractions according to molecular size

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The degradation of dissolved organic matter (DOM) is an important process controlling DOM dynamics in soils. The degradation process of DOM is controlled by soil properties and external factors as well as by the characteristics of DOM. DOM is composed of molecules with a range of chemical, structural and molecular properties. DOM can be characterized with the molecular structure of DOM, functional group content, or the size of the molecules. Very little is known about the link between the degradability, chemical composition and the molecular size distribution of DOM. The technique using ultrafiltration is effective for fractionating broadly heterogeneous humic macromolecules into relatively homogenous fractions (Li et al. 2004). The low molecular weight compounds such as amino acids, low molecular sugars, and proteins are easily degradable and largely appear in the smallest size class. The ultrafiltrate of the smallest size class (< 1 kDa) was the most degradable (Marschner and Kalbitz, 2003) whereas also the solution of the largest molecular size class (> 100 kDa) seemed to be easily degradable (Kiikkilä et al. 2006).

Samples of litter layer were collected from a Norway spruce (*Picea abies* (L.) Karst.) stand located in Eno, middle-eastern Finland. Dissolved organic matter (DOM) was extracted from the litter layer by the centrifugation-drainage technique. DOM was fractionated into four fractions using a tangential ultrafiltration apparatus (Minimate TFF system, Pall Corporation) with membranes having three molecular cut-offs. The four DOM fractions obtained had apparent molecular sizes of < 1, 1–10, 10–100, and > 100 kDa. The total DOM solution and the four DOM solutions with different molecular sizes were studied with microbiological and chemical techniques. To asses the degradation of DOM the solutions were incubated for two months (with and without N addition) and the CO_2 production was measured. To assess the availability or inhibitory effect of DOM to bacteria, the ^{3}H-thymidine incorporation by soil bacteria technique (Bååth et al. 2001) with the modifications introduced by Kiikkilä et al. (2005) was applied. The availability of DOM to fungi was assessed using the ^{14}C-acetate in ergosterol technique (Bååth 2001) with the modifications introduced by Kiikkilä et al. (2006). We are characterizing the chemical composition of DOM by measuring organic carbon and nitrogen, amino acids, carbohydrates (monomers, hemiselluloses), uronic acids, lignin, phenolic compounds and tannins.

Results showed that only a small part of DOM was degraded and the degradability of the solutions with different molecular sizes varied. The solution with the smallest molecular size (< 1 kDa) had the highest degradability. Degradability in relation to the chemical composition of DOM will be discussed.

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The balance between decomposition and litter production rates in an age chronosequence of Norway spruce in SE Norway

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Generally, boreal forest soils have been a net C sink since the last glaciations, creating the large pool of C typical for forests in the Northern hemisphere. The sink strength of the soil is determined by the balance between input of total litter and decomposition of soil organic matter. Short-term variations (decades) in these opposite fluxes, such as during forest stand development, may affect the size of the C-pools significantly. Whereas tree litter is generally the major source for soil organic matter, ground vegetation can contribute significantly both to net primary productivity, including litter production, despite its relatively small pool size (Berggren Kleja et al., 2008). Limited data exist on changes in total litter flux as well as changes in litter types over a rotation period. Parts of the incoming litter will decompose relatively fast, while a remaining fraction decomposes slowly and thus contributes to the stable soil organic matter pool. The decomposition rate as well as the amount of slowly decomposing organic matter, will be affected by factors such as litter types, litter qualities, temperature and moisture (Berg and Laskowski, 2006).

We present data on litter input and decomposition in an age chronosequence of Norway spruce comprising four forest stands approximately 12, 30, 60 and 120 years old, located on a relatively homogenous sandy plain at Nordmoen in southeastern Norway. The litter input estimates were based on fine above ground tree litter collected in 0.16 m^2 litterfall collectors over a two year period, whereas ground vegetation litter production was based on estimated above ground production. Tree and ground vegetation root litter was based on estimates of total root biomass <2mm in soil cores and turnover rate calculated from minirhizotrons during 3 years. The *in situ* decomposition rate estimates of soil organic matter in all stands were based on measurements of soil and root respiration rates, whereas decomposition rates of needle and root litter were measured in two of the stands over a 4.5-year period. Decomposition rates of needles and fine roots were determined in litterbags deployed at the soil surface, in the forest floor and mineral soil. Soil respiration was measured by use of an EGM-SR chamber, whereas root respiration was measured on excised roots in Parkinson leaf cuvette by infrared gas analysis system CIRAS-1.

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Soil carbon accumulation in the dry tundra: the important role played by precipitation

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A positive relationship between the mean annual precipitation (MAP) and the pool of soil organic carbon (SOC) is found in most surveys of subarctic and boreal upland soils. So far, the main interpretation of this trend is that it is caused by increased primary production due to the positive coupling between soil moisture and plant production. Increased soil moisture is indeed known for stimulating primary production but at high latitudes where most of the precipitation falls as snow the positive relationship between precipitation and plant production seems more dubious. In fact, precipitation and plant production may be negatively correlated at these latitudes because a thick snowpack thaws more slowly and may cover the plants long into the summer and thereby shortening the vegetation season (*Ostler, et al.*, 1982). Even though biotic driven processes are unambiguously of importance for the accumulation of SOC, lateral transport of organic matter may derive disequilibrium carbon storage in watersheds at various scales (Yoo et al. 2005). Furthermore, the vertical translocation of organo-metal complex with percolating soil-water may occur in broad range of soils and exert primary control on SOC turnover (Masiello et al., 2004).

In a study of heath tundra soil developed along a 50 km-long subarctic precipitation (snow) gradient in northern Sweden, we assessed mechanisms behind variable SOC pools. Lead-210 dating was used to calculate SOC accumulation rates in the O-horizon, i.e. the chronology of atmospheric inputs is preserved within the stratigraphy of this soil compartment (*Klaminder, et al.*, 2008) and the vertical distribution of lead can be used to infer the age of the organic matter (*Klaminder and Yoo*, 2008).

Despite a slightly decreasing accumulation rate of SOC in the O-horizon (range 0.04 to 0.08 kg C m^{-2} yr^{-1}) and a relative constant litter input (~0.04 kg C m^{-2} yr^{-1}) with MAP, the SOC pool in the upper 1 m correlates positively with MAP (r^2= 0.89). This trend is mainly due to a progressively build-up of SOC in the mineral soil and argued to be the result of an accelerated vertical translocation of SOC at sites overlain by a thick snowpack. Furthermore, the loss of SOC from the O-horizon through wind erosion appears to be more pronounced at snow poor sites. We estimate that vegetated heath soil may loose >0.03 kg C m^{-2} yr^{-1} (~half of the annual litter fall) due to wind erosion in snow poor areas. We stress that lateral and vertical translocation processes inherent by precipitation regimes may be of fundamental importance for the long-term SOC accumulation in tundra soil.

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Effects of changed plant litter input in forest ecosystems on soil carbon stocks and lignin oxidation

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The input of plant litter largely governs carbon dynamics in soils. Microbial degradation of lignin as an important component of plant litter is assumed to control C mineralization and the production of dissolved organic matter (DOM) during latter stages of litter decomposition. On the other hand, lignin degradation as a cometabolic process should be dependent on the amounts of fresh litter. Global climate change will affect the quantities of plant litter input into forest soils. Therefore it is necessary to understand how changes in litter input rates influence lignin degradation and related soil processes.

Detritus Input and Removal Treatments (“DIRT”) were conducted to study the effect of litter input on soil processes in the field by either excluding or doubling litter input on respective research plots. We studied soil samples (forest floor and upper mineral soil to 20 cm depth) and soil solutions from 3 long-term DIRT experiments situated in a spruce forest (Fichtelgebirge, Germany), a beech/oak-forest (Steigerwald, Germany) and a maple/cherry forest (Bousson, PA, USA). Litter input was manipulated for 6, 9 and 15 years, respectively. In particular, the goals of the study were to assess the effect of litter input on

1. soil C-stocks,
2. lignin degradation in the solid phase (forest floor and mineral soil) using the CuO method,
3. amounts and composition of DOM in the forest floor by monthly sampling soil solutions and analysis of dissolved organic carbon (DOC) concentrations, spectroscopic parameters and lignin-derived compounds by the CuO method,
4. the composition of the microbial community (fungi vs. bacteria) and contribution of microbial cell wall residues to soil organic matter by analyzing the content of amino sugars.

First results showed that doubling litter input led to about doubled C stocks in the forest floor and doubled export of DOC into the mineral soil. The composition of DOM changed towards a higher proportion of aromatic, lignin-derived components probably as a result of enhanced co-metabolic oxidation of lignin (“priming effect”). This hypothesis was supported by an enhanced lignin oxidation in the forest floor and the mineral soil at the DIRT sites. However, a larger degree of lignin oxidation was also found in the mineral soil after exclusion of litter input contradicting our hypothesis of a positive relationship between litter input and lignin degradation. We assume that the performance of the microbial community to oxidize complex molecules like lignin increased in case of limitation of easily available carbon. That also means lignin degradation is not only a co-metabolic process.

Modelling changes in forest nutrition in different climatic zones under climate changes

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Projected climate change scenarios for the boreal and temperate forests of the Northern part of East Europe generally show warmer conditions with potential for drought periods. Consequently, a problem of quantification of climate change effects on forest growth, harvesting and carbon budget has arisen. Changes in carbon and nitrogen turnover in the forest plants-soil system as a result of changing climate are drivers of the ecosystem changes. The applications of forest ecosystem model EFIMOD (Komarov et al., 2003) have been conducted for sites in Finland and Russia (Kola Peninsula, Leningrad, Kostroma and Moscow regions and Komi Republic). The integration of processes in both tree plants and soils into a plant-soil model permits a feedback between the plants and soil. This provides a dynamic representation of plants and soil parameters and allows for a simulation of carbon and nitrogen dynamics in the course of forest ecosystem development.

A set of case studies belonging to different forest types have been chosen in mentioned areas. Site for the studies are located in different climatic zones and represented north, middle and south taiga (boreal forests) as well as coniferous-broadleaf forests (temperate forests). Two scenarios of silvicultural regimes were compiled: natural development and cuttings in correspondence with local forest practice. A set of scenarios with climate change using HADCM3 model was compiled for the simulation. EFIMOD application shows that climate warming and harvesting significantly influence the C pools in tree biomass and soil. EFIMOD predicts higher forest productivity and soil resource depletion. Forest productivity growth can be explained by soil nutritional status improvement and more active nitrogen uptake by plants resulted from climate change. Soil resource depletion is related to tree harvesting and more intensive decomposition processes. Difference between the C stocks in the tree plants and soils at climate changes is more distinct in scenarios of unmanaged ecosystem development. Cuttings are smoothing these processes.

Differences and similarities in forest growth and soil nutritional status dynamics for different climatic zones are analyzed. The detailed results show that climate change has indirect impacts to the processes in tree plants-soil system.

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Controls on the adsorption and fate of dissolved organic carbon within forested mineral soils

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The soil-solution partitioning of dissolved organic carbon (DOC) within mineral soil horizons is primarily controlled by processes of adsorption and desorption. These abiotic processes largely occur within a short equilibration time of seconds to minutes, which generally occur faster than microbial processes. To characterise the adsorption of DOC to mineral soils, we used the Langmuir adsorption isotherm, which holds several advantages to the commonly used linear initial mass (IM) isotherm. One advantage to using the Langmuir isotherm is an estimation of the maximum DOC adsorption capacity (*Qmax*). The *Qmax* estimates the number of remaining DOC binding sites available on the mineral soil surface. We also modified the traditional Langmuir isotherm in order to estimate the DOC desorption potential of native soil organic matter.

Sorption characteristics were derived for a broad range of 52 mineral soils collected from 17 soil profiles spanning across Canada from British Columbia to Québec. Mineral horizons with the greatest *Qmax* included the Fe-enriched B horizons of Podzols and Volcanic soils, followed by B horizons not enriched in Fe, followed by A and C horizons. Podzol B horizons were distinct from all other horizons due to significantly higher desorption potential. Soil properties predicting the adsorption characteristics of DOC also predicted the adsorption characteristics of dissolved organic nitrogen (DON). Adsorption of DOC and DON were tightly coupled ($R^2 = 0.86$), however the ratio of DOC:DON in the final equilibrium solution lowered for 48 out of 52 minerals horizons.

A short-term (32 day) incubation was performed to establish the fate of indigenous SOC relative to newly adsorbed SOC to four mineral soils with distinct adsorption characteristics. Soil columns were leached periodically and sampled for DOC and CO_2 production. Two Fe-enriched mineral horizons with high adsorption capacity released low amounts of old SOC, yet released almost all of the newly adsorbed SOC. In contrast, two B horizons without Fe-enrichment released greater amounts of old SOC, and retained a greater fraction of the newly adsorbed SOC than the Fe-enriched horizons. These results identify a contrast between the fate of indigenous and newly adsorbed SOC on mineral soils with differing *Qmax*.

C-sequestration potential in soils after land use changes from crops to natural vegetation

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The Kyoto protocol encourages the soil C-sequestration and requires formulating activities in countries-participants. In Russia more than a quarter of croplands (about 34 M ha) were abandoned since 1990 due to political and economical changes. The abandonment of cultivated lands and successive establishment of natural vegetation lead to carbon (C) accumulation in soil. This study is aimed to estimate the C-sequestration potential of soils after land use change from crops to natural vegetation.

The soils used were loamy Haplic Chernozems (0–20 cm layer) taken from arable site, grasslands (former agricultural fields abandoned 5, 21 and 77 years ago) and forest belt (77 yrs). Carbon immobilized in microbial biomass (C_{mic}) was estimated by fumigation-extraction method before and after 10 weeks of incubation (at 20°C and 60% of water holding capacity) without and following addition of glucose at rate of 730 $\mu g\ g^{-1}$ of soil. C-sequestration potential of soils (CSP, %) was calculated using the ratio between extra C-CO_2 release induced by glucose addition and amount of C applied to soil. Our results showed, that content of C_{org} and C_{mic} was the lowest in arable and the highest in the 77-yrs grassland (Table 1). The total C-CO_2 release during 10 weeks of incubation decreased from 1.01–1.12 mg C g^{-1} in arable soil and young grassland (5 yrs after abandonment) to 0.74-0.77 in older grasslands and forest belt. The addition of glucose induced the extra C-CO_2 release that amounted to 0.22–0.41 mg C g^{-1} of soil depending on land use. The extra C-release was maximal in arable soils. It was found that applying of glucose resulted in more significant increase of C_{mic} in arable soil and 5-yrs grassland in comparison with soils of forest belt, 21- and 77-yrs grasslands. Carbon sequestration potential varied from 44% in arable to 70% in the oldest grassland.

Table 1. Content of C_{org} (%), C_{mic} (μg C g^{-1} of soil), total release of C-CO_2 (TR, mg C g^{-1} of soil) during 10 weeks of incubation without and following addition of glucose, and C-sequestration potential (CSP, %)

Type of land use	Corg,	Cmic	After 10 weeks of incubation				
			Without glucose		Addition of glucose		
			TR of C-CO2	Cmic	TR of C-CO2	Cmic	CSP
Arable	1.71	202	1.12	209	1.60	272	44.3
Grassland, 5 yrs	1.83	208	1.01	219	1.38	236	49.5
Grassland, 21 yrs	2.05	286	0.77	262	1.06	287	60.5
Grassland, 77 yrs	2.42	395	0.76	335	0.98	424	69.7
Forest belt	2.29	279	0.74	238	1.04	301	58.5

We conclude that land use change from crops to natural vegetation leads to organic carbon accumulation, growing of microbial carbon, and increase of C sequestration potential in soils. The conversion of low-fertility arable land to permanent grassland will promote C sequestration in soils.

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Differences in forest carbon stock and timber supply between management options under changing climate

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Understanding tree growth and its interaction with soil processess is needed for projections of the effects of climate change on forests. Increasing temperature is predicted to enhance biomass production, but at the same time, summer droughts may lead to declining growth and, in extreme situations, to increased mortality. The higher temperature may accelerate decomposition and increase nutrient availability, but reduced moisture may on the other hand limit soil biological activity. The objective of this study is to investigate the responses of forest timber supply and carbon stock to changes in temperature and precipitation under different management scenarios.

The analysis was conducted with a process-based forest model (PipeQual) that was combined with a soil water balance model and a soil decomposition model (ROMUL). PipeQual (Mäkelä and Mäkinen 2003) derives annual tree growth and stem structure from carbon acquisition and allocation, describing even-aged stands where trees in different size classes interact through shading and growth space. In this study, variable effects of N availaibility on growth are incorporated on the basis of a recent analysis (Mäkelä et al. 2008a).

In the model, weather and site conditions affect growth through their impacts on specified metabolic parameters. These are evaluated using more detailed, daily time-step submodels. Daily canopy photosynthesis is firstly computed under no soil water stress (Mäkelä et al. 2008b). Soil water dynamics are predicted using a model based on the open-bucket principle (Duursma et al. 2008, Linkosalo et al. abstract submitted to the Biogeomon). Soil moisture (1) reduces canopy photosynthesis and evapotranspiration during drought, and (2) controls the rate of decomposition of soil organic matter. The amount of nitrogen available to plants, as well as emissions of CO_2 are computed using the ROMUL model of soil organic matter decomposition (Chertov et al. 2001). ROMUL is based on the concept of succession stages of soil organic matter decomposition linked with soil biota activities. The litter is split into cohorts characterised by different origin of the decomposing material, and thus different decomposition rates and nitrogen kinetics.

The combined model was applied to assessing the timber supply and carbon balance of a boreal forest ecosystem under different management scenarios in current and changing climate (IPCC scenario A1B). The management scenarios were (i) silvicultural management and harvests according to current recommendations, (ii) delayed thinnings with higher removals, (iii) natural development without management. Detailed results of the simulations under current and changing climate are shown in this presentation. The results of this study can be used for mitigation and adaptation of climate change.

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Long-term movements of ^{15}N-labelled ammonium and nitrate additions to oak and pine forest plots constrain estimates of C sequestration resulting from atmospheric N deposition

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The effects of reactive atmospheric nitrogen (Nr) deposition on carbon (C) sequestration in forest ecosystems depend upon the short- and long-term fates of atmospheric N inputs. The partitioning of N inputs to accumulating wood biomass (with C:N ratios >200), foliage and roots (C:N ≈ 25 to 50), organic soil horizons (C:N ≈ 10 to 30), mineral soils (C:N ≈ 8 to 15), and exports in solution or gaseous forms (C:N = 0) constrain increases in ecosystem C sequestration resulting from Nr inputs. Narrowing of plant tissue and soil C:N ratios in response to N deposition imparts additional constraints on C sequestration. We measured ^{15}N tracer movements into forest ecosystem pools at 2, 8, and 16 years following $^{15}NO_3$ and $^{15}NH_4$ additions to fertilized and non-fertilized plots in pine and oak forests at the Harvard Forest LTER site (USA) in order to assess the impacts of ambient (~ 8 kg N ha^{-1} yr^{-1}) and enhanced (~58 kg N ha^{-1} yr^{-1}) N deposition on C sequestration at decadal time scales. At 16 years after tracer additions, small fractions (<5% of added tracers) were still detectable in rapidly cycling N pools such as foliage. Wood accumulated ^{15}N throughout the measurement period, but soils overwhelmed other pools as long term sinks for ^{15}N additions. These patterns, together with narrowing C:N ratios in plant tissue and soil pools, plus tree growth measurements made on site suggest that Nr deposition effects on forest C sequestration are at the low end of published model-based estimates.

Temporal and spatial variability in soil CO_2 efflux in relation to soil environmental factors in an aseasonal intact tropical rainforest in Sarawak, Malaysia

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Although soil carbon dioxide (CO_2) efflux from tropical forests may play an important role in global carbon (C) balance, our knowledge of the fluctuations and controlling factors for soil CO_2 efflux in the Asian tropics is still poor. Especially, in tropical aseasonal rainforests, where both temperature and moisture are favorable all year round, it is difficult to distinguish a clear temporal and spatial pattern in soil CO_2 efflux and the effects of environmental factors are almost unknown. This study characterizes the temporal and spatial variability in soil CO_2 efflux in relation to temperature/moisture content and estimates annual efflux from the forest floor in an aseasonal intact tropical rainforest in Sarawak, Malaysia.

The study was carried out in a natural tropical rainforest in Lambir Hills National Park (4°12'N, 114°02'E), 30 km south of Miri City, Sarawak, Malaysia. The mean annual rainfall for the period 1968–2001 in this area was around 2740 mm. The mean annual temperature was around 27 °C, with little seasonal variation. Spatial variability in soil CO_2 efflux, temperature and moisture content were measured at 61 sampling points in a 40m × 40 m plot and repeated four times in November and December 2002. Temporal variability in soil CO_2 efflux, temperature and moisture content was determined by the mean of the 25 sampling points measured in the same plot from 2002 to 2006.

Soil CO_2 efflux was highly variable in space, showing up to 17.6-fold differences between the 61 sampling locations (Table 1). Semivariogram analysis revealed little spatial dependence in soil CO_2 efflux. Temperature explained nearly half of the spatial heterogeneity, but the effect varied with time. Seasonal change in CO_2 efflux had no fixed pattern, but was significantly correlated with soil moisture content.

The annual soil CO_2 efflux, estimated from the relationship between CO_2 efflux and soil moisture content, was 173–188 mol m^{-2} $year^{-1}$. As this area is known to suffer severe drought every 4–5 years caused by the El Nino-Southern Oscillation (ENSO), the results suggest that an unpredictable dry period might affect soil CO_2 efflux, leading an annual change in soil C balance.

Table 1. Spatial variability in soil CO_2 efflux (μmol m^{-2} s^{-1}) and effect of soil temperature and moisture content on soil CO_2 efflux (correlation coefficient).

Date	Max	Min	Mean	Range	SD	CV (%)	Correlation coefficient (Temperature)	Correlation coefficient (Moisture)
03/11/02	17.1	1.8	5.7	15.2	2.3	41	0.69***	-0.31
04/11/02	13.9	1.6	5.3	12.3	2.8	52	0.75***	-0.37
07/12/02	22.9	1.3	5.3	21.6	3.2	59	0.26	-0.07
08/12/02	22.3	1.9	5.3	20.5	3.3	62	0.38	-0.15

SD and CV are standard deviation and coefficient variation, respectively.
, * Indicate significance levels of $P < 0.01$ and $P < 0.001$, respectively.

Differential responses in hydrologic export of particulate and dissolved organic carbon from a mountainous watershed to rainfall variability and extremes

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Despite growing interest in the significance of terrestrial C export via erosion and riverine transport for the global C cycle, little is known about short-term variability in hydrologic C export from mountainous watersheds in response to extreme rainfall events. Hydro-biogeochemical responses of particulate (POC) and dissolved organic carbon (DOC) to intense and often extreme monsoon rainfalls have been investigated as part of a long-term biogeochemical monitoring program at a mountainous watershed in northern South Korea. We combined intensive storm sampling and real-time water quality monitoring with biweekly sampling at 14 locations encompassing diverse watershed characteristics to investigate seasonal and short-term variability in watershed C export. Concentrations of suspended sediment were usually higher immediately following antecedent rainfall events and in stream reaches directly influenced by agricultural runoff. Intensive storm sampling during four monsoon rainfall events showed rapid increases in sediment export from both forest hillslopes and agricultural fields corresponding to increasing rainfall amount and intensity. Sediment size distribution was investigated using serial filtration and SEM imaging. The size distribution differed among the sites and during each rainfall event, with silt-size sediments prevalent during the peak flow, especially in the agricultural stream. Although short-term changes in the concentrations of both DOC and POC matched temporal variations in discharge, the response of POC was non-linear and stronger than DOC (Fig. 1). Unlike hydrologic flushing of DOC from surface soil horizons that usually correlates with rising discharge, eroded sediments from hillslopes (or croplands) and stream banks might have resulted in abrupt increases in POC export in response to rapidly rising runoff during intense rainfall events. The results suggest that flashy responses of organic carbon export from mountainous watersheds to intense monsoon rainfalls should be taken into account when predicting changes in C pools and fluxes in mountainous watersheds in response to more extreme rainfall regimes predicted for East Asia under various climate change scenarios.

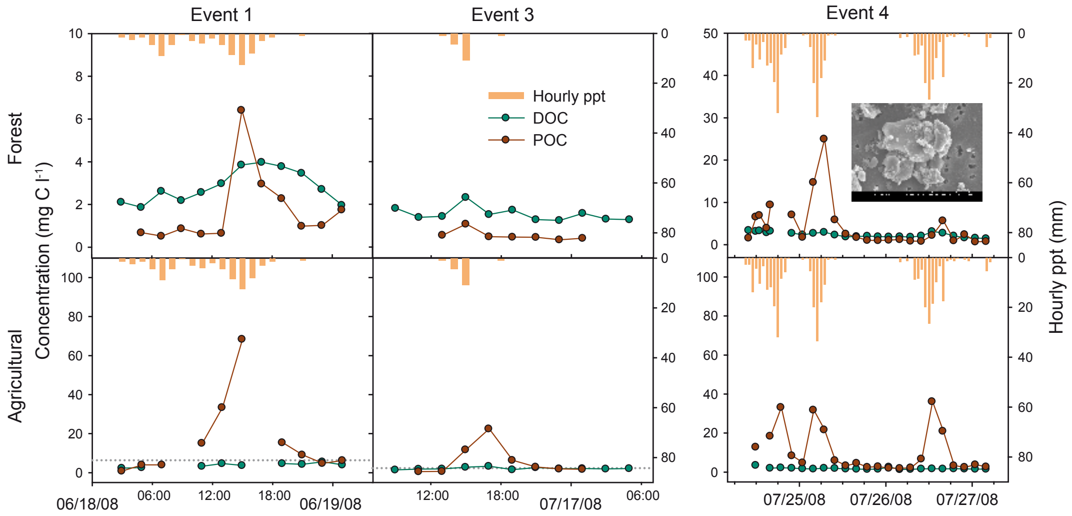

Fig. 1. Short-term changes in DOC & POC concentrations in a forest stream and a downstream agricultural stream during three rainfall events (inset: SEM image of silt-size sediments remained on a polycarbonate filter with 2-µm pore size).

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Change of carbon of solid and gas phazes at different use of chernozems of russia

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Change of the carbon forms compounds of solid and gas phases of the chernozems at different use and management in the Povolzh'e region was studied. There were natural conditions for 50 years: field safeguarding foresting and formed agricultural lands abandoned and agrogenic management: heavy and middle fertilized and nonfertilized rainfed and 75-year-old irrigated soils. Multifactors experiments with different dozes of fertilizers on 6-course cropping for three rotation were carried out. On rainfed rotation was cereal-fallow-clean, on irrigated fields – alfalfa-cereal-clean. Experiments replication was fourfold. Soils are the ordinary chernozems medium loam texture, derived from loess loams. The total soil carbon, different fractions of organic matter (by Tuyrin, 1951), cenoses productivity, total and heterotrophic soil respiration, microbial biomass (by Anderson, Domsch, 1978) were determinated.

On rainfed plots for 18 years soils all experiments plots lost 8–14% of carbon. Maximum carbon loss at minimum productivity was on fields without fertilizers adding. Fertilizers application of rainfed soil decreased organic matter loss, but didn't fill up its damage, connected with mineralization increase and nitrogen taking out with yield. Equations of regression were got, showed interconnection of productivity rotation and dozes of mineral fertilizers and manure in dry years and heavy and middle humidified ones. Yields of the studied plants have 2–3-years cycles and coincide with the solar activity period.

In irrigated plots 30–35% of perennial bean grasses including in rotation and manure adding annually of 7–13 t ha^{-1} and N, P, K of 80 kg ha^{-1} (of acting matter) provided the positive carbon balance. Content of all humic acids fractions and especially labile fraction increased on heavy fertilized fields under the effect of irrigation. In the 50 years of artificial foresting and grassing lands content of organic carbon in the 0–20 cm soil layer increased by around 1.2 time and the soil total and heterotrophic respiration and reserve of microbial carbon increased by 1.8–2 times.

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Connection between photosynthesis of trees and soil processes

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Recent photosynthate emitted from the tree roots play an important role in the carbon and nitrogen cycles of forest ecosystems. During the last two years we have studied the changes occurring in soil CO_2, CH_4 and N_2O fluxes after stopping the carbohydrate flux from tree canopy to roots by girdling. The girdling experiment was conducted in June 2007 at Hyytiälä at SMEARII to study the effect of girdling on the translocation of assimilated carbon within the trees. In addition, we will study the changes occurring in the living root biomass and microbial community of the soil from soil samples taken from the girdled site and control site.

We have measured soil GHG fluxes from collars installed permanently on a girdled and non-girdled Scots pine forest stand. The collars were measured with 14-day intervals with portable closed dynamic chamber for CO_2 and static chamber for CH_4 and N_2O throughout the growing season. We have also monitored CO_2, CH_4 and N_2O concentrations in the soil from air samples extracted manually from gas collectors installed at 10-cm-depth in the soil. The CO_2 efflux from the soil at the girdled site was on average 34% lower than in the adjacent non-girdled control forest during August - September and 28% lower during the whole year. Also the temperature response of soil CO_2 efflux and soil air CO_2 concentrations were significantly lower at the girdled site compared to the control site. The spatial variation in soil CO_2 efflux and especially soil air CO_2 concentration was significantly smaller at the girdled site compared to the control site suggesting that the spatial variability of soil CO_2 efflux is in connection with spatial distribution of tree roots. The results indicate that the contribution of recent photosynthate in the soil respiration is substantial and that the carbon input from tree roots has a large effect on the CO_2 efflux in our experimental forest site.

Fluxes of CH_4 and N_2O are much less affected by the girdling as the CO_2 fluxes. Uptake of atmospheric CH_4 in the girdled area is similar in magnitude as the uptake rates in non-girdled area, whereas the emissions of N_2O seem to be slightly elevated in the girdled area as compared to the control area.

In addition to the CO_2, CH_4 and N_2O exchange, we are studying the effect of recent photosynthate supply to nitrogen processes in the soil by measuring the changes in inorganic and total nitrogen (NH_4-N, NO_3-N, and total-N) concentrations and PLFAs in the soil.

The role of understorey vegetation in the carbon cycling of boreal coniferous forests

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In boreal forests, understorey vegetation forms an abundant and continuous cover in the mature succession phases of coniferous stands (Salemaa et al. 2008). The below-ground components of the understorey vegetation represent a poorly known part of C and nutrient cycling. Rhizomes and roots of ericaceous dwarf shrubs may account for a considerable portion of the C stocks in the organic layer. Further, it is known that ericoid mycorrhizal fungi make significant direct and indirect contributions to soil C stocks (Olsrud & Christensen 2004). In this study we compare biomass and C allocation in the below-ground parts of the understorey vegetation (dwarf shrubs, herbs and grasses) between the southern and northern boreal zones and between stands with different levels of site fertility. Plants appear to enhance their allocation to below-ground biomass when N availability in the soil is low (Helmisaari et al. 2009). We hypothesize that the amount of belowground biomass and C of understorey vegetation is higher 1) in northern than in southern sites, and 2) in nutrient-poor than in nutrient-rich sites.

We selected six study areas, each with one Scots pine and one Norwy spruce plot (30 × 30 m); three from the northern and three from the southern boreal zones. The sampling points consisted of 30 cm × 30 cm squares, seven squares on each side of the plot, giving a total of 28 sample points per plot. The organic layer and all the understorey vegetation growing on each square were removed in one intact piece and frozen prior to pre-treatment. The above- and below-ground biomass fractions of the plant material were dried at 70 °C/48 h before weighing, and the total C and N determined.

Generally 40–60% of the total living biomass of the understorey vegetation was located in the below-ground parts. The rhizomes of ericaceous dwarf shrubs were the most important component of the below-ground biomass. The major part of the below-ground biomass was concentrated in the organic layer. The proportion of the below-ground biomass and C increased towards the north in both the pine and spruce stands, as assumed in the first hypothesis. In contrast, the effect of site fertility on biomass allocation varied between the northern and southern sites. Dwarf shrubs allocated more biomass to the below-ground parts in the nutrient-poor pine stands in the south, according to the second hypothesis. In the north, however, the below-ground biomass was higher in the nutrient rich spruce stands. This may be due to the higher age of the spruce stands than of the pine stands in the north.

The average amount of below-ground biomass of the understorey vegetation ranged from 2360 to 3240 kg ha^{-1} in the northern and from 1200 to 2260 kg ha^{-1} in the southern pine stands. The corresponding values for the spruce stands were 2865–6650 kg ha^{-1} and 40–1060 kg ha^{-1} .

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Effect of wood decomposition rates on forest carbon sequestration

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Terrestrial carbon sequestration is an important strategy to limit atmospheric CO_2 increases. This strategy has largely focused on afforestation programs and the conversion of natural forests to agroforestry systems, and has emphasised fast-growing tree varieties. However, long-term C storage depends not only on growth rates, but also upon rates of coarse woody debris (CWD) decomposition. The duration of biotic C storage in wood has been poorly understood because conventional means to measure wood decomposition typically require decades.

With tropical and subtropical forests as examples, pools of CWD range from 2 to 70 Mg wood ha^{-1}. Reported decomposition rates (k) of tropical and subtropical CWD are even more variable, ranging from 0.03 to 1.2 y^{-1}. These (k) values are influenced by factors including temperature and edaphic conditions, tree species, wood density, CWD fragment size, decay class, lignin content, levels of inorganic nutrients, labile organic compounds, O_2 and water, and characteristics of the wood-decay fungal community.

We suggest that by altering one or more of these factors, CWD decomposition can be slowed substantially. Experiments are now being designed to test this, using field respiration (infrared gas analyser) measurements so that results may be obtained much more rapidly than by conventional monitoring of CWD.

Here we will report results of numerical modelling exercises which explore the sensitivity of forest C balance to variations in (k). The simplest model version holds wood growth and mortality rates constant, and examines CWD-pool responses to variations in (k). Initial results suggest that starting from high decomposition rates (> 0.4 y^{-1}) reductions greater than 80% in (k) are required to double the pool of CWD, with all other factors held constant. In contrast, starting from low decomposition rates (< 0.1 y^{-1}), much smaller fractional reductions in (k) will double CWD pools. More complex model formulations will be presented to explore the (k)-sensitivity of CWD pools over a wide range of forest growth and mortality rates.

Long-term increases in CWD pools represent the value of (k) reductions for forest-carbon sequestration. Goals of this project are to provide a framework to interpret our field manipulations and CWD respiration measurements, and ultimately to provide policy guidance on the plant species and site conditions most suitable for maximising forest C sequestration.

The impact of clear-cut harvesting on the dynamic of dissolved organic carbon (DOC) in boreal first-order streams during rain episodes

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The boreal forests are often referred to be an important part of the global carbon cycle. At the same time, a large part of this region is also being intensively utilized for forest harvesting. In this study we investigated the role of forestry on water quality in first order streams in northern Sweden. The Balsjö experimental area consists of four catchments of which two were clear-cut harvested in 2006 following two years of pre-treatment monitoring. High frequency stream water sampling techniques allow a direct comparison between harvested and undisturbed catchments.

So far the results indicate changes in the hydrological conditions of the soils and the streams draining the deforested catchments. Significant increases in DOC concentrations during the summer month were observed during different runoff episodes. During high flow events the concentrations were higher in the treated catchments. A similar behavior is observed for numerous periods with summer base flow conditions. The differences in concentrations decrease as the summer proceeds, demonstrating less influence of the treatment in late summer. In autumn the effect is no longer statistically significant and factors not affected by the harvesting seem to dominate the dynamics of DOC concentrations. Possible explanations for the observed changes in DOC behavior are (1) changes in the decomposition rates of organic matter and (2) different hydrological flow paths in the soils supporting the mobilization of DOC which is stored in organic rich near stream compartments. Further research will help identifying these major controls of DOC in the Balsjo experimental area. Moreover the findings will allow the development of suggestions for harvesting practices that incorporate water quality aspects.

Soil microbial biomass carbon, fungi/bacteria ratio and production of greenhouse gases (CO_2, N_2O) in soil profile of different forests and under overgrowing arable soil by forest (Southern taiga of European Russia)

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Soil microbial biomass carbon is a living, important and labile part of the total soil organic carbon. A knowledge of soil microbial pool in soil profile under different forests and under overgrowing arable by forest is a very important aspect for ecological investigations, modeling and prediction scenarios. Soil microbial biomass is a main source of greenhouse gases emission from soil to atmosphere. The aim of our investigation is focusing on: a) the estimation of soil microbial biomass carbon and its portion in the total soil C_{org}, b) ratios of fungi to bacteria, c) microbial production of CO_2 and N_2O in various horizons of soil profile under undisturbed old ageing forests and overgrowing arable, and d) relationship between greenhouse gases production from soils and soil microbial parameters measured.

Soil sampling and location. Soil profile (1 m), forests: oak [O], spruce archangel/*Galeobdolon* [SA] (soddy-podzolic/umbric albeluvisols), aspen [A] (gray forest/albic luvisols); spruce herbaceous [SH] (podzol), spruce-broad-leaved [SBL] (burozem) are located in Kaluga and Moscow regions, presenting native reservation and protected area, respectively. Soil was sampled in each horizon along profile gradient. The row of Umbric albeluvisols (0–10 cm) under arable; young fallow; young, secondary and radical forests (20, 45, 90, 450 years old, respectively), presenting “succession row”, is located in Kostroma region. Plant litter was excluded from analysis.

Methods. Soil microbial biomass carbon (C_{mic}) was measured by the substrate-induced respiration method. The ratio C_{mic}/C_{org} was calculated, basal respiration (BR) or CO_2 production from soil was measured. Fungal-to-bacterial ratio was determined by selective inhibition technique using streptomycin and cycloheximide. Gases production (CO_2 and net-N_2O) from soil samples was measured by gas chromatography.

The pool of soil profile (1 m) microbial biomass carbon was found 415, 396, 300, 211 and 142 g C_{mic} m^{-3} for A, SA, O, SBL, SH, respectively. The upper soil mineral layer (0–10 cm) was accounted for 73, 67, 45, 34, 16% of the total C_{mic} profile’s pool in SBL, SH, O, A, SA, respectively. The highest BR was detected for soil profile (1 m) of SBL, the lowest one was in SH, 1035 and 515 mg CO_2-C m^{-2} h^{-1}, respectively. The upper soil layer (0–10 cm) was accounted for 16, 27, 39, 54, 76% of the total soil profile CO_2 production in SA, A, O, SBL, SH, respectively. In the upper soil layer of O, SA, A; SH, SBL the fungi / bacteria ratios were measured 74 ± 8 / 26 ± 3, 55 ± 6 / 45 ± 5, 52 ± 8 / 48 ± 1, 60 ± 5 / 40 ± 1, 53 ± 5 / 47 ± 1, respectively

Along succession soil row from arable towards a radical forest increasing C_{mic} content was found, up 149 to 755 µg C_{mic} g^{-1} soil. The fungal portion in soils of this row was determined up 58 to 68% of the total C_{mic}. The fungi and bacteria portions were by 6.3 and 11.4 times more in radical forest soil compared with arable soil ecosystem, respectively. Microbial CO_2 production was differentiated on fungal and bacterial input.

In the upper soil forests layer (0–10 cm) N_2O production was found 49–199 N-N_2O ng g^{-1} soil h^{-1}, and it was essentially decreased along depth gradient. The direct relationship between N_2O production and C_{mic} values in profile was found. In soils of succession row the lowest N_2O production was detected in natural soil ecosystems (secondary and radical forests), which characterized by the highest C_{mic}/C_{org} ratios. Thus, microbial biomass carbon and microbial CO_2 production of various forests soil profile located in Southern taiga are essentially differ depending on soil-forming material, forest type and relief element. Some peculiarities of C_{mic} accumulation in overgrowing arable soil were detected. The procedure of fungal and bacterial portions in the total C_{mic} was optimized. Some relationships between greenhouse gases production and soil microbial parameters were found.

Effect of Mn concentration in beech leaf litter on CO_2 and DOC releases during incubation

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Litter decomposition is of crucial importance for sustainable production of forest ecosystems. Lignin concentration of organic residues exerts a major control on their decomposition. Among the factors affecting the degradation of lignin, manganese concentration may play a key role, as it essential for the activity of manganese peroxydase (MnP), an enzyme of the lignin degrading system secreted by the white-rot fungi. Correlation between Mn concentration and litter mineralization was observed (Berg et al., 2007), but the role of Mn was not experimentally tested.

This study is aimed to assess the impact of Mn concentration in beech (*Fagus sylvatica L.*) leaf litter on the release of CO_2 and DOC during decomposition. Mn concentration in leaves was experimentally adjusted by dipping of branches in Mn solutions (0 to 2.5 mM). Mn was transported through the transpiration stream and accumulated in leaves. Leaf litter, with identical composition, except Mn concentration (Mn0, 30; Mn1, 35; Mn2, 40; Mn3, 50; Mn4, 130 ppm) were incubated in the laboratory and CO_2 and DOC releases were measured.

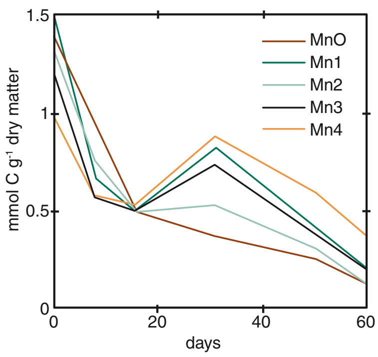
In the beginning of the incubation, Mn0 leaf litter exhibited the largest CO_2 release and Mn4 leaf litter the lowest; after 20 days, it was the contrary (Fig. a). After one month, the DOC/(CO_2+DOC) ratio was significantly lower for the carbon release from the Mn3 leaf litter than from the Mn0 and Mn1 ones (Fig. b). The water extracts of the Mn3 and Mn4 leaf litters exhibited a molar absorptivity (absorbance at 280 nm / DOC concentration) significantly larger.

Our data suggest that Mn concentration affects the release of CO_2 but this influence varies during the decomposition process (Fig. a). Leaf litters with larger Mn concentration release DOC originated preferentially from ligninolysis; indeed, molar absorptivity estimates the concentration of aromatic compounds produced mainly by ligninolysis (Simonsson et al., 2005).

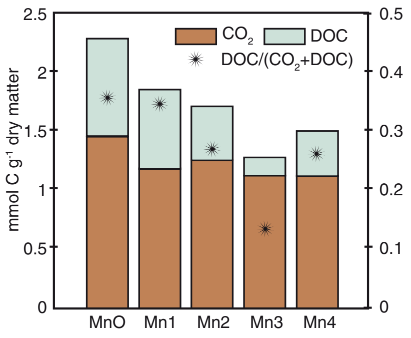
This experiment will be monitored for a larger period and the evolution of lignin content will be studied.

Keywords: Litter decomposition, manganese, lignin, carbon release.

a) Evolution of CO_2 release



b) CO_2 and DOC releases after one month



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Evaluation of carbon stocks in UK forest soils

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Globally, more than twice the amount of carbon is held in soils as in vegetation or the atmosphere, and thus changes in soil carbon content may hugely influence global carbon flux. Forest soils represent a major carbon store with carbon stocks exceeding those under most other land uses. The stability of this store is of primary importance to climate change mitigation and therefore there is a need for an accurate inventory and monitoring programme. Forest management practices that disturb the soil can promote carbon loss, while climate change can have both positive and negative impacts. It is recognised that global warming and rising CO_2 levels in the atmosphere can enhance forest growth, which in turn could increase soil organic matter through greater litter input. Conversely, increasing soil temperatures are predicted to promote microbial activity and therefore decomposition and loss of soil organic matter. The balance of these opposing processes remains uncertain. This study reports the results from the first comprehensive survey of forest soil carbon stocks in Great Britain in order to provide a baseline for evaluating future change.

Soil samples were taken from a total of 167 sites across Scotland, England and Wales during 2007 for the EU BioSoil project, which is part of the International Co-operative Programme on the assessment and monitoring of air pollution effects on forests (ICP Forests). Sites were selected on the basis of the presence of woodland on a 16 × 16 km national grid and covered a wide range of tree species and soil types. Sampling was by both soil horizon and depth (0–5 cm, 5–10 cm, 10–20 cm and 40–80 cm), with all samples analysed for soil carbon concentration and bulk density by standard methods. Participation in European interlaboratory sample exchange exercises and use of benchmark soils underpinned quality assurance. Calculated soil carbon stocks for different soil and forest types are presented, along with an estimate of total forest soil carbon stores by country in Great Britain. These data are compared with those derived from other national surveys and the uncertainties involved in measuring, calculating and upscaling carbon stocks are discussed.

The total carbon content in forest soils across Great Britain ranged between 290 and 700 t CO_2 ha^{-1}. Carbon content varied with soil depth, soil type, forest type and stand age, with the majority of the carbon present within the upper organic horizons (235 to 418 t CO_2 ha^{-1} within the 5–20 cm depth layer). Maximum values ranged between 620–1400 t CO_2 ha^{-1} depending on the age of the stand and the depth of the organic horizon. Carbon stocks across the different soil types decreased in the order *deep peats > peaty gleys > surface water gleys = ground water gleys > brown earths = podzols*. Litter and fermentation horizons contributed an average of 34 t CO_2 ha^{-1} and 49 t CO_2 ha^{-1}, respectively to the overall soil C stock. Forest soil carbon stocks were greater under conifers compared to broadleaves and highest in Scotland (482 Mt CO_2), followed by England (129 Mt CO_2) and then Wales (53 Mt CO_2). Peaty gleys contributed most to the total C stock in Scotland, while brown earths and podzolic soils made the largest contribution in Wales and brown earths and surface water gley soils in England.

A comparison of carbon stocks calculated by different methods highlighted a problem with using ‘standard’ bulk density values derived from the literature. These introduced substantial error and resulted in previous surveys greatly overestimating forest soil carbon stocks. The data showed no relationship between soil C content and measured bulk density in soil samples with C content >25%, emphasising the weakness of using standard regression equations to derive carbon stocks.

Temperature sensitivity of soil organic matter decomposition in southern and northern areas of the boreal forest zone

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Much effort has been made to improve understanding of factors controlling the temperature dependence of soil organic matter (SOM) decomposition. The question of how soils formed in different geographical locations and conditions respond to climatic warming is still open. In addition to climate, residence times of soil organic matter are controlled by its decomposability and microbial community. We studied short-term temperature dependence of SOM decomposition near the northern and southern borders of the boreal forest zone. As carbon mineralization rate is driven by microbial activity, we focused on organic carbon fractions available to microbes and the size, composition and functioning of microbial communities in the soil. Soil samples from forest sites located in northern Finland were transplanted to forest sites in southern Finland. Difference in the annual mean temperature between the sites is about 4.5 °C, which is the mean of warming scenarios for Finland during the next 80 years. When the soil samples are transferred, they are disconnected from the surrounding plant root system. The effect of this was studied by transplanting samples also within the sites. The temperature dependence of CO2 production (Q10) was measured and the microbial community structure was characterized using two methods; composition of phospholipid fatty acids and substrate utilization patterns, before transferring and after two years acclimatization period. Climate, forest site type or root cutting did not affect the Q10 value, but microbial community structure and substrate utilization patterns were affected by all these factors. This study shows that despite the differences in soil microbial community the temperature dependency of carbon mineralization is equal in north and south and not affected by rapid temperature increase. However, a similar increase in temperature causes a larger proportional increase in the decomposition rate at a low temperature compared to a high temperature.

Influence of six European tree species on soil carbon stocks and carbon turnover in a common garden experiment

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The knowledge of tree species effects on soil carbon pools and carbon turnover is limited, particularly for a range of European deciduous tree species. We studied soil C stocks, soil respiration, and rates of C turnover in six European tree species in a 30-yr-old common garden experiment replicated at six sites in Denmark. The six tree species were ash (*Fraxinus excelsior*), beech (*Fagus sylvatica*), lime (*Tilia cordata*), sycamore maple (*Acer pseudoplatanus*), oak (*Quercus robur*), and Norway spruce (*Picea abies*). Soil respiration was assessed monthly in the field, and rates of C turnover were estimated by i) the ratio of soil respiration to C stock in forest floor and top mineral soil assuming a similar ratio between root and microbial respiration among tree species, ii) decomposition constants based on the ratio of litterfall C to forest floor C, iii) foliar mass loss in litterbags, and iv) mineral soil basal respiration in the laboratory.

Forest floor C stocks increased in the order ash=lime=maple<oak=beech<<spruce. Mineral soil C stocks did not differ significantly among tree species, but ash and lime tended to have more C in 15–30 cm indicating a deeper incorporation of C than in species with large forest floor C stocks. Aboveground litterfall was not significantly different among tree species and therefore not likely to be responsible for the large variability in forest floor C stock. Soil respiration differed significantly among species and increased in the order beech<lime<Norway spruce=oak=maple<<ash. Soil respiration was mainly temperature limited with no significant species difference in Q_{10}. Norway spruce soils were significantly driest, and soil respiration was also weakly positively related to soil moisture. The indices of soil C turnover were largely consistent and were also correlated. Carbon turnover rates based on the ratio between soil respiration and C stock increased from spruce and beech over oak and lime to maple and ash. A similar influence of tree species on C turnover was indicated by the litterfall C/forest floor C ratio and by foliar mass loss; rates of C turnover increased in the order spruce<beech=oak<ash=lime=maple. Mineral soil C turnover during laboratory incubation was also highest for ash, maple and oak, and significantly lower for spruce. Litterfall N status was closely related to C turnover indices, but may be a proxy for other litter quality parameters of more causal importance. The results suggest that the six common European tree species had developed consistently different profiles in terms of soil C dynamics three decades after planting.

Spatial variation of CO_2 efflux and partitioning of soil respiration at Bavarian forest sites

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Soil respiration is a major flux of CO_2 in the carbon cycle of forest ecosystems showing a pronounced spatial and temporal variation. Temporal variation is mainly linked to changes in temperature and moisture, whereas the control of spatial variation is largely unknown. In addition to climatic factors, differences in soil properties, tree species and site productivity are commonly considered to influence site-to-site variation of soil respiration and its components. The aim of this study was to assess soil respiration and its components using different partitioning methods (removal of organic layer, trenching of roots, carbon budget approach (Raich and Nadelhoffer, 1989) at seven Bavarian forests. The sites are part of the European Level II programme, consisting of mature Norway spruce, European beech, Scots pine and Oak stands with distinct climate and soil properties. CO_2 fluxes were measured weekly-biweekly over a period of about 2.5 years using the closed dynamic chamber method.

Total CO_2 efflux varied between 534 and 796 $g\ C\ m^{-2}\ a^{-1}$ in non-manipulated control plots. Variation of total CO_2 efflux among the sites cannot be explained by differences in temperature, precipitation, annual litterfall, annual wood increment or organic layer thickness. Among others, deferring contents of phosphorus might be a possible explanation for spatial variation of total CO_2 efflux (Borken et al., 2002).

In comparison to the control plots, CO_2 efflux of the root trenching plots decreased by 8–33%, suggesting a small contribution of live roots to total CO_2 efflux. By contrast, the soil carbon budget approach (Raich and Nadelhoffer, 1989) revealed a CO_2 release of 40–80% from C allocated in the soil via the root system. Increasing portion of belowground originated CO_2 was attributed to decreasing base saturation in the top mineral soil. Hence, in nutrient poor stands, trees seem to allocate relatively more C in the root system than in the aboveground biomass. Therefore, a smaller potential for long-term CO_2 fixation in aboveground biomass may be expected for nutrient poor stands.

Removal of organic layers led to a decline of soil respiration by 20–50% compared with total CO_2 efflux in the control plots, indicating a larger contribution of mineral soil and roots to total soil respiration. This is particularly true for stands characterized by a larger mean residence time of C in the organic layers and a corresponding large thickness of these organic horizons.

Mean residence time of soil organic carbon is negatively correlated with mean annual air temperature. With respect to global warming, sites in mountainous regions holding large soil organic carbon stocks in organic layers pose a potential risk for increasing soil CO_2 efflux.

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Carbon sequestration in SOM pools of Luvic Phaeozem estimated by C3–C4 transition and extended laboratory incubation

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Carbon sequestration during plant litter decomposition and accumulation of soil organic matter (SOM) in stable pools is one of the key processes mitigating greenhouse effect. To separate a complex ensemble of soil organic matter (SOM) into the pools with turnover times ranging from years to centuries, SOM can be analyzed from particle size fractionation of soil. The majority of fractionations yield SOM fractions that are heterogeneous in terms of turnover rates. Combining fractionation with ^{13}C natural abundance approach in soil sampled from C3–C4 transition plots allows estimation of the incorporation of old C (original plant cover) and new C (current vegetation) into soil fractions. Further development of a functional fractionation is the estimation of SOM stability during long-term incubation of physical fractions. We used these approaches in a 5yr field manipulation experiment on Luvic Phaeozem (Pushchino, Moscow Region, 54°50’N, 37°35’E) applying corn litter to a C3 soil at 380 and 1160 g C m^{-2} annually. The first treatment corresponds to mean annual C input into the soil with plant residues in agroecosystems, and the second one is equivalent to C input with NPP in grassland. At the end of field decomposition, soil samples fractionated by particle size were incubated at 22°C and 70% of water holding capacity during 365 days. Turnover rates and mean residence time (MRT) of C in the field experiment were calculated by natural ^{13}C abundance approach using single exponential decay equation (Balesdent & Mariotti, 1996). The same approach was used in incubation study: turnover rates of old and young SOM in the recovered fractions were calculated on the base of annual losses of C3 and C4 derived carbon, respectively.

In the field experiment decomposing litter fragments were included mainly in the coarse soil fractions. Up to 60% of corn derived C was found in particulate organic matter (POM, 100–1000 μm). Incorporation of decomposing litter into fine clay fraction (0.2–1 μm) was much lower and comprised 5% and 15% of C4 carbon for low and high litter treatments respectively. MRT of SOM in low litter treatment amounted to 12 and 63 yrs for POM and clay fraction, respectively. The high apparent stability of new corn derived SOM in fine clay particles was mainly attributed to slow litter fragmentation rather than formation of long lived clay-associated organo-mineral complexes. This conclusion was confirmed by incubation experiments.

Total C losses for the 1yr incubation amounted to 8–11% of initial C content and did not differ significantly in POM and clay particles. Both fractions had approximately the same MRT of 2–3 yrs for the new C4 derived carbon. The approaches used did not allow us to investigate the stabilization of newly formed SOM. We believe that stabilization needs experiments with duration longer than 5 yr. By contrast, old C3 derived carbon turned over more quickly in POM than in clay fraction. Old C in POM had the same MRT as the new corn derived C, while MRT of old carbon in clay fraction was 20 and 47 yrs for low and high litter treatments, respectively. These findings were consistent with NMR spectra of particle size fractions.

The combination of particle size fractionation with the use of isotopic signatures and incubation enabled us to divide SOM into distinct pools with specific stability and homogenous turnover rates.

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Stabilization of extracellular polymeric substances by sorption to Al hydroxide and co-precipitation with Al

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Extracellular polymeric substances (EPS) are continuously produced by numerous bacteria during their growth and metabolism. These EPS are bound to the cell surface, released into solution, or associated with biofilms. Therefore, EPS might significantly contribute to microbial-derived organic C in soils. Until now, the extent of stabilization of these compounds and the involved mechanisms are unknown although microbial-derived C contributes substantially to soil organic matter particularly in subsoils.

In our study we determined the stabilization of EPS against microbial decay by sorption to amorphous Al hydroxide and co-precipitation with Al. As model substance we used EPS isolated from *Bacillus subtilis*, which was characterized by multiple methods including NMR (^{1}H, ^{13}C, ^{31}P) and the analysis of hydrolyzable amino acids. Different amounts of amorphous aluminium hydroxide, representing pedogenic hydroxides with high specific surface area, and Al^{3+} were added to an EPS solution with varying ionic strength (1,7 mM to 170 mM) and pH (3,8 to 6,5). The obtained sorption complexes and co-precipitates were further characterized with FTIR and XPS. We incubated sorbed and co-precipitated EPS for 7 weeks and compared the measured stability against microbial decay with desorption/dissolution patterns of the Al-EPS-complexes. Additionally, we also incubated the non-sorbed and non-precipitated EPS in order to include these fractions into the overall assessment of the stabilizing effects of sorption and co-precipitation.

Up to 60% of the initial carbon could be sorbed by adding 35 mg Al hydroxide per mg EPS-C. Co-precipitation was less efficient in removing EPS from solution with a maximum of 30% being removed at Al/C ratios of 0.1–0.2. Sorption and co-precipitation behaviour of EPS could be described with sigmoid, BET-like isotherms. As the amount of sorbed C was independent of pH and ionic strength we deduced ligand exchange to be the dominating binding mechanism for sorption whereas, for co-precipitation, physiosorptive binding is additionally involved.

The incubation experiments clearly showed that both processes resulted in carbon stabilization against microbial decay. Whereas up to 70% of the pure EPS was mineralized, the extent of mineralization decreased to 20% after sorption to Al hydroxide and to 40% after co-precipitation. These numbers include mineralization of non-sorbed and non-precipitated EPS. Therefore, stabilization was larger by sorption to Al hydroxide than by co-precipitation. Stabilization of sorbed and precipitated EPS increased with increasing Al/C ratio, i.e., as the abundance of Al §orption and co-precipitation. Both processes will contribute to stabilization of EPS against microbial decay. Therefore, sorption and co-precipitation of microbial-derived compounds by Al can contribute to the long-term C stabilization in mineral soils.

Tree Girdling as well as Nitrogen Fertilization Increase N_2O-Formation and Decrease CH_4-Uptake in a Beech Forest

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Tree girdling affects below ground carbon fluxes by interrupting the transport of photosynthates from the canopy to the roots. At the same time plant nitrogen uptake is reduced, which may remove N limitation of the microbial community. Similarly, increased nitrogen inputs from the atmosphere or from fertilization may lead to a shift from nitrogen towards carbon limitation of soil microbes. We measured soil-surface CO_2, N_2O, CH_4 and NO fluxes from a 62 year old beech forest soil that receives 13 kg N ha^{-1} yr^{-1} by wet deposition. A fertilization experiment was carried out over two years. Wet N input was increased by spraying 50kg N ha^{-1} yr^{-1}, in monthly doses.

Girdling enhanced N_2O emission due to 10-fold higher nitrate concentrations in soils. Fertilization also increased N_2O emissions by 20–25%. Girdling reduced CO_2 efflux by 22–28% as did nitrogen fertilization. Girdling and nitrogen fertilization reduced CH_4 uptake, evoked occasional CH_4 emission and thereby reduced the sink strength of the soil for CH_4.

Our results permit new insights on how changing carbon and nitrogen availability may affect ecosystem processes through shifts in microbial decomposition processes.

Invertebrate colonization of manipulated plantations on fire-affected areas

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Fire is one of the disturbances influencing the composition and distribution of flora and fauna as well as biogeochemical cycles in the natural environment. In Hong Kong, the combination of dry weather and grave sweeping activities attributed to the high risk of hillfire, especially in autumn and winter months. Fire is a major threat to terrestrial animal community, the composition of which is very rich in shrublands and woodlands, and is the main force that shapes the local landscapes (Chau and Marafa, 1999).

Artificial planting are usually adopted by forest managers to restore disturbed habitats (Lindenmayer and Hobbs, 2004). Manipulation experiment with different tree plantings (native species, exotic species and mixed planting) was conducted in different plots in a burnt site in the Tai Lam Country Park located in the central part of the New Territories to determine faunal recovery seven months after fire disturbance. The assemblages of ground dwelling invertebrates were studied. Results show that total nitrogen, total phosphorus, organic carbon and pH of soil from the fire disturbed sites were all lower than the woodland reference site with the same geoecological features. Mean biomass of ground dwelling invertebrates in native plantations was the highest, which was followed by mixed plantations and exotic plantations. Ant was selected as bioindicator for further analysis of their community structure. Among the various physicochemical parameters and vegetation parameters analyzed, Pearson correlation shows that pH, grass coverage, litter depth and litter coverage correlated with the faunal biomass significantly. Invertebrate assemblages in exotic plantations are less diverse than those in native ones. Advantages and disadvantages of various plantations will be discussed.

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Effects of nutrient additions on colonization of macrobenthic community in a man-made mudflat

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A manipulated experiment was conducted in a 1 ha man-made mudflat to examine the response of macrobenthic community to addition of nutrients using slow-release gypsum matrix fertilizer stakes containing nitrogen (N) and phosphorus (P). Three treatment groups: 0× (control), 2× (15.86 g N m^{-2}, 12.34 g P m^{-2}) and 8× (68.76 g N m^{-2}, 51.13 g P m^{-2}) of background nutrient concentrations were set up, in which calculated amount of fertilizer stakes was applied to 108 plastic trays (H: 7.4 cm, L: 27.4 cm, W: 20.7 cm) containing defaunated sediment. These trays were randomly deployed on the mudflat over a period of one year. Three trays from each treatment were retrieved at monthly intervals from the deployed trays, sediment trays were brought back to the laboratory for analysis of macrobenthic infauna and physio-chemical parameters, including *in situ* measurements of redox and pH, and laboratory analysis of sediment particle size, chlorophyll *a*, TKN, TP and TOC. Results of analysis of variance on the physico-chemical data in the experiment showed that there was significant difference ($p<0.05$) among the 3 treatment groups. Higher chlorophyll *a* concentration and lower redox potential were noted in the 8× treatment than in the 2× and control groups. The increase in chlorophyll *a* content in the 2× and 8× treatments implied that additional nutrients enhanced primary production. Species number and *H*' from 3 replicates in the 2× treatment group was higher than that in the control, which was, in turn, higher than the 8× treatment. The low redox potential in the 8× treatment suggested that a reducing state with lower oxygen content was developed, result of which might cause stress on the colonization of macrobenthos in the experimental trays. Results of present experiments showed that colonization of macrobenthos can successfully occur in a man-made mudflat over time, and even be enhanced by addition of proper amount of nutrients. The present findings thus have implications on the re-establishment of ecologically important habitats.

The impact of differing soil hydrology on the soil surface gas fluxes of nitrous oxide and methane in two Danish forests

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The emissions of the strong greenhouse gasses (GHG) methane (CH_4) and nitrous oxide (N_2O) from soils are enhanced at high soil moisture contents, where anaerobic microsites are formed. In forests, most GHG flux measurements have been performed on flat terrain, excluding the wet and seasonally wet parts of the forest area in the landscapes.

To study the impact of soil hydrology on GHG flux dynamics in temperate Danish forests CH_4 and N_2O fluxes were measured along small scale hydrological/landscape gradients in two Danish beech (Strødam) and oak (Vestskoven) forests, respectively. The annual water regimes along the hydrological gradients ranged from fully saturated (>90 vol%) to well aerated, dry conditions (<15 vol%). Thus, the hydrological gradients were assumed to represent natural manipulation experiments of a wide range of drainage conditions and water level in the soil. The experimental setup at the two study sites were designed similarly, consisting of three transects on gently sloping terrain with a small pond at the bottom. Along each of the transects chambers to measure gas fluxes were installed from the low to high parts in the terrain. Soil water content at 4 to 5 depths, soil temperature as well as the groundwater level was measured at each chamber on every sampling occasion.

The landscape position influenced the soil water content to a large degree, but the soil temperature remained constant in all measurement points on a specific sampling occasion. Both the soil water content and temperature showed seasonal fluctuations. Fluxes of N_2O were very variable over time in all investigated points along the transects. However, seasonally wet soils with an average soil water content of 40–60 vol % showed the largest average fluxes of N_2O of up to 60 times higher than the drier and permanently wet soils (Fig. 1). Average fluxes of CH_4 fluxes were also highly variable but emissions only occurred in the intermediate to wet soils (water content above 50 vol %) and increased considerably with the wetness of the soil (Fig. 1). However, uptake of CH_4 occurred in the whole range of soil water contents but the magnitude of CH_4 uptake in the soil was more or less constant. The accumulated CH_4 emissions from the wet soils over the entire study period were about 80 times higher than the accumulated uptake from the drier soils.

Even though the study areas were located on different soil types and with different tree species the same general trends were found at both sites. Thus, it was indicated that factors such as different hydrological regimes determined by the topography played an equally important role in regard to GHG flux dynamics as site specific properties. Based on the findings in this study and seen in the context of a changing climate, e.g. increasing temperatures and amounts of precipitation as projected for northern Europe, it could be expected that forest soils would become wetter thus increasing the source potential for N_2O and CH_4 of forest soils. It is therefore of great importance that the different hydrological dynamics observed in the landscape are understood and addressed in future assessments of GHG source and sink potentials of forest soils.

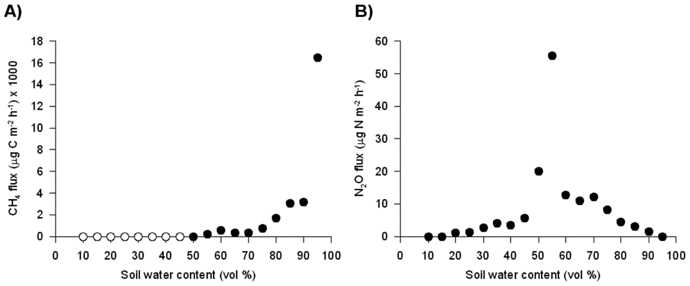

Fig. 1 Average methane (A) and nitrous oxide (B) fluxes (µg m^{-2} h^{-1}) for the whole study period as a function of soil water content measured at the two study sites, Strødam and Vestskoven. Emission and uptake are shown with filled (●) and open (○) circles, respectively

Contribution of simulated nitrogen deposition to forest soil acidification in area with high sulfur deposition

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The impacts of increasing nitrogen deposition on a typical acidified soil under a Masson pine (Pinus Massoniana) forest was studied through field experiments at Tieshanping, Chongqing in Southwest China. Nine adjacent sample plots of 10 × 10 m^2 were under three treatments with three repetitions each. The three treatments consisted of two different fertilizing treatments (monthly spray of NH_4NO_3 and $NaNO_3$ solution respectively on the soil surface with the same N dose of 40 $kg \cdot hm^{-2} \cdot a^{-1}$, which is approximately equal to the total N deposition in this area in 2003) and a reference treatment.

The changes of soil water chemistry in different soil layers within two years (2005-2006) after the treatment indicated that the pH value decreased a little (treated by NH_4NO_3) or increased somewhat (treated by $NaNO_3$) (Fig. 1). Simultaneously, the concentration of base cations, i.e. Ca^{2+} and Mg^{2+} increased, especially in the $NaNO_3$-treated plots, together with the increasing concentration of Al^{3+}, which lead to the increase of the Al^{3+} to base cations (sum of Ca^{2+}, Mg^{2+} and K^+) molar ratio from 0.5 of the reference to around or even higher than 1.0. The activation of toxic Al^{3+} indicated the deterioration of soil acidification by nitrogen deposition in this area.

In addition, the nitrogen saturation occurred with the increasing NO_3^- leaching, and the newly added NH_4^+ (treated by NH_4NO_3) transformed rapidly to NO_3^- and showed an even larger NO_3^- leaching than the purely addition of NO_3^- (treaded by $NaNO_3$) (Fig. 2). Since it was detected that NH_4^+ had more effect on soil acidification and eutrophication than NO_3^- with the same equivalence, ammonia (NH_3) emission abatement should be preferred to nitrogen oxides (NOx) for nitrogen deposition control in China.

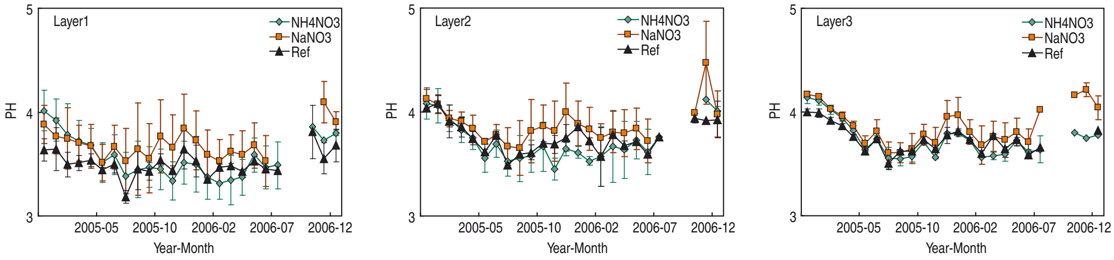

Fig.1 Monthly variation of pH value of soil water (Layer 1, 2 and 3 as upper, middle and lower soil layer respectively) under each treatment during 2005–2006. Error bars show standard deviations.

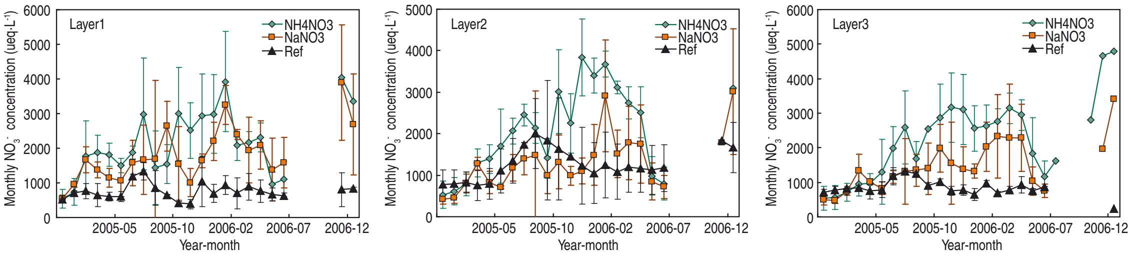

Fig.2 Monthly variation of NO3- concentration of soil water under each treatment during 2005–2006

Effect of limestone and magnesite application on a masson pine forest ecosystem in Southwest China

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The remediation of a typical acidified soil under a masson pine (Pinus massoniana) forest was studied through field manipulation experiment at Tieshanping, Chongqing in Southwest China. Six adjacent sample plots of 10 × 10 m^2 were divided into two blocks of three plots each. Within each block, one plot was randomly assigned to one out of three treatments. The three treatments consisted of two different liming treatments (one-time addition of limestone and magnesite respectively on the soil surface in 2003) and a reference treatment.

During the five years after treatment, monitoring results of soil water chemistry in different layers showed significant increase of pH value (fig.1) and concentration of relative cation, i.e. Ca^{2+} or Mg^{2+} (fig.2), and notable decrease of inorganic monomeric aluminum (Ali) in the liming plots. However, the supply of one nutrient element (e.g., Ca) in the acidified soil stimulated the vegetation uptake, which might cause larger loss and even enhanced deficit of other elements (e.g., Mg) from soil. Therefore, application of limestone or magnesite only is not sufficient for remediation of soil and restoration of forest ecosystem. The change of soil water chemistry was much more notable in upper layer of soil than lower, which means that it will take long time to achieve the whole-profile soil remediation.

Ecological investigations carried out at the end of the growing season just before and each year after the treatments indicated that some trend of ecological recovery had also happened in general, e.g., the increase of tree DBH (diameter at breast height), acceleration of restocking, growth of root and needle biomass, and change of specie abundance, as a result of soil chemistry change.

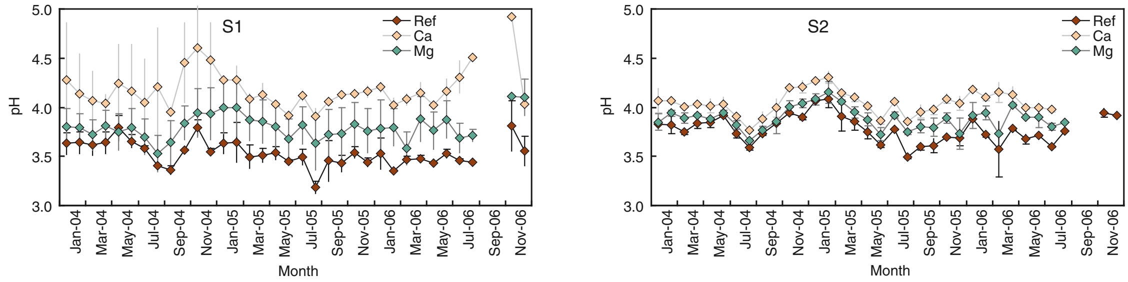

Fig.1 Monthly variation of pH value of soil water (S1 as upper layer and S2 lower) under each treatment during 2004–2006. Error bars show standard deviations.

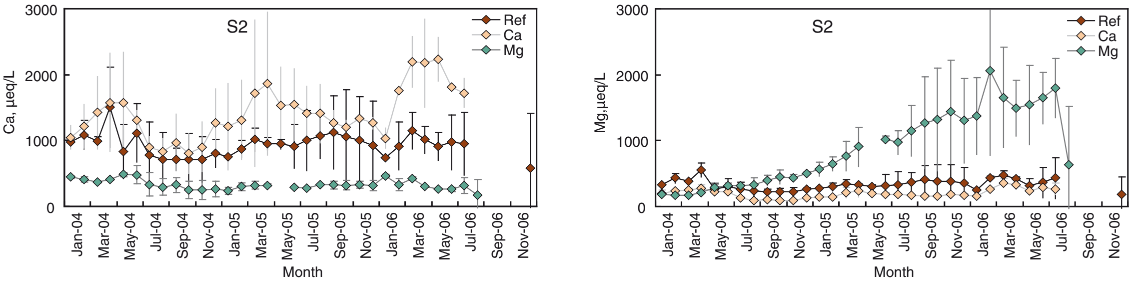

Fig.2 Monthly variation of Ca^{2+} and Mg^{2+} concentration in soil water (lower layer) under each treatment during 2004–2006

The artificial catchment 'Chicken Creek' ('*Hühnerwasser*') as a tool for understanding the interactions of processes and structures of initial ecosystem development

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The analysis of water and element cycling plays a key role in drawing conclusions about functioning, stability, elasticity and resilience of the ecosystem. The definition of clearly outlined budget areas is inevitable therefore, which is typically approached by using natural surface and subsurface watersheds. Compared to natural catchments the boundaries and inner structures of artificial watersheds can be planned and defined in advance. Both local boundary conditions, e.g. the accordance of the surface and the groundwater catchment or the drainage pattern, as well as internal structures, e.g. discharge points and stratification, can be influenced and most of all precisely documented during the site construction.

The attempt to study patterns and processes of initial ecosystem development at an artificial catchment is a novel approach to disentangle the complex interactions and feedback mechanisms typically found in mature ecosystems and to understand the relevance and importance of initial conditions on further development and future state of an ecosystem. Beside these fundamental objectives and questions the approach aims to transform its result to more applied problems like improving hydrological models as well as restoration measures and management options for disturbed or degraded landscapes.

To allow the clear definition of as homogeneous as possible starting conditions at ´point zero´ and to be able to integrate spatially distributed processes and patterns to larger units, an artificial catchment was constructed in the mining area of Lusatia, Germany. This artificial catchment ´Chicken Creek´ with an area of about 6 ha was constructed as a 2–4 m layer of post-glacial sandy to loamy sediments overlying a 1–2 m layer of Tertiary clay that forms a shallow pan and seals the whole catchment at the base (Fig. 1). No further measures of restoration like planting, amelioration or fertilization were carried out to allow natural succession and undisturbed development. The construction plan allowed the establishment of a small lake with a diameter of around 70 m and a maximum depth of 3 m in the lower part of the catchment. The site was fenced in completely to avoid disturbances and vandalism particularly by human visitors but also by abundant game animals in the area. The construction operations were completed in September 2005 which can be defined as the 'point zero' of the ongoing development of the site.

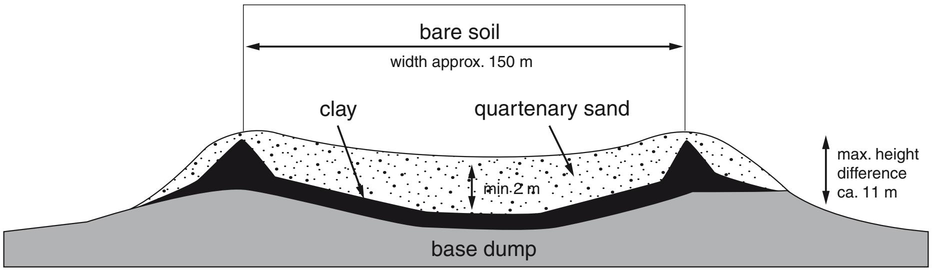

Fig. 1. Schematic cross-section of the artificial catchment ´Chicken Creek´

Interacting effects of sulphate pollution, sulphide toxicity and eutrophication on vegetation development in fens: a mesocosm experiment

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During recent decades, both increased agricultural fertilization and the use of polluted river water to compensate for water shortage have, directly or indirectly, led to a higher availability of nutrients, sulphate pollution and the formation of potentially toxic compounds such as sulphide. As a result, many characteristic plant species have disappeared and have been outcompeted by a few fast-growing species, leading to a strong decrease in biodiversity, vegetation development and terrestrialization. Eutrophication, however, may lead to higher biomass production and root development, which can have a dilution effect on toxic compounds in plant tissue and lead to oxidation of reductive sediments. Therefore, we investigated the effects of sulphate pollution in outdoor, semi-controlled fen mesocosms under nutrient-poor and nutrient-rich conditions using aquatic and semi-aquatic macrophyte species with different growth strategies.

Fertilization led to higher concentrations of PO_4, NO_3 and NH_4, whereas SO_4 addition increased alkalinity and concentrations of sulphide, SO_4 and humic acids. After three years, however, concentrations of PO_4 and NH_4 were highest in the SO_4 treatments, probably due to higher decomposition rates and PO_4 mobilization from iron binding sites.

Biomass production of aquatic and semi-aquatic macrophytes was higher after fertilization of the peat, and colonization of the water layer by semi-aquatic macrophytes increased. SO_4 addition led to toxic sulphide levels, which reduced both biomass production and colonization considerably. Furthermore, fertilization and SO_4 addition each led to decreased vegetation N:P ratios, indicating a shift from P- to N-limitation.

Macrophytes in the fertilized treatments were less vulnerable to sulphide toxicity, probably because of a combination of dilution due to higher biomass production and greater oxidation of the peat bank by radial oxygen loss due to higher root biomass. Since aquatic macrophytes can take up nutrients from the water layer, they were less susceptible to sulphide in the sediment.

This mesocosm experiment clearly shows that competition between species, vegetation succession and terrestrialization are not only influenced by nutrient availability, but also by toxicity, which strongly interacts with the level of eutrophication. This implies that previously neutralized toxicity effects in eutrophied fens may appear after nutrient reduction measures have been taken, leading to a vegetation collapse. It is, therefore, important for the restoration of biodiversity and terrestrialization in fens that not only nutrient loads, but also sulphate pollution will be reduced.

Soil leaching before and after clear cutting of the acidified Norway spruce stands Ballyhooly (Ireland) and Höglwald (Germany) as influenced by N and sea salt deposition

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We compared the ion concentrations of seepage water before and after clear cutting of two long term experimental Norway spruce forests, Ballyhooly (Ireland) and Höglwald (Southern Germany). Both stands exhibited similar soil and stand properties and comparable stand history, but Ballyhooly was influenced by seasalt deposition and was considered as “non N limited”, while at Höglwald N deposition was high and the site was “N saturated”. These differences were clearly reflected in seepage water concentrations (40 cm depth) of the intact mature stands. Ion concentrations at Höglwald were dominated by NO_3^- (mostly above the EU level for drinking water of 806 μmolc l^{-1}) and Al. Ballyhooly exhibited high concentrations of Na and Cl, but elevated NO_3^- and Al concentrations were observed only at discrete events. After clear cutting the stands showed similarities in their response on NO_3^- leaching. Average peak concentrations at Höglwald reached a maximum of 2595 μmolc l^{-1} and at Ballyhooly of 2018 μmolc l^{-1}. At Ballyhooly the NO_3^- concentrations were continuously elevated over 1.5 years. At the Höglwald clear cut subplot, which was replanted with spruce or beech saplings periodically elevated NO_3^- concentrations occurred with two distinct NO_3^- peaks over a two year period, but in between also lower concentrations were found in comparison to the control. A subplot with a pre existing dense regeneration of Norway spruce exhibited the lowest NO_3^- concentrations before and also after the clear cutting. Al showed the same trend as NO_3^- on both sites. K^+ concentrations were hardly impacted at Höglwald, while at Ballyholly a sharp increase was observed after the cutting. Ca^{2+} and Mg^{2+} peaks were also more pronounced at Ballyhooly. Generally, lower concentrations were observed for Na^+, Cl^-, and SO_4^{2-} at both sites after clear cutting. Some implications for forest management are given in the presentation.

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Effects of elevated ozone and temperature on growth and below-ground processes of silver birch (*Betula pendula*)

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Northern ecosystems are already experiencing climate change. In the near future, anthropogenic influence on climate and thereby on northern forests is expected to accelerate even further. According to climate change scenarios, the mean global surface temperatures will continue to increase during this century (IPCC 2007), and simultaneously forests will be exposed to damaging ozone (O_3) stress (IPCC 2007, RS Policy Report 2008). In Nordic countries the use of fast-growing plant species and soils as C sinks is suggested to be one way to mitigate anthropogenic climate change. However, there is still a lack of information how climatic warming and O_3 stress in combination will affect these C pools and what will be ultimately their C sink strength.

Both the single and combined effects of warming and tropospheric ozone on four different genotypes (gt12, gt14, gt15 and gt25) of silver birch (*Betula pendula*) were studied in an open-air exposure field experiment. Experimental field is located near University of Kuopio in central Finland (62° 53'N, 27° 37'E). In the field, four plots were exposed to elevated O_3 level and four to ambient air (control plots). All ozone and control plots were further divided into two infra-heated sub-plots and two ambient temperature sub-plots. Hence, in total there were four treatments per each genotype (control, elevated temperature alone, elevated O_3 alone and elevated temperature + elevated O_3 in combination). Data discussed here have been collected in the second exposure season 2008.

In 2008, soil respiration rates were measured seven times and at the end of the exposure season the same trees were harvested for the total mass determination. Based on above-ground growth data, temperature increment in general stimulated tree growth (temperature main effect, $p < 0.0005$). However, genotypes differed in their ozone response (gt x ozone interaction effect, $p = 0.040$). Thus, in the fastest growing genotypes (gt14 and gt25) ozone decreased total above-ground dry mass clearly and this O_3 effect was not fully negated by elevated temperature, whereas in smaller gt12 and gt15 trees ozone effects on above-ground growth were negligible. In addition, soil CO_2 efflux rates showed that genotypes responded quite differently to elevated ozone and temperature treatments (gt x ozone x temperature interaction effect, $p < 0.005$). Only gt14 showed a clear temperature-induced increase in soil respiration under ambient and elevated O_3, whereas in other genotypes significant temperature-induced increases were either observed only under ambient (gt25) or elevated O_3 (gt15). Furthermore, in gt12 the temperature effect on soil respiration was partly reduced due to O_3 in the combination treatment. The above results suggest that the growth and below-ground processes can be clearly altered in warming climate, but also tree genotype and prevailing ozone levels may modify some of these responses. In winter 2008–2009, we continue to analyse root data (biomass and mycorrhizal analyses) as well as 13C-CO_2 labelling samples (labelling experiment conducted with gt15 only) to get a better picture of possible C allocation changes.

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Longterm Effects of Soil Freeze-Thaw Cycles Differ Strongly Between Vegetation Types

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Soil freeze-thaw cycles (FTC) influence nutrient cycling, but their consequences for vegetation are not well investigated. Ongoing global warming will increase the recurrence of FTC in cool-temperate and other high-latitude regions.

Here, we compare the above- and belowground biomass production as well as the nitrogen nutrition of two common vegetation types, grassland and heath, after intensified FTC in a controlled field experiment in Central Europe. Furthermore, we analyze the duration of the observed effects. Five FTC were stimulated by buried heating wires in addition to three naturally occurring FTC during winter 2005/06. Intensified FTC significantly increased aboveground production of grassland early in the following growing season. However, no reaction was found for heath. Biomass production of heath communities dropped significantly and C/N ratio increased in the freeze-thaw treated plots in the second year after the manipulation, whereas production in the grassland communities was no longer affected significantly, except for an increase in C/N ratio.

The results show the high ecological importance of climate changes during winter, with the outcomes differing strongly between contrasting vegetation types. Furthermore, we show that short term climatic events cause long-lasting effects, sometimes emerging in the vegetation only after considerable lag times (here: one growing season).

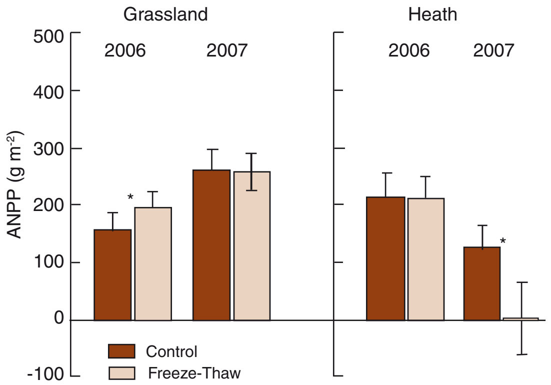

Figure 1. Aboveground Net Primary Production (ANPP) over each growing season (mean values and standard errors). Freeze-thaw manipulation took place only in Winter 2005/06. An asterisk marks significant treatment effects (ANOVA, Tukey HSD post hoc comparison: $p < 0.05$).

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Connecting Experimental Even-Aged Stands with Old Field Temperate Grassland Communities in Face of Extreme Climatic Events

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Novel qualities of expected future climatic conditions have to be investigated experimentally. Just monitoring and observing the responses is not a promising perspective and will not help in disentangling causal interactions. Controlled and replicated experiments with defined composition and structure of vegetation are affected. There, the species specific and community dependant effects of certain events can be identified. However, the artificial nature of such experiments can be criticized. Especially the installation of even-aged stands differs from heterogeneous populations in established perennial communities. Here, we apply identical climatic manipulations as well to highly controlled field experiments as to neighbouring semi-natural grasslands. We focus on responses in aboveground productivity. This research is part of the EVENT-experiment (Jentsch et al. 2007).

Extreme weather events are expected to increase in frequency and magnitude. Responses of ecosystem functioning are widely unknown. Increasingly, field experiments are carried out in order to study this. In our experiment we mimic, based on extreme value statistics, a local 1000-year drought event. In contrast to expectations, overall productivity of the young stands remained stable in the face of drought and heavy rainfall, despite significant effects on the performance of single species and on community tissue die-back (Kreyling et al. 2008). A significant decline in productivity was found for the established stands. These results imply that experimental findings cannot directly be transferred (and upscaled) to natural stands. Not, however, because young stands react more strongly, but because young stands remained more stable within this study, although being furthermore significantly more diverse in terms of species richness. Potential causes for the observed phenomenon and implications for experimental research will be discussed.

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Detrital inputs influence stabilization of soil organic matter

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Recognition of the importance of feedbacks from plants in determining soil nutrient dynamics and C storage led to a large number of litter decomposition studies. Despite growing knowledge of short-term litter dynamics, we know relatively little about the fate of plant litter and its role in determining SOM content and nutrient cycling over time scales ranging from decades and centuries. To address this gap, we established long-term studies of controls on soil organic matter formation in an old-growth forest at the H.J. Andrews Experimental Forest, OR. This study complements a network of recently established similar experiments that pan climatic and soil gradients, as well as the original DIRT experiment established in the Wisconsin Arboretum in 1956 in both grassland and forested sites. The central goal of the DIRT project is to assess how rates and sources of plant litter inputs control the accumulation and dynamics of organic matter and nutrients in forest soils over decadal time scales. Treatment plots include doubled litter (needle) inputs , doubled wood, no above ground litter (screened) inputs, no root inputs (trenched), and no inputs (screened and trenched).

For the 50th anniversary of the Wisconsin sites and the 10th anniversary of the H.J. Andrews site, we used sequential density fractionation of soils from all treatments to determine if adding or removing either below- or above-ground litter inputs influenced carbon stabilization as soil organic matter. After 50 years, double litter plots in both prairie and forested soils had higher %C in the 0–10 cm horizon. In the forested site, plots showed increased C content of the lightest fraction, which represents relatively young SOM with a short turnover time. However, the first two heavy fractions also showed increases in C with added aboveground litter, suggesting the importance of aboveground litter inputs to SOM in the forest. No such pattern existed for the prairie soil, and we hypothesize that this is because aboveground, labile litter adds very little to stabilized SOM in grasslands, and that root-derived C is the dominant control on SOM stabilization in grasslands. These results were confirmed with analysis of labile C (short –term respiration measurements) and acid hydrolysis resistant C across treatments. The relative contribution of aboveground vs. belowground litter was analyzed through the analysis of cutin and suberin acids, and we found that the detrital source of litter was retained in soils and could be fingerprinted through this analysis. Thermal analysis, including thermogravimetry (TG) and differential scanning calorimetry (DSC) performed simultaneously is currently being applied to explore both SOM quality and stability.

CLIMAITE – consequences of multifactor climate change on the carbon and nitrogen cycles

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The earth's climate is changing. In the future, ecosystems will face simultaneous changes in three main factors: elevated atmospheric CO_2, elevated temperature and altered precipitation patterns. These are key factors in the regulation of biological processes and will therefore profoundly affect natural ecosystems. However, the combined effect of all these factors on ecosystem functioning is still poorly understood.

In a Danish research project, CLIMAITE, a multifactorial field scale experiment is being conducted in a semi natural shrubland ecosystem. The three main factors are manipulated alone and in all combination to mimic the conditions predicted for Denmark in the year 2075. The manipulations are (Mikkelsen et al. 2008):

- CO_2: Elevated CO2 (510 ppm) is supplied by a FACE system.
- Temperature: Warming (1-2 °C) by passive night time warming.
- Drought: Extreme drought for 1-2 months is supplied by automatic rain covers.

The effects of the treatments are investigated at the species, community and ecosystem level. The treatments were started in 2005, and the short term results after 2 years of treatment show that the responses to the individual factors are as expected. Warming preferably affects below ground processes through stimulated carbon and nutrient turnover and altered functional rooting depth, root nitrogen uptake and microbial biomass. Drought affects ecosystem processes directly through the reduced soil moisture content and water availability causing reduced plant nutrient uptake and changed nitrification and indirectly, e.g. by reducing stomatal conductance. Elevated CO_2 mainly affects aboveground processes through increased photosynthesis, water use efficiency and growth, which mediates indirect effects down through the ecosystem, e.g. increased gross mineralization rates and reduced inorganic nitrogen leaching due to increased plant N uptake and/or increased microbial immobilization. Combining the treatments leads to a complicated pattern of interactions and feedbacks, particularly mediated through the direct and indirect effects of the three treatments on the water availability. The effects of these interactions on carbon and nitrogen budgets will be presented.

The CLIMAITE site at Brandbjerg, DK, showing an octagonic study plot in the front with a night time warming cover pulled over the vegetation and a rain out shelter (hanging). The octagon hosts 4 treatments (ambient, warming, drought and warming + drought). A neighbouring plot hosts the same treatment but combined with elevated CO_2.

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Dynamics of whole tree sap flux density of a mixed Eucalyptus woodland pre-, during and post a hot bushfire in the wet-dry tropics of northern Australia

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Xylem sap flux density in 32 trees from a native mixed Eucalypt woodland was monitored at the end of a 6-month-long dry season in the wet-dry tropics of northern Australia in 2008. A hot wildfire at early hours of night ravaged the study area and caused various degree of damage to the tree canopies from total defoliation to almost no defoliation, depending on their topographic locations in the 86 ha catchment. Whole tree sap flux density was declining and low at 7:00–8:00 PM when the bush fire passed the area. Sap flux density rapidly increased in many of the trees and remained high over several hours. In contrast some other trees of different species had hardly noticeable increase in nighttime sap flow.

However regardless of the contrasting responses to the scorching conditions, daytime whole tree sap flux density declined rapidly to near zero in all affected trees over 1–3 days as the result of total defoliation. Measurement of whole tree sap flux density closely correlated with degree of damage to the canopy.

Interestingly those damaged canopies re-foliated within 2 weeks after rainfalls totaling 50mm over 1 week, and reached a canopy coverage higher than the pre-fire level. Whole tree sap flux density recovered progressively over this period and reached a level similar or above the pre-fire level.

The amazing speed of recovery of this key physiological function (transpiration) reflected the high level of resilience of the natural woodland facing adversary natural disturbances, in this case, a damaging hot fire. This resilience is apparently achieved by the right mixture of tree species evolved and adapted to the local fire regimes. The ultimate purpose of this study is to provide key knowledge to the establishment of a self-sustaining woodland on a rehabilitated mining site.

Effects of experimental soil frost on fluxes of C and mineral elements in a temperate forest soil

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In an interdisciplinary field study we simulated the effect of a dry-cold winter climate and soil frost by snow removal in a Norway spruce stand. We tested the hypothesis that freezing and thawing of the soil alter solute and gaseous fluxes of C and N in relation to unfrozen controls.

Lowest soil temperatures at 5 cm depth at the snow removal plots were -5 °C while the control plots experienced no soil frost. In the three months after thawing, the *in situ* N net mineralization in the forest floor and the upper mineral soil was not affected by soil frost. In late summer, NO_3^- concentrations increased in forest floor percolates and soil solutions at 20 cm soil depth in the snow removal plots relative to the control. The increase lasted for about 2-4 months at a time of low seepage water fluxes. Soil frost did not affect DOC concentrations and ^{14}C signatures of DOC. No specific frost effect was observed for K^+, Ca^{2+} and Mg^{2+} in soil solutions, however, the Na^+ concentrations in the upper mineral soil increased. In the 12 months following snowmelt, the solute fluxes of N, DOC, and mineral ions were not influenced by the previous soil frost at any depth.

Cumulative soil respiration during 20 months was 22% less at the snow removal plots and no peak of CO_2 occurred during thawing. Only 14% of this difference was attributed to reduced soil respiration during the soil frost period, whereas 63% originated from differences in the summer of 2006. ^{14}C signature of CO_2 revealed that heterotrophic respiration was reduced much stronger than rhizosphere respiration. A peak of N_2O emissions was observed during thawing. The cumulative N_2O emissions at the snow removal plot exceeded those of the control by about 103 mg N m^{-2}. The frost significantly increased fine root mortality. However, enhanced fine root production nearly compensated for the fine root losses caused by low temperatures.

Our experiment suggests that cold-dry winter climatic conditions with extended periods of soil frost increase C sequestration in the soil as compared to unfrozen conditions, but had little effect on fluxes of mineral elements and nitrogen.

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Manipulative reduction of water table during summer does not affect gaseous CO_2 fluxes in a fen in southeast Germany

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The IPCC (2007) has predicted a change of precipitation patterns and therefore an increase of the frequency of extreme meteorological events like e.g. summer droughts. For the fen studied here, located in the Fichtelgebirge in southeast Germany, it has to be assumed that a reduction of rainfall in summer will lead to a reduction of the water table. Going along with this reduction of the water table we expected: (1) an increase of the unsaturated zone and of oxygen availability leading to an increase of soil respiration (SR); (2) increased mineralization rates and therefore an increased nutrient availability resulting in an increase of primary production.

Three control plots of 6m × 6m were established to measure natural carbon (C) flux dynamics. Nearby, three manipulation plots of the same size were established on which we artificially reduced water table during the summers of 2006, 2007 and 2008 to simulate summer drought. Water table reduction was achieved by temporarily installing a transparent roof to exclude precipitation and by eliminating lateral water inflow by using an automated drainage at 1 m depth beside the manipulation plots.

We measured SR and CO_2 concentration in the soil profile in all three years except during winter when access to the study site was impossible. In 2007 we also measured net ecosystem exchange (NEE) and calculated gross primary production (GPP) on all 6 plots. In 2008, we measured radiocarbon signature at two occasions to calculate the mean residence time of respired CO_2 and compared the results to radiocarbon signatures of organic matter measured in different soil depths.

Water table in the manipulation plots was effectively reduced for several weeks during the years of 2007 and 2008. SR fluxes followed a typical seasonal pattern and did not differ on the control and the manipulation plots in any of the three years. Also, no significant differences were found for the CO_2 concentration in the soil profile. The NEE measurements in 2007 did not reveal any effect of the reduced water table neither on NEE nor GPP. Mean radiocarbon signature of SR (±SE) was 72.2 ‰ (±3.4) indicating a mean residence time of respired C of only a few years.

Summarizing, the reduction of the water table had no effect on the C fluxes in the fen studied here. Possible explanations might be: (1) The reduction of the water table did not lead to an oxygen infiltration as expected and therefore to no increase of mineralization rates; (2) Low substrate quality in the additionally oxygenated soil did not significantly increase respiration rates as compared to control conditions. The original assumption, that extended periods of summer drought will have a significant effect on C fluxes in this fen can not be supported by these results.

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Seasonal and long-term variation of stream water chemistry at Bear Brook Watershed, Maine USA

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Seasonal changes of weather include temperature, precipitation, and solar insolation. The differences among seasons or even months are seen in the chemistry of solutes in precipitation, throughfall, soil solutions, and stream water. Inter-annual comparison of mean monthly stream chemistry allows identification of processes affecting individual solutes. The West Bear (WB) watershed, Maine, has been treated bi-monthly since November 1989 with 1 800 eq $ha^{-1}y^{-1}$ of $(NH_4)_2SO_4$; the reference East Bear (EB) watershed has been recovering from ambient acidification. We divided the 18-year dataset of weekly samples from EB and WB streams into three periods: 1988–1989 (pre-treatment), 1990–1995 and 1996–2006 to evaluate seasonal changes of concentrations in stream water during progressive acidification at WB and slow recovery at EB. Monthly concentrations of Cl^-, entirely of atmospheric origin, evolve relatively similarly at both catchments. Seasonal patterns of Na, supplied by atmospheric deposition and weathering, were similar at both catchments for all periods. Evolution of seasonal concentrations has occurred for SO_4^{2-} and NO_3^-, supplied to WB by ambient deposition plus treatment but to EB by ambient deposition, only. Nitrate has strong seasonality and its monthly concentrations in period 1990–1995 have increased due to treatment at WB. In period 1996–2006 NO_3^- has not further increased in WB (Figure), whereas it has declined in EB, in spite of relatively constant ambient input. Nitrate seasonality was strong in both streams, with low NO_3^- concentrations at both watersheds in the growing season (Figure). Sulfate has the least seasonality, and has declined in EB while increasing to a near-plateau after seven years in WB. Calcium and Mg concentrations in WB stream water increased in 1990-1995; their depletion in WB soils caused a decrease in 1996–2006. At recovering EB, concentrations of Ca and Mg gradually decreased through all three periods. Increasing concentrations of SO_4^{2-} and NO_3^- and decreasing base cations caused a significant decrease of pH at WB, accompanied by increases of Al_i; a small decline of pH at recovering EB caused relatively small increases of Al_i. Potassium concentrations are strongly elevated during spring and fall leaf senescence and depressed during the growing period at both watersheds. K has increased in WB and decreased in EB. Si, supplied to streamwater almost exclusively by weathering, did not change through the 20-year record at both watersheds. Dilution at higher flow (spring and fall) is the major control. DOC shows no evolution through time at either watershed.

Seasonality patterns for all analytes are caused by dilution, biological uptake and release, and evapotranspiration. Changes in absolute values are caused by acidification (treatment of WB) and long-term response to it, and by recovery from acidification.

Does a lake thermocline depth affect methyl mercury concentrations in fish?

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During 2004–2007 we conducted a whole-lake manipulation experiment (THERMOS) to increase by ~1.5 m the thermocline depth of Halsjärvi, a small polyhumic boreal lake in southern Finland. The intention of the manipulation was to simulate the projected increase in the lake mean temperature, i.e. heat content, by the end of the 21st century due to climate change. The project aims were to quantify potential effects of climate change on biogeochemical cycles, including Hg, foodweb structure, productivity and biodiversity in dystrophic lake ecosystems.

Here we will examine the impacts of manipulation-induced changes in lake mercury chemistry on the mercury concentrations in fish. Mercury and methyl mercury in water and in sedimenting seston were monitored before and after the treatment. Small perch (*Perca fluviatilis*) were collected each year in September 2004–2007 for the determination of MeHg in muscle. The length, weight and age were determined and samples were taken for MeHg and stable isotope analysis (SIA, the ratio of the heavy to the light isotopes expressed relative to a standard, $\delta^{13}C$‰ or $\delta^{15}N$‰). SIA will be used to study possible changes in the trophic position of fish, which might help to explain variation in MeHg concentrations. The oxygen concentration seemed to determine MeHg production at layers with intensive sulphate reduction. Methyl mercury production decreased due to the smaller volume of anoxic hypolimnion during the mixing experiment in summer, which should be expected to decrease the bioavailability of MeHg in the food web. Our question, therefore, is whether this expected response could be measured as decreased MeHg concentrations in fish.

Nutrient enrichment in tropical wetlands: ecosystem changes after six years of phosphorus addition

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Herbaceous wetlands of northern Belize are part of a phytogeographically related group of limestone-based marshes that cover extensive areas of the Yucatan Peninsula, Caribbean islands and South Florida. We used these oligotrophic, P-limited marshes to assess how changes in nutrient availability impact species composition and ecosystem processes. In 2001, P, N, and NP enrichment plots were established in 15 replicated marshes. In 2005, +P plots in a subset of six marshes were split into two halves, each dominated by *Eleocharis cellulosa* and *Typha domingensis* to document the impact of dominant macrophytes on sediment microbial processes.

The addition of P or combination of N and P resulted in rapid switch from a microphyte (cyanobacterial mats, CBM) to macrophyte *(Eleocharis*) domination**,** while N addition did not have any impact. The switch was caused by significant changes in *Eleocharis* stem density and height, and consequently, the aboveground biomass, which, when compared to controls and +N, increased more than 5 fold to > 500 g m^{-2} in +P and +NP plots. *Typha* transplanted into plots grew exponentially in +P and +NP plots and its aboveground biomass reached up to 750 g m^{-2}, while in control and +N plots it grew slowly or did not survive. Decreased light under the dense canopy of *Eleocharis* in +P and +NP plots significantly reduced the CBM growth (Sirova et al 2009). The replacement of cyanobacterial mats by macrophytes increased the quantity of organic matter input to the sediments, constrained autotrophic nitrogen (N) fixation, but supported heterotrophic N fixation (Šantrůčková et al. 2009; Kubešová et al 2009).

There were significant differences in NH_4-N both in soil extracts and in the interstitial water with soil and water NH_4-N being significantly lower in P-addition plots. The elimination of N_2-fixing CBM and increased microbial and plant demand for N are potential reasons for a decrease in available sediment N.

Eleocharis tissue P also increased 4- to 5-fold in +P and +NP plots when compared to P content in plants from control and +N plots. Tissue P remained high due to internal nutrient recycling. Improved litter quality (C:P ratio >4000 and ~500 for controls and +P litter respectively) and higher microbial biomass resulted in significantly faster decomposition rates in P enriched plots. *Typha* contained less P but more phenolic substances in its tissue than *Eleocharis*, which resulted in lower decomposition rates of *Typha* litter.

External addition of P dramatically changed the macrophyte/cyanobacterial community thus changing the quantity and stoichiometry of the organic C input to the sediments and consequently the composition and activities of sediment microorganisms.

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Unpredictable responses to interactions between climatic drivers: Impact of warming, elevated CO_2, drought and their combinations on photosynthesis and growth patterns of heath plants

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The impact of elevated CO_2 [CO2], warming [T] and drought [D] on heath ecosystem processes are investigated in the CLIMAITE project in which the modelled climatic scenario for Denmark in year 2075 are simulated [1]. The experiment is unique as it evaluates the interactions between drivers on ecosystem processes across scales ranging from ecosystem to leaf gas-exchange, primary production and biodiversity, in order to unravel the complex multi-factor impacts on water, carbon and nitrogen cycles.

Here we focus on the responses in growth pattern and photosynthesis for the evergreen dwarf shrub *Calluna vulgaris* during most of a growing season. From mid April, the first shoot growth phase of *Calluna* was characterized by shoot extension and increased leaf area per unit biomass, and also the leaf C/N ratio increased. The photosynthetic capacity was unchanged, as maximal electron transport rate (J_{max}) and maximal velocity of Rubisco carboxylation (V_{cmax}) showed little variation between May and July. However, the rates of photosynthesis and transpiration were stepwise decreased during this phase in parallel with decreasing water availability. After flowering a second phase of shoot growth from August to October was characterized by shoot extension and increase in leaf area per biomass, high leaf nitrogen concentration and increasing green-to-brown biomass ratio. The photosynthetic capacity was higher and no indications of senescence were significant even in late October. Hence, the photosynthetic rates increased and transpiration levels were high, in parallel with increasing amounts of precipitation and extraordinary warm autumn temperatures. From this growth pattern we hypothesize *Calluna* to have the potential to benefit from an extended growing season in response to [T] and also to benefit from CO_2 fertilization in response to [CO2]. In addition, *Calluna* is expected to exhibit drought tolerance in response to [D].

Across the season [CO2] did not induce any down regulation of V_{cmax} or J_{max} but increased net photosynthesis directly via increased intercellular CO_2 concentration. [T] caused an earlier start of the growing season via shift in phenology but *per se* [T] did not pose strong effects on photosynthesis and transpiration. However, the increased water consumption led to water shortage when combined with [D] resulting in a significant [T*D] and [T*CO2] interaction during the experimental drought. In late autumn the [T] increased the green to brown biomass ratio and photosynthesis, but only in combination with [CO2], which caused a significant [T*CO2] interaction in October. In addition to the natural drought, the experimental drought decreased the soil water content even further and extended drought conditions for several weeks. The decrease in soil water content had negative impact on the plant water potential and transpiration in [D]. This led to decreased photosynthetic capacity via decreased J_{max} and V_{cmax}, and photosynthesis was reduced in response to [D]. In parallel, growth and green-to-brown biomass ratio were decreased in response to [D] and [T] during the experimental drought period.

The response patterns clearly demonstrate an earlier start up caused by warming, promoting water shortage and decreased net photosynthesis during the experimental drought period. Elevated CO_2 increased the net photosynthesis during the growing season, and to a larger degree than expected when combined with warming. [D] has a negative effect on water relations and decreased photosynthesis, and more than expected when combined with either warming or elevated CO_2. These findings could not be deduced from single factor experiments. Therefore, the multifactor experimental approach does indeed contribute to our understanding of the impact of climatic change on ecosystems.

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Larch taiga on permafrost is facing a risk of catastrophic degradation by complex of frequent ground-fire and increasing precipitation regimes

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Forest decline suddenly appeared in larch taiga on permafrost in 2007-2008, in the following 3 years-increasing precipitation regimes, central Yakutia, Russia. Here, we show what the increasing precipitation regime resulted in nearly soil water saturation caused the forest decline; especially the forest attached by ground-fire at the past 10 years. We discussed this forest ecosystem is structurally weak to increasing precipitation regime due to small amount of maximum soil storage in active soils underlying permafrost adapted to small annual precipitate corresponding to continental climate. Furthermore, our ground-fire experiment in a mature larch forest from 2004 revealed the fire disturbance increased soil water content, shifting forest to weak to increasing precipitation regime. To our knowledge on the forest history, this phenomenon is the first appearance, so that we can not evaluate if this is really serious or not, nevertheless our finding provides new serious scenario as following. Forest decline with melting soils and wetting sometimes becomes a trigger of thermocarst process well-known as the most serious ecological shift of forest degradation to make wet land in cryolithozone. The larch taiga has a massive carbon storage function, thus the forest decline and the start of thermocarst process lead to the massive carbon loss in the terrestrial ecosystem in eastern Siberia. In the thermocarst process, massive methane emission is occurred, so that the forest decline might increase the source of methane gas emission. The increases of CO_2 and methane gases emission must accelerate the global warming. Consequently, we challenged a serious scenario of forest degradation in cryolithozone under climate change playing role of positive feedback to global warming.

Decadal responses in stream and soil Ca and Mg in an experimentally acidified watershed in the eastern United States

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Soil acidification, whether natural or anthropogenic, accelerates the leaching of calcium (Ca), magnesium (Mg) and other base cations in forest soils, ultimately decreasing the percent base saturation (BS). The Bear Brook Watershed in Maine, USA (BBWM) is a long-term acidification experiment in a forested watershed approaching 20 years of treatments. During this period, stream base cation concentrations in the reference watershed have continuously declined, while base cation concentrations in the treatment watershed first increased then decreased to near pretreatment concentrations. Studies of soil response in 1998 after 9 years of treatments showed decreases of Ca and Mg concentration (Fernandez et al., 2003), with the most significant declines in the O horizon. In 2006, pedons from the 1998 study were re-sampled and analyzed to determine if temporal changes in soil chemistry parallel the trajectory of stream Ca and Mg concentrations.

In the 2006 soil samples, the O-horizon and 0–5 cm increment of the B-horizon from hardwood stands in the reference watershed showed increased exchangeable Ca (Fig. 1) and Mg concentrations. These increases reflect recovery of soil base saturation due to declining ambient SO_4 deposition and are consistent with decreasing stream Ca, Mg, and SO_4 export. The O-horizon and 0–5 cm increment of the B-horizon from hardwood stands in the treated watershed showed continued decreases in exchangeable Ca (Fig. 1) and Mg concentrations, consistent with progressive acidification. Soils supporting softwood stands showed a greater depletion of exchangeable Ca and Mg compared to hardwoods in the 1998 study. Yet, in 2006 soils under softwoods showed little additional response to treatment suggesting softwood soils may have reached a new chemical equilibrium (Fig. 1).

These data demonstrate linkages between terrestrial and aquatic components of forested ecosystems in their response, and recovery, to anthropogenically driven acidification. The timing and character of these responses are strongly influenced by forest composition, and were evident on a decadal time scale.

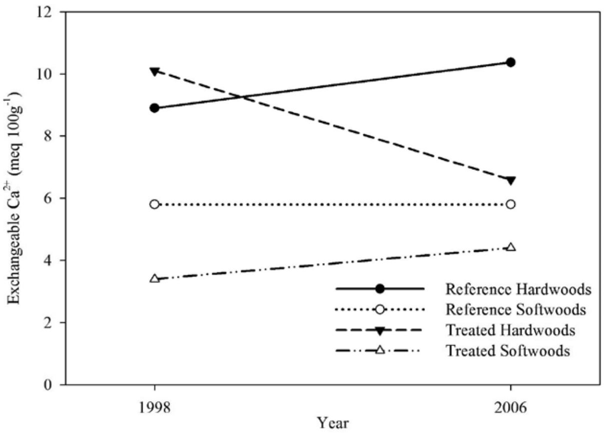

Fig. 1. Response of O-horizon exchangeable Ca^{2+} in reference and treated watersheds by forest type.

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Nutrient enrichment in tropical wetlands: shifts in autotrophic versus heterotrophic nitrogen fixation

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Herbaceous wetlands of northern Belize are part of a phytogeographically related group of limestone-based marshes that cover extensive areas of the Yucatan Peninsula, Caribbean islands and South Florida. We used these oligotrophic, P-limited marshes to assess how changes in nutrient availability impact species composition and ecosystem processes. In 2001, P, N, and NP enrichment plots were established in 15 replicated marshes. The addition of P or combination of N and P resulted in rapid switch from a microphyte (cyanobacterial mats, CBM) to macrophyte *(Eleocharis*) domination**,** while N addition did not have any impact (Sirová et al. 2009). In 2005, +P plots in a subset of six marshes were split into two halves, each dominated by *Eleocharis cellulosa* and *Typha domingensis* to document the impact of dominant macrophytes on sediment microbial processes. The replacement of cyanobacterial mats by macrophytes constrained autotrophic nitrogen (N) fixation and increased the quantity and quality of organic matter input from dead biomass and root exudates to the sediments (Rejmánková et al. 2009, Kubešová et al. 2009).

We predicted that (i) the activity of sediment heterotrophic N fixers will be impacted by these changes, (ii) root associated N fixers will play important role in N input and (iii) sulphate reducing bacteria will contribute to heterotrophic N fixation. To verify the predictions, we measured nitrogenase activity (NA) in sediments and rhizosphere of *Eleocharis cellulosa,* or *Typha domingensis,* from controls and treatment plots that have been P enriched since 2001 and dominated either by *Eleocharis* or *Typha*. To distinguish NA of sulphate reducing bacteria, sodium molybdate was added to the sediment or roots.

NA in P enriched plots was 2–3 orders of magnitude higher than NA in controls. It was positively correlated with the soil reactive P, both total organic and microbial carbon, live root biomass, and total phospholipid fatty acids (PLFA) as an indicator of active microbial biomass. It was negatively correlated with the concentration of ammonium nitrogen. N fixation by root associated bacteria always significantly exceeded that of sediment bacteria in each treatment. The contribution of sulphate reducing bacteria to total NA was about 30% in sediment and about 55% in rhizosphere. The estimate of N balances indicated that microbial N fixation can potentially cover a substantial part of plant N demand.

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Impact of increased temperature on C and N transformations in organic soils; experimental setup with open top chambers

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The general aim of the project is to assess the impacts of rising temperatures on the transformations of C and N in peat soil, and the effects on greenhouse gas exchange. We will study the effects of temperature and changes in ground water level on microbial biomass, microbial community structure and activity, carbon allocation to root biomass, fungal mycelia, ground vegetation, litter decomposition and emissions of CO_2, N_2O and CH_4.

We have installed 165 transparent polycarbonate-plastic open top chambers (OTC) (hexagonal model, 50 cm high) in 2008 on seven different locations in Finland covering rather wide temperature sum range (1150–706 d.d.). The experimental setup will be maintained at least until the end of 2011.

In Närhinneva, Lakkasuo and Pallasjärvi areas there are three ground water level treatments (pristine, shallow drainage in 2008 simulating the assumed seasonal ground water-level drawdown in boreal mires caused by global warming, and forestry drained peatland). Alkkia, Haapua and Hepokangas are drained peatland forest sites with variable total nitrogen levels in peat comprising three N levels (low, medium, high) in each site for the OTC experiment. In Siikajoki area increase in temperature with OTC will be studied with simultaneously increased ground water level.

From these sites we have measured in 2008:

- temperature (loggers, +2m, +30cm, -5cm, -15cm, -30cm), ground water level
- peat samples in autumn 2008; nutrients, microbial biomass, pH
- fungal biomass in peat (total, extramatrical mycorrhizal mycelium with in-growth mesh bags from three sites)
- CO_2, N_2O, CH_4 (from the sites with ground water level treatments).

The preliminary results from the first season (July-September) in one site revealed that OTC raised the temperature on open mire 1.1 °C degrees in average at + 30 cm level above ground, and 0.7 °C degrees in below ground soil layers (5, 15, 30cm). On drained forest site the temperature effect by OTC was smaller: 0.3 °C at + 30 cm level above ground and between 0.1 °C and 0.5 °C in 5, 15 and 30 cm deep in soil.

The first GHG measurements and soil samples are in progress for analyses and evaluation.

Climate Change studies in large scale experiments in vulnerable ecosystems across Europe

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The global climate is changing. This has been studied during the last 10 years in large scale field experiments with non-intrusive manipulations of temperature and precipitation and at one site also combined with enhanced atmospheric CO_2 concentrations. The experiments are placed in vulnerable scrubland ecosystems across Europe and has been part of the EU-projects CLIMOOR and VULCAN and the coming infrastructure INCREASE. Shrubland ecosystems were chosen because they represent an important natural resource, which are known to be sensitive to observed changes in environmental pressures, and they provide a range of services for the society. The poster will present the experimental approach and a summary of climate change effects on ecosystem processes and functions.

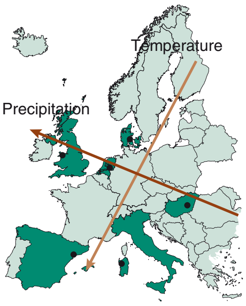

Figure 1. VULCAN and INCREASE sites span natural gradients in precipitation and temperature. The same climatic variables are manipulated at each site.

The experiments combine 2 different approaches to study climate effects on ecosystems. The first approach is known as “space for time” substitution, where the long term effect of a pressure on the ecosystem, e.g. temperature, at any particular site is studied by moving to another site, which is already exposed to the change in focus. This was done by carrying out the same studies in comparable ecosystems in UK, Denmark, the Netherlands, Hungary, Spain and Italy – 6 sites which are naturally exposed to large differences in the climatic conditions we wanted to study (see figure 1). The other approach applied is “ecosystem manipulations”, which means that the ecosystem is exposed to the changes in the field by realistic manipulations of temperature and water and in one experiment in combination with CO_2. In summary one could say that we superimposed manipulations with water and temperature on existing gradients with respect to the same factors. This combination of gradients and experimental manipulation of temperature and precipitation increases the potential for evaluating the generality of the observed responses to the changes in the climatic drivers. The effects of the treatments on the plants, soils and fauna were studied throughout the project together with risk assessment of the vulnerable shrublands. We observed effects of both warming, drought and increased atmospheric CO_2 on a number of key processes. However, the combined effects of the treatments often counteracted the main effects. This emphasizes the need to investigate interactions between climate change factors as these may be unpredictable based only on single factor studies.

Invitation for external researchers to use the infrastructure. The experiments have been running for 10 years. The coming four years, they will be part of the network INCREASE (Integrated Network on Climate Change REsearch Activities on Shrubland Ecosystems), which is a new EU-funded research infrastructure. Within INCREASE we will improve the technology and methodology for studies of climate change effects on European shrublands and stimulate collaboration within the scientific community around climate manipulation experiments. One tool is to provide access to this set of large scale climate change experiment for European scientists. We hope to hear from you if this is of interest.

Reforesting roads in conservation areas

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Boreal coniferous forests and forested peatlands in Finland have been harvested intensively during the last decades. In the process, more than 120,000 km of gravel roads have been built to facilitate the transfer of timber and to excavate soil for construction purposes. Some of these roads are located in recently established nature conservation areas. Thus, it would be expedient to reforest the most remote parts of gravel roads in these areas. Reclamation of the less used gravel roads improves habitat connectivity and facilitates ecosystem processes (Switalski et al. 2004). However, road reclamation experiments have been carried out in temperate forests and grassland ecosystems, whereas information from boreal environments is virtually missing.

Owing to the cool climate and deficiency of nutrients, forest rotation in boreal environments takes decades. The high costs of road reforestation raise a question about its long-term benefits. We therefore need experimental work on its impacts on soil properties and regeneration of vegetation. Our research area in eastern Finland belongs to the middle boreal vegetation zone. Typical tree species are Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), and silver and downy birch (*Betula pendula* and *B. pubescent*). Willow species (*Salix* spp.) are common along roadsides. In autumn 2007 we reforested three roads (0.8 to 2.1 km in length), each in a different protected forest area. On each road we established a 3 x 2 full-factorial experiment replicated in three blocks. Ripping treatments consisted of 1) none; 2) ripping to approximately 20 cm depth; or 3) ripping to approximately 50 cm. Revegetation treatments were either no transplanting or transplanting hummocks containing tree saplings. Our objective is to document the costs and outcomes of different reforestation methods and here we report our initial findings.

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Drought alters plant response in a heathland ecosystem

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We investigated the effect of five sequential summer droughts on plant response at a heathland in the Netherlands with an automatic and non-intrusive method of intercepting precipitation two months during peak growing season (Beier *et al.* 2004). Plant response was measured with a combination of detailed phenological measurements, annual point-quadrat measurements and chemical analysis of newly formed plant tissue

Plants were directly and indirectly affected by the summer droughts. Directly by (a) a reduced ability to recover from a heather beetle attack, (b) a decreased elongation of the main shoots and (c) a decreased amount of buds that developed to flowers during a drought. Indirectly by changes in microbial dynamics and nutrient mineralization as the size of the microbial biomass P was reduced with 79% during peak drought (Van Meeteren *et al.* 2008). The mineralized P was available for uptake by microorganisms and plants. Plants could have benefited from this extra P availability, as the released P comprised more than the regular yearly plant P uptake. However, plant biomass, as well as N and P concentration in present year shoots decreased after drought (Fig. 1). Summer drought increased the pre-drought length of the main shoots.

We hypothesize that although during each natural drying and rewetting cycles P is released from microbial biomass, plants don't profit from this increased P availability, probably by competition with the new microbial population. Further, we think that the sequential summer droughts will eventually lead to the decline of the ecosystem as plant resilience to for example herbivore attacks decrease.

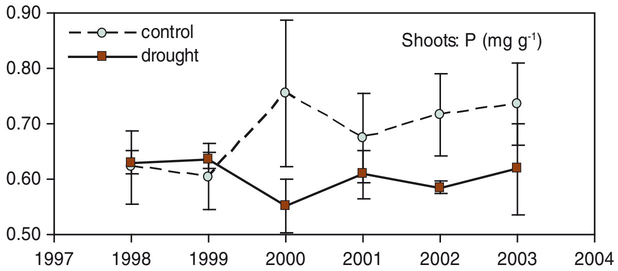

Fig. 1. P concentration (mg g^{-1}) in newly formed shoots.

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The impacts of water table level on the redox-potential in the acid sulfate soil monoliths

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Large areas of acid sulphate soils are drained for cereal cropping in Finland (Yli-Halla ym. 1999). After drainage they produce highly acidic load and harsh environmental impacts to watercourses. Growing perennial bioenergy crops such as reed canary grass that tolerate high watertable may reduce these deleterious effects. We studied the impact of groundwater level on the redox potential of soil monoliths taken from a boreal cultivated acid sulfate soil field in 2007 and 2008. The soil was classified as *Sulfic Cryaquepts* (Yli-Halla ym. 2008). The monoliths were sampled into PVC tubes (height 1.0 m, diameter 0.5 m). The experiments were carried out in an outdoor greenhouse compartment with a glass roof and wire-net walls. We started the study with two uncropped monoliths in 2007, and continued with eight cropped and two uncropped monoliths in 2008. We planted the monoliths with reed canary grass. The ground water table level was controlled by a water supply system with an inlet at 80 or 90 cm depth from the soil surface, at the lowermost part of structured soil (BC horizon) overlaying the massive reduced C horizon. Four water supply tubes were mounted evenly around the tube and the variation in water table and soil moisture was monitored by pipe observation and time-domain reflectometry, respectively. Soil redox potential was measured continuously at five depths: 10 cm (Ap), 30 cm (Bgjc), 50 and 70 cm (BCgc), and 90 cm (C1) below the surface. The automated data acquisition system was constructed of Pt electrodes, a common Ag/AgCl reference electrode connected to each monolith with a saturated KCl salt bridge and a datalogger (Agilent 34980A, the input impedance 10 GΩ) that scanned the electrodes at 10-minute intervals. Electrical conductivity, temperature and soil moisture were measured continuously at 10-minute intervals with ECH$_2$O-TE/5TE probes and dataloggers (Degacon Em50) in three different soil horizons (Ap, BCgc and C1). Soil pH was measured manually with an ISFET electrode through access holes in the PVC wall.

The water table was raised gradually from 70 cm up to 10 cm below the soil surface in the uncropped monoliths in autumn 2007. The redox potentials decreased only slightly with rising water table, in the range from 600 to 450 mV (Eh) in the BCgc horizon. The slow response of redox potential to the water table elevation in the monoliths was supposedly due to low temperatures and the absence of plants, and the consequently low biological activity. In 2008, the experiment was conducted at higher temperatures and included both cropped and uncropped monoliths, and two ground water levels: in HW the water table was rised from 50 cm up to 20 cm, and in LW the water table was lowered from 50 cm to 70 cm. There were both cropped and uncropped monoliths in HW, and only uncropped monoliths in LW.

The redox potentials decreased with soil depth and were least in the massive bottom layer which remained always reduced in all treatments (Eh -29 to -173 mV). High water table decreased redox potential in the upper layers compared with the low water table (Table 1). Notwithstanding the fact that plants are the main source of easily degrading organic matter in the soil, we could not confirm that redox potentials at high water table would be decreased more in the cropped soil than in the uncropped soil. An obvious reason for this is that the transpiration of plants lowered the water table in the cropped monoliths more than in the uncropped monoliths (35 cm and 23 cm, respectively). The oxidation rates of soil seem more rapid than reducing rates.

Table 1. Mean redox potential (mV) at different soil depths and the mean ground water level in the experimental treatments of the monolith experiment during 22 Jul 2008–20 Nov 2008.

Water level	Cropping	Soil depth, cm					GWL, cm
		10	30	50	70	90	
Low	Cropped	410 ± 60	580 ± 100	400 ± 100	270 ± 100	-29 ± 11	73
High	Cropped	440 ± 110	270 ± 100	180 ± 90	110 ± 60	-110 ± 50	35
High	Uncropped	360 ± 190	140 ± 70	520 ± 40	220 ± 120	-173 ± 10	23

GWL ground water level

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Climate Manipulations Impair the Greenhouse Gas Budget of a Mountain Forest Soil

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Upland forest soils in Central Europe constitute a source for the greenhouse gases CO_2 and N_2O, whereas they normally act as a sink for CH_4. The underlying microbial processes within the carbon and the nitrogen cycle show different temperature sensitivities. Field soil warming studies focused on the difference in soil respiration under actual and elevated (future) soil temperatures. Accordingly, we warmed the topsoil of a mature spruce forest by 4°C compared to the actual soil temperature during the growing seasons since 2005. The overall increase of soil respiration due to soil warming amounted to 2.8 t C ha^{-1} y^{-1} which meant an enhancement by up to 47%. At the same time N_2O emissions were promoted whereas the uptake of CH_4 slowed down. During July 2008 we simulated a one-month summer drought by building roofs over warmed and control plots. A reduction of soil respiration and N_2O emission was observed on plots where drought was simulated. Until September, the simulated summer drought offset the warming effects on an annual basis. The overall effects of climate manipulations on the greenhouse gas budget of this soil will be discussed and set into relation to forest growth.

Land-atmosphere exchange of elemental mercury in uncontaminated ecosystems

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Due to its high volatility mercury is dispersed globally, deposited to land and sea and eventually transformed to toxic methylmercury that is accumulated across the aquatic food chain. Mercury in the atmosphere is primarily present in its elemental form (Hg^0) and its exchange with soil and water surfaces controls the levels that are available for methylation.

In order to quantify the exchange of Hg^0 in uncontaminated areas we performed flux measurements over several grasslands along the Alps with two classical micrometeorological methods: the aerodynamic method and the modified Bowen ratio method. To estimate the seasonal variation of the Hg^0 land-atmosphere exchange we measured Hg^0 gradients over an entire year at a sub-alpine site in central Switzerland. The results showed average Hg^0 dry deposition rates between 1.7 and 4.3 ng m 2h 1 during the vegetation period and were estimated to account for two thirds of total mercury deposition.

We complemented the measurements with campaigns at two other grassland sites in Switzerland and Austria with the aim to assess the spatial and the diurnal variation of the Hg^0 exchange. Similar exchange rates were detected at these sites and we could confirm that grasslands of the temperate climate region are small net sinks for mercury.

The application of the micrometeorological methods in the field proved challenging, as the Hg^0 concentration gradients were extremely low and the temporal resolution of the analytical system at times insufficient.

In a study that is currently being prepared we intend to expand our Hg^0 flux measurements to boreal wetlands, which seem strongly linked to methylmercury contamination of boreal aquatic ecosystems. We are planning to apply the relaxed eddy accumulation method to quantify Hg^0 fluxes and intend to discuss the results in relation to the redox status of the wetland.

Biogeochemistry of trace elements in tundra ecosystems of Polar Urals

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The biogeochemical peculiarities of mineral content of the plants of tundra ecosystems of Polar Urals on ultramafic (serpentine), basic (gabbro-ampibolite), acid and carbonate rocks in the basin of Makar-Rus and B. Paipudina rivers were estimated. Local flora on ultrabasic rock is twice as poor comparing with zonal acid rocks and especially poor comparing with floras on carbonate and basic rocks (Yurtsev et al., 2001). 124 soil samples at a depth of 0–10 cm and 320 plant samples (leaves) of 156 species from 25 families were collected in the most typical ecotopes. The concentrations of K, Ca, Mg, Fe, Mn, Zn, Cu, Ni, Cr, Co in plants and soils were determined by means of atomic-absorption spectrophotometry. The relative standard deviations calculated from replicate analyses were generally < 5%.

The close dependence of the soil concentrations of elements on the chemical composition of the underlying bedrock was shown. The main peculiarities of the soils on ultramafic rock were the predominance of Mg over Ca and the relatively high concentrations of Ni and Cr. The accumulation level of trace elements in plants on carbonate rocks is strongly connected with Ca excess in the soils. On four types of rock the mineral composition of the plants was corresponded with the levels of potentially mobile and mobile forms of trace elements in the soils. Only on ultramafic rocks plants accumulate Cr, Co and Ni in the amount >10 ppm. The toxic effect of these heavy metals might be one of the causes of the absence of some species on ultramafic rocks (Proctor et al, 2005). We estimated the scale of differences in metal uptake characteristics between species and some families according various strategy of adaptation to unfavourable edafic factors.

The plant-soil relationships were described with the coefficient of biological absorption (CBA) - the ratio of the element concentration in the plant to the concentration of the available form of the element in the soil.

Most species from families *Salicaceae, Caryophyllaceae, Scrophulariacea, Asteraceae* posses high accumulation activity. We have also found Ni hyperaccumulators *Alyssum obovatum* and *Thlaspi cochleariforme* (fam. *Brassicaceae*), which absorb >800 ppm Ni.

Variability of trace element level in plants and soils in elementar geochemical landscapes on different rocks was discovered. So it was showed that tundra plants act as integrators and successful indicators of their metalliferous environment.

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Specific features of toxic effect of heavy metals excess in the nutrition medium on cereals seedlings

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The problem of the specific features of toxic effect of heavy metals (HM) excess on higher plants is not investigated enough and can be studied only in experimental conditions. The tolerance of cereals *Avena sativa L.* (25 cultivars), *Hordeum vulgare L.* (14 cultivars), *Triticum aestivum* (2 cultivars) to high concentrations of HM in the nutrition medium was studied in model experiments. We compared the toxic effect of Ni and Cu, the excess of which occur in the soils on geochemical anomalies and at technogenic pollution and Mn, which is a stress factor on strongly acid soils.

On the seedlings of various cultivars of each species the influence of 2 and 3×10^{-3} M Mn, 5×10^{-5} and 1×10^{-4}M Ni, 1 and 5×10^{-5}M Cu on morphological (the growth of roots and shoots), physiological (the level of pigments and mineral content of the leaves), anatomic-cytological (cell division and DNA synthesis) parameters were investigated. The accumulation of K, Ca, Mg, Fe, Zn, Mn, Cu, Ni were detected on AAS, the content of individual carotenoids with paper chromatography. The comparative toxic effect of HM on the growth was assessed with the index of tolerance I_t **-** ratio of root or leaves elongation in experimental and control variants. The length of leaves was slightly altered, Mn had the most effect. The root growth was more sensitive and according to this parameter the same rye of toxicity for all species and cultivars was obtained: Cu> Ni> Mn.

High concentrations of Cu, Ni, Mn in the nutrient medium changed the ion gomeostas of leaves. The concentrations of K, Ca, Fe decreased, the concentrations of Mg and Zn were more stable. The specific effect of HM on the level of individual carotenoids in leaves was showed. Cu increase the level of lutein and violoxanthin, Mn and Ni decreased. The concentration of β-carotene was the most stable. In common, the pigment system of *Avena sativa* was more stable than those of *Hordeum vulgare.* The differential reaction of some cultivars of the species on the high concentrations of HM was established.

Investigated HM had different effect on the cell division of root meristem. Cu has the most inhibiting effect on the mitotic index of meristem cells of the root, Mn – the less effect. The toxic influence of the last adjust in longer time of mitosis. The meristem cells of *Hordeum vulgare* seedlings were the most sensitive to HM excess.

More detailed mechanisms of suppressed action of HM on cell divisions were investigated in the different tissues of the root tips of *Triticum aestivum* seedlings at the influence of 1×10^{-4} M Ni in the nutrient medium. Index of the cells labeled with metil$^{3}H_{1}$-thymidine (ILC) and mitotic index (MI) were measured on the permanent preparations - autographs. We observed a sharp decrease in ILC after 6 hours and gradual decline in the MI after 12 hours in the examined tissues. Autoradiography showed that the earliest effect of Ni on the processes of root morphogenesis observed in 6 h was a suppression of cell transition to DNA synthesis (Demchenko, Kalimova, 2008). The cells, where DNA synthesis has already started or which were in other stages of the cycle, continued to pass slowly through the cycle and completed it. Exit of the cells from proliferation to the state of dormancy at the G_1 stage of the cycle is most probably a sort of root adaptation to stress. The compared study of Ni and Cu influence on these processes is of great interest as the valuable forms and character of translocation of these trace elements are different.

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Lichens as bioindicators of air heavy metal pollution in city stands

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A man-caused activity is an extremely unfavorable matter for ecological purity of atmosphere. Heavy metals (HM) as one of the most dangerous contaminants of environment are mainly collected on the surface both soils and plants. Among the existing methods for sanitary assessing of air quality and HM ambient levels an application of the local available plant species is the more effective biological approach. Some lichen species are known to accumulate HM at very high concentrations in their thalluses when grown on the metal rich substrates. However, lichens themselves are less sensitive to HM toxic effects, so, they can be used for air bioindication in strained urban territories and stands (Cuny et al., 2004, Alirzayeva et al., 2006).

In present study the biomonitoring of degree of air HM pollution in the different areas and stands of Azerbaijan (particularly in Baku and Ali-Bayramli cities) located in various distance from intensive vehicle traffics and urbanization, also in places of industrial activities was carried out. Two foliaceous lichen species *Xanthoria parietina* (L.) Th. Fr. and *Physcia adscendens* (Fr.) Oliv. widespread in these areas were investigated for their HM accumulative capacity. Five HM Cd, Cu, Ni, Pb and Zn were determined in thalluses of lichen species by ICP method.

Both lichen species tested were found to be effective in accumulation of Zn, Cu, Cd, Ni and Pb in their thalluses in all selected areas. Analysis of data on indication of airborne and soil pollution by metals in different places of Baku showed that centre of city crowded and with intensive traffic is the most contaminated part (Table 1). These species also exhibited the same high amounts along of intensive road in suburban area of Baku.

Table 1. Heavy metal concentrations in thalluses of lichen species collected along intensive route in Baku.

Locations	Plants	Elements, mg kg^{-1}				
		Cd	Cu	Ni	Pb	Zn
Along intensive route	Xantoria	1.5	43.0	27.5	88.8	284.2
	Physcia	0.9	29.5	17.3	56.5	163.1

The generally accepted close correlation between the levels of HM in the lichen thalluses and environmental HM concentrations gives evidence for high air contamination in all tested locations, especially in transport-related sites. Lichens could be considered as beneficial tool for sanitary monitoring for assessment of atmospheric trace element contamination and necessary precautions against potential population risk.

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Influence of surfactants on the Cu phytoremediation potential of a salt marsh plant

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The capability of salt marsh plants to accumulate trace metals is, in principle, advantageous for phytoremediation processes. Sites contaminated with metals are frequently also contaminated with organic pollutants of different families, like surfactants. The simultaneous presence of pollutants of different families might change plants capacities for extracting and accumulating metals, thus changing phytoremediation efficiency. To our knowledge, the effect that surfactants may have on metal phytoextraction/ phytostabilization potential of salt marsh plants has not been investigated yet, despite surfactants being frequently found among the pollutants present in some estuarine environments.

This study aimed to investigate the effect of both an anionic (SDS) and a non-ionic (Triton X-100) surfactants, on the Cu phytoextraction/phytostabilization potential of the salt marsh plant *Halimione portulacoides*. (a plant commonly found in Portuguese salt marshes, which is capable of accumulating several metals, including Cu).

Two sets of experiments were carried out in the laboratory with plant roots exposed to: (1) elutriate solution and (2) sediment soaked in elutriate solution. Elutriates were prepared with sediment and water retrieved from a salt marsh from Cávado River estuary. Plants grown in a greenhouse were exposed for 6 days to media with 0.16 mM added Cu (II) in the absence and in the presence of each one of the two selected surfactants, at concentrations lower than the respective micellar critical concentration. Afterwards, Cu was determined in the media and in plant tissues (roots, stems and leaves) by atomic absorption spectrometry, after digestion assisted by high pressure microwave.

Results showed that the plant could absorb and translocate Cu from all media. The non-ionic surfactant Triton X-100 and, in less extent, also the anionic surfactant SDS, favoured Cu accumulation in the plant roots but not Cu translocation, indicating that surfactants may favour Cu adsorption to the roots (phytostabilization). On the other hand, both surfactants favoured Cu solubility from the sediment.

Therefore, the presence of surfactants, which are frequently found in estuarine areas, as a result of urban and industrial effluent discharges, may condition metal distribution in those environments.

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Exudation of organic acids by two salt marsh plants: *Juncus maritimus* and *Scirpus maritimus*

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This work aimed to evaluate, *in vitro*, the capability of roots of salt marsh plants to release low molecular weight organic acids (LMWOAs) and to ascertain whether Cu contamination would stimulate or not organic acids exudation. The sea rush *Juncus maritimus* and the sea-club rush *Scirpus maritimus*, both from the lower Douro river estuary (NW Portugal), were used. Plants were collected seasonally, four times a year in 2004, during low tide. After sampling, plant roots were washed for removal of adherent particles and immersed for 2 h in a solution that matched salinity (3) and pH (7.5) of the pore water from the same location to obtain plant exudates. In one of the seasons, similar experiments were carried out by spiking the solution with Cu^{2+} in the range 0 to 1600 nM. In the final solutions as well as in sediment pore water organic acids were determined by high performance liquid chromatography.

This study demonstrated that plants are able to release, in a short period of time, relatively high amounts of LMWOAs (oxalate, citrate, malate, malonate and succinate) (Fig. 1), probably contributing to the presence of some of these organic compounds in the sediment pore water, where oxalate, succinate and acetate were also detected. Although the release of oxalate by *J. maritimus* increases with Cu increase in the media, exudation of the other LMWOAs did not seem to be stimulated by Cu contamination in the media. This fact is compatible with the existence of alternative internal mechanisms for Cu detoxification, as denoted by the fact that in media contaminated with Cu both plants accumulated relatively high amounts (29–83%) of the initially dissolved Cu. To our knowledge, this is the first time that effect of plant-species, season and metal contamination on LMWOAs exudation by salt marshes plants was studied. The capability of *J. maritimus* and *S. maritimus* to release LMWOAs into the environment, conjugated with their known capacity to oxidize anaerobic sediment around roots, indicate that these plants can play an important role in controlling metal distribution in the water / sediment system in salt marshes.

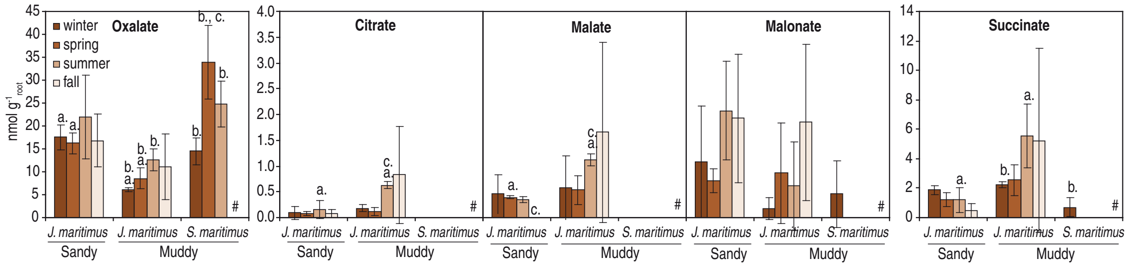

Fig. 1. Seasonal variation (mean and standard deviation, n = 3) of LMWOAs released into solution, normalised for the dry mass of roots. (#) S. maritimus was senescent in fall. (a.) Significant difference (p<0.005) between J. maritimus collected at the sandy site and at the muddy site. (b.) Significant difference (p<0.005) between J. maritimus and S. maritimus collected at the muddy site. (c.) Significant difference (p<0.005) relatively to the previous sampling.

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Concentrations of trace metals in epigeic moss *Hylocomium splendens* and needles of Scots pine and Norway spruce on Estonian ICP Forests sites

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In order to study the role of trace metals in forest ecosystem a comparative study of the contents of Fe, Al, Zn, Mn, Cd, Pb and Cu on ICP Forests Level II monitoring plots was performed. The metal contents of the current and second year needles of Scots pine, Norway spruce and indicator species – epigeic moss *Hylocomium splendens* were compared.

Foliar chemistry monitoring within ICP Forests is carried out on eight intensive monitoring plots. Five plots are established in Scots pine stands and three in Norway spruce stands.

Needles were taken from the upper third of the crown. The current year and the second year needles were sampled. Sampling was performed during the dormancy period. The moss samples were collected in summer 2008 under canopies of the intensive monitoring sample plots and the last two year's shoots were analysed.

All samples were analyzed in the Environmental Studies Laboratory in Tartu. The trace metals analysis was carried out using ICP-AES method, Inductively Coupled Plasma spectroscopy, according to standard EN ISO 11885, pre-treatment using microwave oven (with HNO3).

During the period 1999–2007 there was no reliable trend for most trace metal average concentration in current year needles except Pb. Pb concentration indicated a decreasing tendency (from 0,30 in 2001 to 0,15 mg/kg in 2007).

Table 1. The variation of concentrations of trace metals (mg/kg) in current year needles, second year needles and epigeic moss *Hylocomium splendens* on Estonian intensive monitoring plots.

Sample	Limits	Fe	Al	Cd	Zn	Pb	Mn	Cu
Current year needles	Minimum	26	38	0,01	21	0,1	120	1,6
	Maximum	74	300	0,16	88	0,4	920	3,9
Second year needles	Minimum	32	72	0,01	16	0,1	150	1,5
	Maximum	66	380	0,18	86	0,7	1100	3,2
Hylocomium splendens	Minimum	210	240	0,10	23	2,7	80	3,0
	Maximum	590	540	0,14	35	3,5	320	5,1

The average concentration of Fe, Al, Cd and Pb is highest in *Hylocomium splendens* compared to second and current year needles. The concentration of Pb in moss is about 10 times higher compared to second year needles and 27% higher in second year needles compared to current year needles. The concentration of Cd in moss is 33% higher compared to second year needles and 6% higher in second year needles compared to current year needles. The average concentrations of Zn and Mn are higher in second year needles compared to current year needles (accordingly 10 and 25%) and significantly higher in current year needles compared to moss (accordingly 27 and 51%). The average concentration of Cu is 26% higher in moss compared to current year needles and 18% higher in current year needles compared to second year needles.

In 2005 the trace metals were determined in throghfall precipitations at intensive monitoring plots and the deposition loads calculated for Fe, Al, Cu, Mn and Zn under canopies and open area. The deposition loads of trace metals were higher accordingly 53, 62, 24, 80 and 28% under canopies compared to open area. The concentrations of Cd and Pb were below detection limits in precipitations.

In 2007 no significant differences were detected in trace metal average concentration of *Hylocomium splendens* gathered under canopies on ICP Integrated Monitoring area at Saarejärve compared to ICP Forest plots. In 2005 samples of *Hylocomium splendens* from Saarejärve open area had concentration of Fe 45% and Pb 23% lower than under canopies.

Carbon and contaminant trace metal biogeochemistry in surficial organic-rich terrestrial systems

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Since the onset of the Industrial Revolution, atmospheric release, subsequent transport and deposition of anthropogenic elements such as Pb and Hg has resulted in markedly increased inventories in UK sediments and soils, e.g. in Scottish freshwater loch sediments, Pb inventories of up to 13.6g m^{-2} and, even in rural upland areas such as Glensaugh, NE Scotland, soil inventories of ~7.4g m^{-2} have been recorded. Although depositional fluxes of Pb have been decreasing since ~1960, a large amount of the previously deposited anthropogenic Pb is still contained in the upper sections of the soil.

In contrast with Pb, anthropogenic Hg emissions continued to increase through most of the 20th Century and although there is now evidence of a decrease in Europe and northern America, emissions continue to rise in Africa, Asia and southern America. European emissions may decrease by ~40%, but it is projected that global Hg emissions in 2020 will be within ±20% of the 2190 ton global emissions calculated for 2000. Continuing emissions on this scale will undoubtedly lead to increases in worldwide soil Hg inventories due to atmospheric dispersion and widespread deposition in soils. As a result, Hg retention in soils is becoming an increasingly important area of research.

Metal contaminants are often considered to be strongly retained by organic-rich soils and humic substances are frequently implicated in metal binding in such environments. Alternatively, Pb sequestration in surficial forest soils has been attributed to Fe/Mn mineral phases and it is suggested that the stability of these mineral phases will have a controlling influence on Pb storage. With respect to long-term contaminant fate, however, organic matter and Fe/Mn phases are often intimately linked, as are the processes controlling their dissolution. In this respect, the predicted increasing loss of organic matter from soils as a consequence of climactic change may be highly significant. While emissions of CO_2 and CH_4 remain the dominant routes of carbon loss, increasing outflow of colloidal and particulate organic matter has the potential to mobilise and transport stored metals such as Pb and Hg. Association with colloids/suspended particulate matter has recently been demonstrated as a viable route for Pb and Hg loss from surface soils but there has been limited characterisation of the colloidal and particulate materials.

The aim of this project is to characterise Pb and Hg associations in key solid- and aqueous- phase compartments of ombrotrophic peat, minerotrophic peat and forest soil ecosystems. The soil matrices all have surficial organic-rich horizons but have varying amounts of mineral matter. In addition to the determination of soil Pb and Hg concentrations, the nature of organic binding, distribution and mobility of the contaminants will be explored. It is hoped that the derived data will contribute to the quantification of aqueous carbon fluxes as well as an improved understanding of long-term contaminant storage in organic-rich soils.

In the initial stages of this work, microwave assisted-acid digestion (US EPA Method 3052) followed by ICP-MS analysis has been used to determine Pb concentrations and isotopic ratios while a new method involving adaptation of digestion procedure by addition of HCl has been developed for the determination of Hg concentrations by ICP-MS. For separate soil extracts, HPLC-ICP-MS is being used for Hg speciation. Method validation results and concentration and isotope ratio data relating to a vertical soil profile from Glentress Forest, nr Peebles, SE Scotland will be presented.

Distribution of heavy metal contents in forest soils of the Jizera Mountains (Czech Republic)

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Atmospheric deposition of anthropogenic substances can cause soil acidification as well as soil pollution. The soils of the Jizera Mountains region have been studied for their acidification and consequent labile aluminum release due to strong acid inputs in the second half of the 20th century (e.g. Boruvka et al. 2005, Pavlu et al. 2007). Nevertheless, simultaneous deposition of heavy metals occurred in the region, too. The aim of this study is to show the level of heavy metal (Cd, Cu, Zn, Pb, and Mn) concentrations in different soil horizons and assess some effects influencing their distribution.

Samples were collected in the frame of soil acidification projects; details see in (Boruvka et al. 2005). In total, 138 samples were used. Simple extraction of heavy metals from soil using 2 mol L^{-1} HNO_3 (soil solution ratio was 1:10, w/v) was used, followed by metal determination by means of flame atomic absorption spectrometer (Varian Spectra 200 HT).

The highest concentration of heavy metals was found in the surface organic horizons (Table 1). The strongest topsoil enrichment was recorded for Pb and Cu. Cadmium and Zn showed stronger transportation through the soil profiles, leading to a more even distribution in the profiles. Highest concentration of Mn was determined in the deeper soil horizons, indicating thus its lithogenic origin. The effect of vegetation, namely the difference between beech and spruce forest and the presence of grass cover, was proved particularly for Cd distribution.

Table 1. Mean values of heavy metal contents (mg kg^{-1}) in the whole Jizera Mountains region.

Horizons	Cd	Cu	Zn	Pb	Mn
O	0.82	15.17	14.64	162.98	37.13
A	0.34	4.75	8.44	52.65	12.34
E	0.26	4.04	6.25	32.60	15.08
B	0.49	3.13	13.59	38.22	81.40

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Trace metals in small Irish lakes

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The interaction between the deposition of atmospheric pollutants and the geochemical environment play a major role in determining the concentration of trace metals in surface waters. The level of trace metals in lakes is related to a number of variables including lithology of the catchment, atmospheric inputs, climatic conditions, and anthropogenic activity. Although heavy metals are a natural component of the environment, human activities can greatly contribute to the total environmental concentrations. Studies in Europe and North America have observed trace metal contamination in lake waters resulting from long-range atmospheric transport associated with the emission and deposition of acidifying compounds. The potential toxic effect of many trace metals has led to surface water surveys in Europe and North America (Canada, United States, Russia, Norway, Finland, and Sweden). While several studies have investigated the concentrations of trace metals in Irish soils (Fay et al., 2007) and lake sediments (Bauman & Harlock, 1998), few studies, if any, exist for Irish lakes.

The objectives of the current study were to determine the baseline concentrations of trace metals in small Irish lakes, and to evaluate the sources and geochemical controls on trace metal concentrations. The study sites were selected to be free from local sources of pollution and were generally located in remote, high-altitude, acid-sensitive areas along the coastal margins of the country. During spring 2008, 126 small lakes were sampled and analyzed for total (unfiltered), dissolved (< 0.45 µm) and fractionated metals using an Element2 High Resolution ICP-MS. Fractionated samples were passed through a 0.45 µm filter and a Varian ELUT jr SPE (solid phase extraction) cartridge prior to analysis. All samples were analysed for Be, B, Al, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Sr, Mo, Sn, Ag, Cd, Sn, Sb, Ba, Tl, Pb, Bi, and U. In addition, a sub-set of 54 lakes were analyzed for total mercury using a TEKRAN 2600 series CVASF Mercury Analysis System. Unfiltered lake samples were also analyzed for pH, alkalinity, conductivity, major cations and anions, and dissolved organic carbon (DOC).

The sources and geochemical processes controlling the distribution of total, dissolved and fractionation trace metals were investigated by statistical correlation with land-use, geology, soil type, and water chemistry. The objective of the analysis was to determine the minimum number of variables that explained the observed concentrations. However, the analysis primarily focused on four explanatory variables: acidification status (expressed as pH), organic matter (expressed as DOC), geochemical weathering (expressed as non-marine calcium and magnesium) and long-range transport (expressed as non-marine sulphate deposition).

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How do salt marsh processes contribute to estuarine system remediation?

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Salt marshes were often installed in the proximity of cities and industrialized areas. In these cases, flooding transports large quantities of contaminants in both dissolved and suspended particulate forms to the salt marsh areas. Anthropogenic metals are incorporated in the sediments, decreasing their availability in the water column. Vascular plants in salt marshes are determinant to the dynamics of the estuarine ecosystem and strongly influence the processes of accumulation and retention of heavy metals in these areas. The utilization of wetlands as filters has gained great interest in the past decades. However, the role that plants play in the filter function of wetlands in relation to metals is still a matter of investigation.

When the metal contaminants enter in the salt marsh they spread along with the tides and periodic floods and interact with soil and the biotic community. Salt marsh plants are known to accumulate large amounts of metals in their aerial and belowground organs but also for their ability to phytostabilize these contaminants in the rhizosediment, playing an important role in the this ecosystem autoremediative processes and biogeochemistry.

When we consider the possible toxic effects of metals to the marsh ecosystem and also to human health, the total amount of metal is not as important as the chemical form that is present, responsible for the bioavailability to the plant uptake and consequently to the introduction in the food web. Activity of plant roots and associated microbes can alter physical and chemical properties of the sediment, influencing geochemical fractionation of metals and thus availability to the plant. The aim of this paper is to gain a better understanding about the influences of vascular plants and microbial activity in salt marsh heavy metals speciation.This would help us to determine which species and location is more appropriate to induce phytostabilization of heavy metals in polluted salt marshes by immobilizing them in low available chemical phases.

Catalytic degradation of pyrene from contaminated soils by nano-scale δ-MnO_2 and TiO_2

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Chemical oxidation has been increasingly regarded as relevant alternative to conventional treatment technologies and can be applied to a variety of recalcitrant organic contaminants, including PAHs (Rivas, 2006). The catalytic degradation of pyrene spiked in quartz and alluvial and red soils by nano size δ-MnO_2 or TiO_2 has been carried out in the presence and in the absence of sunlight under 33.3 kPa soil moisture tension and submerged condition. The results showed that the catalysis of synergistic effect of sunlight irradiation and TiO_2 was efficient for the degradation of pyrene in its contaminated quartz and alluvial and red soils. However, the catalytic degradation of pyrene by δ-MnO_2 was not significantly different between with and without sunlight irradiation. In the reaction process effects of catalyst dose was also studied on the catalytic degradation of pyrene in 1 h reaction period (Fig. 1). The results showed that the rate of catalytic degradation of pyrene by δ-MnO_2 was substantially larger than that by TiO_2. It was observed that the sequence of catalytic degradation of pyrene by δ-MnO_2 or TiO_2 in quartz and alluvial and red soils was quartz sand > red soil > alluvial soil. This mainly resulted from the reactions between pyrene and soil components. Further, this study revealed that catalytic degradation of pyrene by δ-MnO_2 is an effective, economic, and faster mode from pyrene-contaminated soils compared to TiO_2.

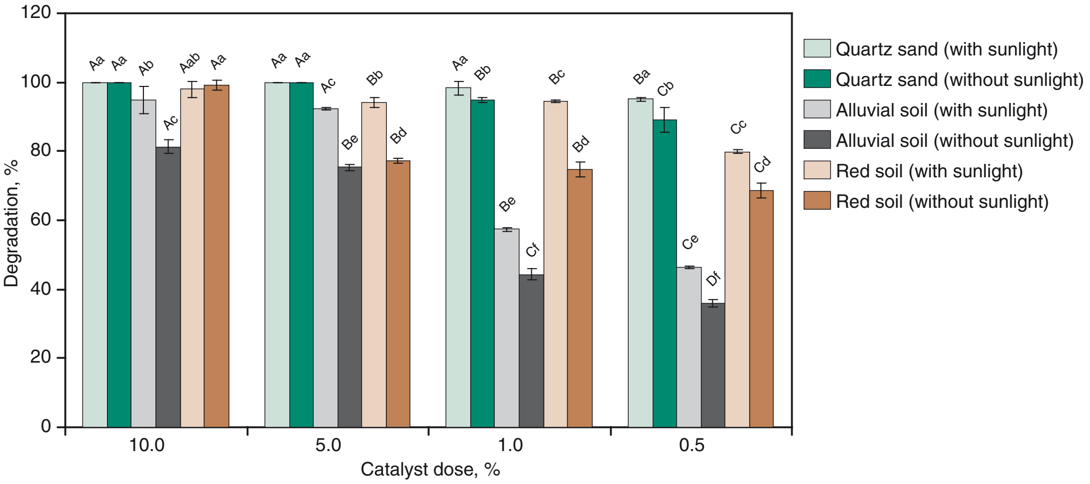

Fig. 1. Effect of catalyst (δ-MnO_2) dose in pyrene-contaminated soil with or without sunlight irradiation on degradation of pyrene.

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Natural and anthropogenic components in metal distribution in stream sediments from a small mining and smelting watershed: assessment of potential toxic effects

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The Riou Mort River watershed (SW France), representative of a heavily polluted, small, heterogeneous watershed, represents a major source of the polymetallic pollution affecting the whole Lot/Garonne/Gironde fluvial-estuarine system, due to former mining and ore-treatment activities. In order to assess spatial distribution of the metal/metalloid contamination in the watershed, high resolution hydrological and geochemical monitoring surveys were performed during one year at four permanent observation stations. Additionally, thirty-five sediment samples were collected at representative key sites and analyzed for metal/metalloid concentrations. Multidimensional statistical analyses combined with metal/metalloid maps generated by GIS tool were used to establish relationships between elements, to identify metal/metalloid sources and localize geochemical anomalies attributed to local geochemical background, urban and industrial activities. Combining geology/lithology-dependent geochemical background values, metal/metalloid concentrations in stream sediments and mass balances of element fluxes, anthropogenic contributions to particulate element fluxes were estimated 90–95% for Cd, Zn and Hg in the more downstream sub-catchments of the Riou Mort watershed.

A variety of methods have been developed to evaluate the degree of contamination in aquatic systems which can affect aquatic organisms. Although field transplantation of aquatic species is a straightforward and robust method to visualize ecotoxicological effects, this approach is limited by the number of sites and individuals, by the studied period, by site-specific interferences and by complex interactions between metal concentrations, metal species and biota. Alternatively, sediment quality guidelines (SQG) were designed to assess contamination, protect aquatic life, support or maintain designated uses of freshwater and to assist different sediment management objectives. The concentrations of particulate trace metals in stream sediments from the Riou Mort watershed were compared to the SQGs (MacDonald et al. 2000). The so-called Threshold Effect Concentration (TEC) represents concentrations of sediment-associated contaminants below which adverse effects on sediment-dwelling organisms are not expected to occur. The Probable Effect Concentration (PEC) defines concentrations above which adverse effects on sediment-dwelling organisms are likely to be observed. For each subcatchment, an overall stream sediment contamination index Ic was proposed for six metals/metalloids (Cd, Zn, Hg, Pb, Cu and As). It corresponds to the sum of elements for which sediment concentrations were greater than TEC and PEC values respectively and varies between 0 (none of the six metal/metalloid concentrations exceeds TEC or PEC in a given subcatchment) and 6 (each six metal/metalloid concentrations exceed TEC or PEC). This index was used to identify river segments and watershed areas where improved waste management and remediation should be given priority. For example, the obtained maps suggest that in sediments from the urban area of Decazeville city (i.e. upstream of the former ore treatment plant) five of the selected elements (Cd, Zn, Pb, Cu, As) showed concentrations greater than PEC. Accordingly, different sources contribute to the generally poor sediment quality observed for important zones of the Riou Mort watershed including river segments upstream from the former ore treatment plant, which probably represents serious threats to aquatic life. Localization of anthropogenic metal/metalloid point sources with high contamination index offers great perspectives to control metal into the downstream fluvial-estuarine ecosystems.

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Origin and distribution of heavy metals in soils and vegetation from the Susa Valley (Piedmont, Northern Italy)

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The Susa Valley (NW Italian Alps) is heavily impacted by anthropogenic activities, due to the simultaneous presence in a rather narrow valley floor of one highway connecting Italy to France, two provincial roadways, one railway and numerous industrial activities. The construction of a new railway tunnel is foreseen in the near future, raising some concern in the local population. The objectives of the study are the evaluation of the present-day heavy metal levels in soils and vegetation, compared to a previous survey conducted in the mid-nineties, and the selection of appropriate indicators to monitor in the future the impact of the new railway tunnel. The heavy metals considered in the study are Co, Cr, Cu, Mn, Ni, Pb, V and Zn. In nine sampling sites, soil profiles, grass samples, leaves and pine needles, wood branches and bark samples were collected, acid digested and analysed by ICP-OES. In addition, wood cores were also taken with an incremental borer from selected conifer species in order to test the applicability of heavy metals analysis on tree rings with LA-ICP-MS.

Results indicate that the Susa Valley is characterised by a high natural background level of Cr, Co and Ni, due to the presence of numerous outcrops of ultramafic rocks in the drainage basin. This is evidenced by the soil mean concentrations of these metals and the content increase with depth. On the other hand, Pb and Zn are systematically enriched in the topsoil, with a Top Enrichment Factor (TEF) rarely exceeding 2. The most heavily contaminated area is located close to the village of San Didero, because of the emissions from a point pollution source (smelter). Both soils and *Pinus strobus* needles reveal high concentrations of heavy metals: soil Pb and Zn reach concentrations close or beyond regulatory limits and TEF values of 4 and 2,6 respectively, while pine needles contains 8,47 and 47,5 ppm respectively. Soil profiles indicate that the contamination is confined in the 20 upper cm, therefore a transfer to pine needles by root uptake is unlikely. Vehicular traffic monitoring stations did not evidence an accumulation of heavy metals in the top soils with respect to concentration data of the mid-nineties (IPLA, 1997). In particular no net increase of heavy metals has been observed due to the doubling of highway traffic following 1990. Sampling with increasing distance from the major roads indicates that heavy metals decrease sharply at 10 m distance.

Concerning monitoring tools the most interesting results are provided by pine needles, which seem to well reflect the local contamination levels (Dongarrà et al., 2003). Grass samples reflect the heavy metals abundance in the top soil. The preliminary interpretation of heavy metals concentrations in tree rings is controversial due to analytical and standardisation difficulties. Nevertheless this is a promising technique for the chronological reconstruction of environmental pollution events (Facchinelli et al., 2008).

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Soil-plant interactions in metal polluted Mediterranean woodlands

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The alteration of the biogeochemical cycles of soil trace elements may have different consequences for terrestrial ecosystems. These could include alterations in nutrient cycles, interferences in plant growth and reproduction, or accumulation of toxic elements through the food webs. In Mediterranean ecosystems, the effects of metal pollution have not been much studied. We studied different ecological processes in the soil-plant subsystem in a metal-polluted area in SW Spain. We analyzed the patterns of metal availability in soils and their transfer to the aboveground biomass of the woody plant community. We also assessed the nutritional status of the main tree species in the area (*Olea europaea, Populus alba*, *Quercus ilex* subsp. *ballota*) and the influence of the soil conditions on nutrient uptake. Finally, we study the survival, growth, establishment and chemical composition of Holm oak seedlings over a gradient of soil pollution. We combined field observations and experiments under controlled conditions.

A high part of the variability of the available metals was explained by soil pH; other edaphic factors such us texture, organic matter content and cation exchange capacity had little influence. In general, leaf composition of the studied woody plants did not reflect the variability of metal availability. Cadmium, Zn and Cu were the most mobile elements in the soil-plant system. In any case the trace element concentrations in the leaves of the woody plants were low, with the exception of *P. alba* and *Salix atrocinerea*, which accumulated up to 1.7 and 7 mg kg^{-1} of Cd and 400 and 800 mg kg^{-1} of Zn, respectively (Domínguez et al., 2008a). Root retention may be an important mechanism of avoidance of high metal concentrations in the leaves of these species; for *Q. ilex*, greenhouse experiments confirmed that Cd is mostly retained in the fine roots, with a maximum of 0.3 % of translocation from roots to leaves. The cost of tolerance to high concentrations of Cd in the substrate was a reduced shoot growth. Some leaf nutrients, especially phosphorus, were influenced by soil metal availability. In the case of *O. europaea,* pollution explained a 40% of the variability of leaf P concentrations, and in highly polluted sites the trees showed a high P deficiency, as indicated by a N:P value much higher than 16. Under field conditions seed germination and seedling emergence was scarcely influenced by metals. Seedling establishment and growth were slightly lower in polluted sites than in control sites. However, other environmental factors, particularly light and soil moisture were more determinant for *Q. ilex* seedling performance (Domínguez et al., 2008b).

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Stability of arsenic/antimony forms in pure and contaminated soils

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Arsenic has been of an increasing environmental concern for a long time due to its risk to plant, animal, and human health, while antimony can be considered a typical incoming contaminant, which represents the ecological problem for future generations. The geochemistry and environmental behaviour of both elements are very similar because of the same inorganic species abounded, i.e. arsenates/arsenites and antimonates/antimonites, depending on the redox potential and pH value. Arsenic and antimony are highly toxic; they are carcinogenic, mutagenic and teratogenic. Their mobility and transport in the environment are strongly influenced by associations of the As/Sb species with solid phases in soils and sediments, which represent the most wide-spread accumulators of As/Sb in the environment.

The average arsenic content in uncontaminated or slightly contaminated soils varies from 5 to 10 mg/kg depending on soil chemistry and mineralogical bedrock, antimony occurs rarely in negligible concentration.

The sorption capacity of soils depends on a presence of hydrated oxides and/or hydroxides of Fe, Al and Mn, preferably Fe, because As/Sb oxyanions have a strong adsorption affinity to these phases forming stable inner-sphere surface complexes. The sorption properties of soils are also affected by the presence of dissolved organic carbon (DOC), which can occupy some of the adsorption sites, and/or the pH value connecting to the distribution of surface charge. Finally, the genesis of soil chemistry and mineralogy is also important. A concentration of As/Sb in soils can be intensified by other sources including mining activities, agricultural practices and disposal of industrial waste. The concentration gradients of As and Sb species accumulated in soil profiles can be succeeded by the release of available As/Sb forms from soils to groundwater – surface water systems.

The adsorption/desorption properties of three soil types related to $As^{III,V}$/$Sb^{III,V}$ oxyanion were measured under different physical chemical condition (initial As/Sb concentration and oxidation state, pH, retention time). The obtained data will open the possibility to predict potential As/Sb risk for soils, streams and water sources depending on atmospheric deposition and the physical chemical properties of soil profile, but independently of locality

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Storage of arsenic in various compartments of forested catchments along a pollution gradient

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To assess the fate of athropogenic arsenic in ecosystems, we constructed arsenic input/output mass balances for three polluted and one relatively unpolluted forest catchments in the Czech Republic. The sites spanned a 6-fold arsenic pollution gradient, and hydrochemistry was monitored for 11 water years (1995–2006). Two of the four sites currently exhibit large net arsenic export via runoff solutes (5 g As ha^{-1} yr^{-1}). This contrasts with previous studies which concluded that upland forest catchments are a net sink for atmogenic As both at a time of increasing and decreasing pollution. The amount of exported arsenic closely correlated with water fluxes via runoff (Erbanova et al., 2008). Based on these conclusions, we proceeded to characterize As accumulation in various ecosytem compartments.

Six replicate samples of the following organic-rich materials were taken in spruce stands in 2003–2004: spruce needles class 1, spruce needles class 2, moss *Pleurozium schreiberi*, grasses *Calamagrostis villosa* and *Deschampsia flexuosa*, soil horizons O_l, O_f, O_h, Ah, and B. Thirty samples of fresh bedrock were also obtained from outcrops in each catchment and pooled for As analysis. Spruce tree rings were sampled from one tree per site by sampling full ring-shaped wood segments, each spanning 5 years. The age of the trees was 30 to 97 years.

Atmospheric deposition of As at individual sites decreased in the order JEZ ≥ UDL > UHL >> LIZ. Arsenic concentrations were significantly higher at JEZ than at LIZ in seven out of eight types of solid samples of ecosystem compartments. In spruce needles, moss, grasses, O and A soil horizons, the most polluted site JEZ had high As concentrations, while the lest polluted site LIZ had low As concentrations. The only exception was spruce biomass whose As concentrations (mass-weighted across tree rings) were statistically indistinguishable between JEZ and LIZ. For three sample types (spruce needles class 1, *Pleurozium schreiberi* and *Calamagrostis villosa*) there was no difference in As concentrations between JEZ and UDL. In contrast, organic soil horizons (O_l, O_f, O_h and Ah) at UDL had significanly lower As concentrations than at JEZ. The moss *Pleurosium schreiberi* takes practically all As from the atmosphere. Due to its large surface area, the absolute As concentrations were ca. 10 times higher than in the case of grasess and spruce needles. For *Pleurosium schreiberi*, there was a significant positive correlation between present-day atmospheric depositon of As and As concentration in the moss (R=0.88). *Calamagrostis villosa* exhibited the second strongest correlation betwen As input and As concentration in the tissue (R=0.82). Interestingly, As concentration did not increase from spruce needles class 1 to class 2, as described at less polluted sites. Arsenic concentrations in humus were previously reported to be 180 times higher than in spruce needles. We found found 400 times higher As concentrations in humus relative to the needles. In agreement with previous reports from less polluted areas, there was no correlation between As concentration in spruce needles and individual soil horizons, indicating that uptake of gaseous or soluble As compounds through the needle surface may occur. Export of As from catchments via stream discharge was not correlated with the total As soil pool size, which was over 78% geogenic in origin.

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Experimental in situ transformation of smelter fly ash in acidic forest soils

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Base-metal smelting was recognized to be one of the most important local sources of metallic pollution. Extremely high concentration of metals (Pb, Cd, Zn) and other contaminants (As, Sb) were found in forest and agricultural soils in the vicinity of Pb smelters (e.g., Ettler et al., 2005). At one Pb smelter-affected site, Ettler et al. (2005) found up to 3.5% Pb in organic horizons of forest soils. Such high contaminant concentrations in soils are related to the deposition of smelter fly ash particles during periods of the filtering inefficiency in the smelter flue-gas cleaning technology. In particular, fly ash from secondary Pb smelting (Pb scrap processing) is composed of highly soluble metal-bearing salts ($Na_3Pb_2(SO_4)_3Cl$ and KPb_2Cl_5) as documented by various leaching tests (Ettler et al., 2008).

To simulate the transformation of smelter fly ash in soil, we carried out a 1-year experimental study in two forest soils (developed under the spruce and beech cover) and one control soil (meadow) in an acidified area (soil pH was 3.4–5.6). The smelter fly ash (0.5 g) was placed into double polyamide bags (NYTREL TI polyamide; 2 cm × 4 cm,; mean mesh size of 1 μm). Bags were inserted horizontally into the soil horizons (litter, O, A and B) and left for 1 year. There were three replicates per set introduced into the soil pit front. After 1 year, the bags were collected together with the soil samples in their vicinity. Bags were weighted and their content was analyzed by X-ray diffraction analysis (XRD) and transmission electron microscopy (TEM). The soil samples were analyzed for metals and metalloids and Pb isotopic composition (ICP-OES and ICP-MS) and compared with “unpolluted” soils sampled before the experiment.

Mass losses indicated that more than 60% of fly ash was dissolved during the experiment, releasing metallic contaminants (Pb, Cd, Zn) into the soil system. The highest mass losses were observed in organic soil horizons. XRD analysis showed that KPb_2Cl_5 was completely dissolved and secondary anglesite (PbSO4) was formed. This phase was also detected in soils at smelter-polluted sites (Ettler et al., 2005) and was suggested to be final and stable alteration product of fly ash weathering (Ettler et al., 2008). A strong increase of concentrations (up to ~70times) of metallic contaminants (Pb, Cd, Zn) was observed after the exposure especially in the litter and surface organic horizons. Fly ash dissolution and mobilization of contaminants was also confirmed by Pb isotopes, with signatures corresponding to smelter fly ash. This study was supported by the Czech Science Foundation project no. 526/06/0418.

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Biogeochemical Cycles of trace Elements in forest Coenoses

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The aim of the study was to find the patterns in chemical element transport and redistribution in the soils of forest coenoses that predetermine the directivity of soil formation process, ecological state of the soils and formation of soil fertility under natural conditions and under human impact. We investigated geochemical processes in forest coenoses in the North of European Russia, with Republic of Karelia as the example. Distinctions in the migration of chemical elements within the profile and their distribution in the soil cover depending on the combination of hydrometeorology, lithology, and plant community characteristics were thus identified. Significant attention was paid to the physiochemical and biological properties of forest soils (texture, organic matter content, acidity, redox potential) controlling the transport and deposition of chemical elements.

Correlations between storage of trace elements in soils and the chemical composition of parent rocks were identified. The content of iron, manganese and cobalt in soils is also closely related to their content in parent rock. Biogenic copper and zinc accumulate in forest litters. Trace elements content in soils with fine particle size over valved clays is higher than in sandy soils over aqueoglacial sediments. Having performed chemical analysis of mosses, we determined the list and quantities of trace elements deposited on the soil surface as air-born pollutants. The main sources of heavy metal pollution for Republic of Karelia are industrial enterprises in its biggest cities as well as highways.

Levels of autochthonous and allochthonous storage of trace elements in mosses and forest soils in Karelia were determined. Digital maps of the elements' concentrations were compiled.

Table 1. Minimum, maximum and average concentrations of trace elements in mosses and forest litters in Karelia for period 1995–2005, µg/g

Elements	Ni	Cu	Co	Cr	Pb	Cd	Zn	Mn
Mosses								
Minimum	1.60	2.97	0.50	1.90	2.30	0.10	23.65	132.0
Maximum	5.91	10.26	3.78	6.90	10.30	0.53	69.15	928.70
Averade	2.69	4.50	0.89	3.37	5.03	0.30	37.95	431.06
Forest litters								
Minimum	2.90	6.10	0.80	0.01	11.00	0.29	21.60	48.00
Maximum	17.2	178.9	8.84	25.20	46.00	1.04	189.60	2053.10
Averade	7.2	63.36	1.98	9.97	26.64	0.54	83.04	403.07

Release of organic carbon, silica, major and trace elements from degrading plant litter under microbial activity in laboratory experiments

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Quantification of major and trace elements recycling by plants is hampered by the lack of physico-chemical data on chemical elements release from degrading plant litter in soil and model laboratory environments. In this study, we applied a laboratory experimental approach for determining the organic carbon and approx. 30 chemical elements release rates from litter of typical temperate and boreal plants: larch (*Larix gmelinii*), elm (*Ulmus laevis Pall.*), tree fern (*Dicksonia squarrosa*), in 0.01 M NaCl solutions, circumneutral pH and temperature equals to 25°C. Open system, mixed-flow reactors equipped with dialysis compartment (1 kDa, or approximately 1 nm pore size) and batch reactors were used. Comparative measurements were performed under sterile and non-sterile conditions with evaluation of the number of active heterotrophic bacteria via counting the number of colony-forming units (CFU) on the agar plates. Litter degradation results suggest that chemical elements release rate is independent on dissolved organic carbon release (cellulose hydrolysis). In the open-system mixed flow experiments, most elements are released at the very first stage of litter dissolution. In the closed-system (batch) experiments over 1 month observation time, the sterile biomass of larch needles liberates similar amount of organic carbon and trace metals (Al, Ti, Fe, Mn, Cu, Sr, Y, Zr, Mo, Pb) as in biotic experiment with the presence of soil bacteria. At the same time, Si release rate in sterile condition (0.74 µmol/g/day) is an order of magnitude lower than in the presence of bacteria (6.2 µmol/g/day). The abiotic release rate of TE in experiments with dialysis compartment (< 1 nm) is at least an order of magnitude lower than that in conventional batch experiments (< 0.22 µm) for many trace elements (Al, Fe, Cu, Ni, Zn, Pb…) likely due to colloidal organic matter control onto speciation of these litter-borne trace metals in solution. Elements that are present in the form of free ions or inorganic complexes (Li, B, Na, Mg, Ca, Si, Rb, Sr, Mo, As, Cs…) exhibit similar, by the order of magnitude, release rates in flow-through dialysis compartment and in the batch dialysis-free experiments. The presence of bacteria (100 to 107 colony forming units per L) in the course of biotic plant litter degradation experiment does not significantly modify the release of organic carbon and major (Ca, Mg) and trace elements (Al, Ti, Mn, fe, Cu, Sr, Pb) both for larch tree and fern biomass.

The dry-weight normalized dissolution release rates of at circumneutral pH range (approx. 1–10 nmol/g/day) of most trace elements is several orders of magnitude higher than the rates of element release from common soil minerals (kaolinite, smectite, illite) as well as from primary silicates. We demonstrate, from the viewpoint of the mass balance and the rates of abiotic and microbially-controlled reactions, that the plant litter reservoir is able to provide the dominant contribution of major petrogenic and most trace elements elements (Si, Ca) to the riverine chemical erosion flux.

Iodine fluxes in Lake Constance and its catchment: A mass-balance approach

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Iodine is an important trace element for terrestrial, atmospheric and oceanic cycles. Iodine is a vital micro nutrient for all mammals, and insufficient iodine intake leads to a number of health disorders such as goitre and cretinism. Despite the WHO listing iodine deficiency as the most easily preventable cause of brain damage, there is still very little known about iodine dynamics in fresh waters. Our aim was to study the fluxes into, out of, and within Lake Constance, a large lake in Southern Germany that supplies water to more than 4 million people. From this data a mass balance model for iodine fluxes was constructed to help constrain major iodine sources and sinks within the lake. Monthly filtered water samples were taken from all major and some minor inflows and outflows during 2005 and were analysed for iodine by ICP-MS. Sediment trap samples were also obtained from two sampling stations, one near the Rhine inflow and one further into the lake and were analysed by the thermo-extraction spectrometric method described by Gilfedder et al. (2007).

It was found that iodine fluxes in all major tributaries into the lake followed the water inflow flux, with the Rhine being the dominant iodine source (51%). The tributaries derived from the Alps (e.g. the Alpen Rhine) displayed a maximum iodine influx during the summer, which is due to major snow melt and precipitation during this time (Fig. 1). In contrast, the lowland tributaries (e.g. Argen) produced maximum iodine fluxes into the lake during the winter and spring. Surprisingly, the catchment normalised flux was essentially identical between most of the tributaries (~1.5 kg m^{-2} yr^{-1}), despite very different catchment morphologies.

The mass balance calculation for the lake resulted in a net influx of 17311 kg of iodine per year and an output of 19117 kg, with a net of -1169 kg. A total of 79742 kg of dissolved iodine is stored within the lake. It is thought that the extra iodine input into the lake required to account for the negative mass balance calculated by our measurements is derived from release of iodine from the sediments into the lake. Iodine concentrations in the sediment trap were highly influenced by season, with up to 20 times higher iodine concentrations in the falling sediment during winter. However, the absolute flux did not show such seasonal changes, with a median of 12.4 mg m^{-2} yr^{-1} near the Alpen Rhine inflow and 7.1 mg m^{-2} yr^{-1} further afield. Therefore, only a very small proportion of the iodine deposited on the lake bottom needs to be mobilised to balance the negative lake flux from above.

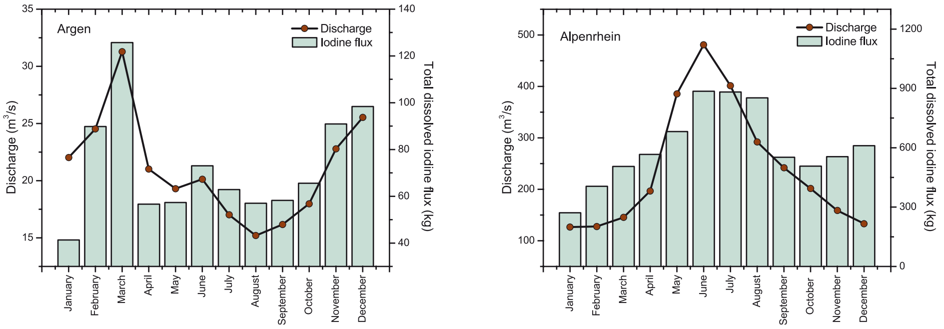

Figure 1. Fluxes from two Rivers flowing into lake Constance. The Argen is a lowland river, whereas the Alpen Rhine has its source more than 2000 masl in the Alps.

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Modelling lead binding to soils: in search for the missing sorbent

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The last decade has witnessed considerable progress in geochemical modeling of trace element behavior in soils. By considering the known binding of metals to isolated humic and fulvic acid, Fe (hydr)oxides and clay, it is possible to predict the dissolved concentrations of trace metals such as Cu, Zn and Cd in whole soil samples within a factor 2–5. However, the dozen or so attempts that have tried to predict Pb binding, using the same methodology, have invariably failed. Usually the models predict levels of dissolved Pb that are about one magnitude or more too high. In the literature, various speculations about the reason can be found, including incorrect model parameters for Pb adsorption to Fe (hydr)oxide, and strong sorption to a sorbent not considered by the model, for example Mn oxide (see, e.g., Bonten et al., 2008; Khai et al., 2008).

In this contribution we present new data collected in batch experiments made with Swedish Oe and Bs horizons from Spodosols. The pH dependence of Pb binding was studied, as well as the dependence on the initial Pb addition (Pb binding isotherms). Competitive interactions with Fe(III) and Al were elucidated. Furthermore, we reviewed existing data for the binding of Pb to Fe (hydr)oxides, humic and fulvic acid to provide a solid base for geochemical modeling, which was carried out with Visual MINTEQ ver. 2.60, employing the CD-MUSIC and Stockholm Humic models for Fe (hydr)oxide adsorption and complexation to humic/fulvic acid, respectively.

Our results agree with previous studies concerning the unsatisfying ability of the geochemical model to describe dissolved Pb accurately. Particularly at low pH and at low equilibrium Pb concentrations, the deviation between the model and the observations was very large, and competition with Fe(III) and Al was overestimated by the model. The model fit could not be substantially improved by changes to Fe (hydr)oxide adsorption parameters, within realistic limits. However, if the existence of a high-affinity site for Pb is assumed, which does not sorb other cations (such as Fe(III), Al, Ca etc) appreciably, much improved and consistent model fits can be found, both for the pH dependence, Pb binding isotherms, and the competition with Fe(III) and Al. Based on the patterns we have observed, we speculate that these specific high-affinity binding sites for Pb may be found in non-humic organic matter, perhaps on the cell walls of roots or bacteria.

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Effect of excess nitrogen deposition in forest watershed on the leaching of heavy metals

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Atmospheric deposition supplies some nutrients to forest ecosystem, serving as a source of reactive nitrogen, sulfur and the toxic metals. Although nitrogen and sulfur have been deposited in Japan as well as in Europe and North America, the impacts of the deposition of reactive N and S such as acidification of surface water and forest decline have not been reported yet. Itoh et al. (2004) reported high nitrate concentrations in stream waters mostly on the periphery of metropolitan Tokyo in Japan. In these forest watersheds, a high level of reactive nitrogen deposition may enhance the nitrification process and thereby acidify the forest soils. In turn, soil acidification can cause increased solubility of metals in the forest soil. In the surface forest soil layer, heavy metals derived from the atmosphere and mainly anthropogenic sources have been accumulating for long time in Japan (Itoh et al., 2007). The increasing mobility of the metals could pollute stream water or ground water, and thus damage the forest ecosystems in the future.

The objective of this study was to compare the behavior of potentially toxic metals (Al, Pb, Cd, Cu, and Zn) in forest soil profiles in two forest sites: the Tsukuba experimental forest watershed (high NO_3^- concentration in stream water) and the Katsura experimental forest watershed (low NO_3^- concentration in stream water). Two soil profiles were studied at Tsukuba and one soil profile at Katsura. Soil solution was collected from suction cups (PTFE) installed at each plot at depths form 10 cm to 100 cm. Concentrations of metals were determined using an inductively coupled plasma mass spectrometer (Agilent 7500).

The soil solutions were acidic at Tsukuba. The pH values of soil solution did not increase from the surface soil layer to deeper layers (< pH 4.5). Elevated nitrate leaching from the rooting zone was also observed. At Tsukuba, the concentrations of potentially toxic metals (Al, Pb, Cd, Cu, and Zn) were significantly higher than those at Katsura. Higher N deposition loads from the atmosphere and higher nitrification rate in the soils were also observed at Tsukuba. Therefore, the acidification of soil resulting from nitrate leaching may increase the mobility of potentially toxic metals in the soils. Although high nitrate concentration was observed constantly in the stream water at Tsukuba, acidic pH values were not observed and metals concentrations were at low levels. Surface water acidification and high losses of metals from forest ecosystems have not been detected yet.

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Heavy metal accumulation in different parts of coniferous forest

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Research of heavy metal accumulation in different parts of coniferous forest has been carried out at two ICP IM (International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems) monitoring sites in Estonia. Vilsandi area is located on Estonia's westernmost island (58º23´ N, 21º50´ E) and Saarejärve is located at the forested sub-catchment area (109.2 ha) of Lake Saare in eastern Estonia (58º39´ N, 26º45´ E).

Heavy metal concentrations have been analysed in bulk deposition, throughfall, stemflow, soil water, needle fraction of litter, non-needle litter, bark, moss in open area, current year needles, soil organics, roots and moss under pine and spruce canopies.

Cd, Cr, Cu, Fe, Ni, Pb and Zn were analysed using acid digestion method in closed system pretreatment and atomic absorption spectrometry (AAS).

Heavy metal concentrations of Zn, Cd, Pb and Cu in litter needles (estimated from annual composite sample) during 1995–2007 show statistically significant increasing trends for Cu and Cd in Vilsandi. At the same time increased Cu and Cd concentrations in needles and litter needles could indicate increased mobility of these in the soil organic and promoted uptake by pine roots. Heavy metal (Pb, Cd, Cu and Zn) concentrations (mg kg^{-1}) in soil organic layer (estimated from two depths: 0–5 cm and 5–10 cm) of studied stands at Saarejärve and Vilsandi show elevated Pb concentrations in both stand at Saarejärve and elevated Cu concentration in top layer of organics in Vilsandi pine stand and to a certain extent in Saarejärve pine stand. Zn-concentrations are elevated in all stands, especially in top organics. Lower concentrations of Pb in top organics compared with deeper organic layer indicate probably decreased atmospheric input assuming that uptake of the least mobile Pb by vegetation is negligible.

The capert-forming moss species *Pleurozium schreberi* and *Hylocomium splendens* are good bioaccumulaters of heavy metal deposition because of they obtain all nutrients directly from precipitation and dry deposition by their whole surface. The ability of the moss to sorb and retain various metals follow the order: Cu, Pb>Ni>Cr>Cd >Zn, whereas the efficiency factor for lead and copper is about 100%. Average moss uptake efficiency is lower for Cr 84%, Cd 65%, V 54%, and Zn 41% (Rühling et al, 1987). No significant differences in concentrations have been found between the two moss species (Liiv, Kaasik, 2004). The decreased concentration of Cd, Cr, Fe, Ni and Pb in mosses during 1994–2005 were characteristic for both area as well for country-wide averages.

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Long-term trends of lead and cadmium at the Integrated Monitoring site Zöbelboden (Austria) – Evidence of new findings regarding their relocation in soil

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The relocation of lead and cadmium in soils has been investigated in numerous studies relating to various soil parameters. However the transferability of these results to long-term processes in forest ecosystems has been rarely verified. Here we present long-term data about airborne deposition and trends in soil and soil water between 1992 and 2007. Soil data originate from two soil inventories conducted in the years 1992 and 2004 on a 100 m grid across the entire watershed. Moreover throughfall and stemflow deposition, litter fall input and soil water has been sampled on a biweekly basis on two intensive plots representing the two dominating forest and soil types: a deep Cambisol with Norway spruce forest with a perched watertable and a shallow Leptosol with a mixed beech-spruce-maple forest. Hydrological modeling (BROOK90) was used to establish time series of soil water fluxes at a daily resolution.

Both Pb and Cd yield decreasing trends in the throughfall deposition and litter fall input. In soil the concentrations decrease significantly except slightly increasing concentrations of Cd in the organic layer (changes in the second decimal) (Table 1). The soils are mainly characterised by high pH-values, high content of organic matter and high cation exchange capacity and therefore known for effective retention and accumulation of heavy metals. The trends of deposition of acidifying air pollutants result in increasing pH-values in several ecosystem compartments. Moreover the DOC concentrations increase in soil water. Therefore the unexpectedly fast relocation of Pb and Cd in the soils despite increasing pH-values seems to be promoted by the formation of complexes with soluble organic acids enhanced by increasing DOC concentrations. Moreover soil water chemistry indicates that large portions of Pb and Cd are leached during high precipitation events. The widespread opinion of long-term accumulation and retention of heavy metals in organic top soils has to be reconsidered in order to understand recovery processes during times of decreasing airborne deposition.

Table 1. Trends (median values) of Pb and Cd concentrations in the period 1992 and 2004. P values are derived using a paired Wilcoxon signed rank test. Significant trends at the 0.05 confidence level are given in bold letters.

	Median 1992	Median 2004	Median Trend	P value
		Organic layer		
Cd (mg kg-1)	0.6	0.6	0	0.091
Pb (mg kg-1)	38.0	32.0	-7.3	0.002
		Mineral soil layer (0-5cm)		
Cd (mg kg-1)	1.5	1.6	-0.1	0.018
Pb (mg kg-1)	72.5	68.0	-9.3	0.010
		Mineral soil layer (5-10 cm)		
Cd (mg kg-1)	1.4	1.2	-0.3	0.002
Pb (mg kg-1)	63.2	52.0	-14.1	0.002

Methods comparison of heavy metal bioavailability assessment in contaminated soils from a former mining area (La Union, Spain)

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Mining activities generate huge amounts of heavy metal contaminated wastes and erosion processes that contribute to the contamination of surrounding soils. In order to assess the risk of heavy metal transfer to the plants, mobility of the pollutants should be quantified considering both the soil properties and rhizospheric interactions. A rhizospheric biotest, consisting in a thin layer of substratum in close contact with roots of *Lolium multiflorum* with two different nutrient solutions, was used during one month on two contrasting contaminated soils issued from a former Pb/Zn mining area in Cartagena (La Union, S.E. Spain). On top of this biotest, soil properties and heavy metal content measurements, as well as $CaCl_2$ selective extractions, were performed on these soils.

Total heavy metal contents show that the Cabezo soil is the most polluted one (Table 1), with concentrations exceeding largely legal criteria. Selective extractions take into account soil characteristics. These measurements indicate that heavy metal mobility is higher in the Brunita soil, and highlight the major effect of soil pH on heavy metal mobility. On the other hand, rhizospheric biotests consider plant absorption and specific ionic interactions during root absorption processes in addition to soil parameters, leading to a more integrative measure. Interpretation of this test is more complex, with biomass production variations for plants in contact with the different soils, and singular behaviors for each heavy metal. Conclusions of the three tests diverged, with the two first ones (total soil content and $CaCl_2$ extraction) pointing to a different soil as the most dangerous one in terms of toxicity risks and the third test (rhizospheric biotest) giving a mixed result. This study showed the necessity to perform different measurements in order to evaluate and well understand heavy metal mobility in contaminated soils.

Table 1. Comparison between heavy metal concentrations obtained from total soil content, CaCl2 selective extraction and rhizospheric biotest for the two contaminated soils.

	Total soil content [mg/kg soil]		$CaCl_2$ extraction [mg/kg soil]		Rhizospheric biotest [mg/kg plant]	
	Cabezo	Brunita	Cabezo	Brunita	Cabezo	Brunita
Cd	49	< 4	3.1	0.5	6.3	1.5
Cu	274	123	0.8	1.7	8.3	7.1
Fe	94659	152349	10.7	19.2	35.3	131.7
Mn	8107	2268	9.6	216.5	94.0	222.5
Pb	4194	750	2.7	17.6	17.9	4.3
Zn	23361	869	107.6	208.6	713	299.4

Cadmium concentrations in ecosystem components within an oligotrophic lake Orijärvi contaminated by mining wastewater

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Cadmium is a global pollutant introduced to Finnish watersheds mainly through mining. Lake Orijärvi, in Southern Finland, is a clear watered headwater lake, which has been affected by mining. Mining in the catchment area has occurred from 1750's to 1950's (Poutanen 1996). The impact of wastewater from mine tailings on cadmium (Cd) concentrations in ecosystem components was studied. Samples from sediment, water, vegetation (*Equisetum fluviatile*), bottom fauna (*Asellus aquaticus*) and fish flesh (*Perca fluviatilis*) were taken and Cd concentrations analysed with an atomic absorption spectrometry analyser. To estimate the background levels of Cd, samples from an adjacent lake (Määrjärvi) and six other lakes were taken.

All components of the ecosystem in lake Orijärvi showed clearly elevated concentrations of Cd in comparison to the other lakes (Table 1). For instance the concentration of Cd in *A. aquaticus* (9.25 µg/g dw) was twice that of other lakes in which the Cd levels mostly remained below 4.2 µg/g dw. The concentrations of Cd in fish samples taken from lakes Orijärvi, Määrjärvi and Valkea-Kotinen, were almost 10-fold to the previously reported Cd concentrations in perch, Finland (Venäläinen et al. 2004). Despite these elevated concentrations, especially in lake Orijärvi (*P. fluviatilis,* 0.024 µg/g ww), the maximum levels of cadmium (0.05 mg/kg ww) allowed in foodstuff (EU Commission Regulation 466/2001) were not exceeded.

Table 1. Cadmium concentrations in ecosystem components of the studied lakes.

Lakes Cd concentrations		Määrjärvi	Orijärvi	Pääjärvi	Valkea-Kotinen	Vesijärvi	Tavilampi	Horkkajärvi	Vitsjön
Equisetum fluviatile	avg	0.53	1.47	0.25					
µg/g (dry weight)	sd	0.09	0.54	-					
	n	n = 2	n = 5	n = 1					
Sediment	avg	0.66	3.56	-	1.12	1.24			
µg/g (dry weight)	sd	0.08	1.53	-	-	-			
	n	n= 2	n = 5	-	n = 1	n = 1			
Asellus aquaticus	avg	3.91	9.25	1.76	1.00	4.20	3.39	0.90	
µg/g (dry weight)	sd	2.14	7.49	0.37	-	-	4.60	0.37	
	n	n = 6	n = 15	n = 2	n = 1	n = 1	n = 3	n = 2	
Water µg/l	avg	0.014	0.052	0.003	0.038	0.008	0.003	0.023	
	sd	0.00	0.01	-	-	-	-	-	
	n	n = 7	n = 10	n = 1	n = 1	n = 1	n = 1	n = 1	
Perca fluviatilis	avg	0.011	0.024	0.004	0.010	0.002	0.003	0.002	0.003
µg/g (wet weight)	sd	0.004	0.016	0.002	0.008	0.000	0.001	0.002	0.001
	n	n = 9	n = 23	n = 20	n = 20	n = 10	n = 9	n = 9	n = 9

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Trace elements in leaves of trees and shrubs in south Spain: ecosystem perspectives

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Global Change affects directly to plant physiology, growth and fitness, causing changes on communities assembly, and lastly on the dynamics of nutrients and carbon cycles in the ecosystem. In particular, modifications in the proportion of different leaf traits have consequences for ecosystem functioning, through the processes of primary production and litter decomposition. Thus the decomposition rates are determined by the chemical composition of litter (which are strongly determined by the chemical composition of the green leaf), and by the moisture and temperature conditions in the soil. The objectives of this study are 1) to describe the leaf spectrum of variability in the accumulation of trace elements for Mediterranean woody species, 2) to evaluate the use of leaves as bioindicators of soil quality, 3) to analyse the contribution of differential trace element accumulation among woody species to the ecosystem heterogeneity.

We compare results from two forest areas in south Spain: a mixed oak forest in Aljibe Mountains and a remediated and afforested floodplain in the Guadiamar valley. In the mountain forest we explore the variability in the accumulation of trace elements in the leaves of 17 woody species. We analyse the bi-directional relationship with soil heterogeneity (Quilchano et al. 2008). Plants uptake elements from the soil volume explored by the roots (besides the aerial deposition on leaves), and at the same time affects the ecosystem through the species-specific leaf traits, including decomposition rates and concentration of trace elements.

In the floodplain afforested area we use leaf concentration of trace elements as biomonitor of soil quality after remediation of a mine-spill , and to assess the risk-based effects of contaminants on ecosystems (Madejón et al. 2006). In general the bioaccumulation coefficients (plant/soil concentration quotients) were low (<0.4) for all the trace elements and the eight studied plant species, with the exception of Cd and Zn in *Populus alba* which accumulated up to 3 mg kg^{-1} of Cd and 410 mg kg^{-1} of Zn (Domínguez et al. 2008).

The combined multivariate analysis of the concentration of eight trace elements in leaves of 25 woody species allows to infer the relative importance of the species factor and the site factor in trace element patterns. The influence of the biogeochemistry of trace elements on the ecosystem behaviour is discussed.

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The estimation of heavy metal mobility in soils

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The influence of a contaminated soil on the entire ecosystem directly depends on the particular groups of metal compounds in the soil. The aim of the work is the determination of heavy metals (HM) mobility in soils by data on their distribution on separate groups. The estimation of HM mobility system in soil includes the following stages:

1. *HM forms determination.* The exchangeable forms of HM were extracted from soil by 1 M NH_4OAc, pH 4.8, buffer. The amount of complex-bound forms was calculated as a difference between the metal contents in the 1% EDTA in 1 M NH_4OAc extract and 1 M NH4OAc buffer. The amount of specifically adsorbed forms was calculated as a difference between the metal contents in the extracts of 1 M HCl and 1 M NH_4OAc.
2. *HM forms grouping*. The weakly bound group (WB) includes exchangeable, complexing and specifically adsorbed metals (Minkina et al, 2008). The difference between the total HMs and their WB demonstrates the amount of metals within the group of strongly bound compounds (SB).
3. *Calculation* the mobility of metals. The mobility of metals in the soil can be assessed from the ratio between their groups and expressed in the form of mobility coefficient (Km):

$$Km = WB/SB$$

4. *Calculation of metal forms in percent from group*. This calculation allows to estimate of HM contribute in the changing of metal mobility.

This approach has been used to assess the mobility of Zn compounds in Chernozem (clay 53%, C_{org} 2.3 %, $CaCO_3$ 0.4% with pH 7.5) and its changes upon the soil contamination with Zn acetate added with different dozes (Table 1). In the studied uncontaminated soil the portion of weakly bound HM is only 10% of their total contents. Specifically adsorbed heavy metals constitute up to 92% of the WB. In the case of artificial contamination, the total content of metals increases and the share of WB among them also increases by 3–4 times. The portion of WB increased with an increasing of the soil contamination degree. The changes in the mobility related to the formation of Zn compounds weakly bounded with the soil organic matter. During the second year after contamination the portion of specifically absorbed forms of Zn increased.

Table 1. The changing of Zn mobility after soil contamination

Dose of metal, mg/kg	Total content, mg/kg		WB/SB*		Weakly bound compounds, mg/kg		exchangeable/complex/ specifically sorbed**	
	1 year	2 years	1 year	2 years	1 year	2 years	1 year	2 years
No added metal	69	65	10/90	11/89	7	7	7/1/92	5/4/91
50	119	121	30/70	41/59	36	50	7/4/89	3/4/93
100	165	159	42/58	47/53	69	75	11/10/79	5/5/90
300	365	360	31/69	37/63	112	134	23/26/51	17/15/68

Note: *Weakly/strongly bound compounds, % of the total content.
** % of weakly bound compounds.

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Diel mercury-concentration variations in wetlands adjacent to Great Salt Lake, Utah, USA

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The open water and adjacent wetlands of the Great Salt Lake (GSL) ecosystem support millions of migratory waterfowl and shorebirds from throughout the Western Hemisphere and a multi-million U.S. dollar brine shrimp industry. Recent biogeochemical assessments of the GSL ecosystem have found elevated levels of methyl Hg (> 30 ng/L) in whole-water samples and Hg(total) in three duck species that consistently exceeded the U.S. Environmental Protection Agency screening level for human consumption. The 192,000 hectares of wetlands surrounding GSL likely play a key role in the transformation of inorganic Hg to the significantly more toxic methyl Hg species. Only a few studies have examined short-term cycling of Hg in wetland systems. The objective of this work was to measure changes in methyl Hg concentration and loads in water discharging from the Howard Slough wetland adjacent to GSL over a 24-hour interval during July 23–24, 2008. During the start of the diel experiment, the concentrations of filtered (< 0.45 μm) methyl Hg consistently decreased during daylight hours to a low of 0.34 ng/L at sunset (Fig. 1). After sunset, methyl Hg increased by > 100 % to a maximum concentration of 0.70 ng/L between 0100 and 0200 hours. After sunrise on July 24th, methyl Hg steadily decreased, returning to a low value of 0.30 ng/L at 1100 hours. Dissolved oxygen concentrations decreased significantly after sunset and continued to decrease to near 0 mg/L prior to sunrise on July 24th. The likely mechanism for the nighttime increase in methyl Hg was convective turnover of the wetland water column driven by dropping nighttime air temperature which cooled the surface water. During this convective overturn of the water column, methyl-Hg rich water near the sediment-water interface was likely mixed into the wetland water column resulting in the observed increase in methyl Hg concentration at the outflow structure. Vertical water temperature profiles at the outlet structure indicated thermally stratified conditions during daylight hours and a convergence to homogenous water temperature during nighttime cooling (Fig. 1). Simulations of convective overturn during nighttime cooling using hydrodynamic modeling are currently ongoing. The large fluctuations in methyl Hg concentrations over a 24-hour period can have significant implications when estimating methyl Hg production and mass export from the large expanse of wetlands surrounding GSL. Most water-quality samples and discharge measurements for loading estimates are collected during mid-morning to mid-afternoon time periods, resulting in significant underestimation in methyl Hg loads produced and exported by GSL perimeter wetlands.

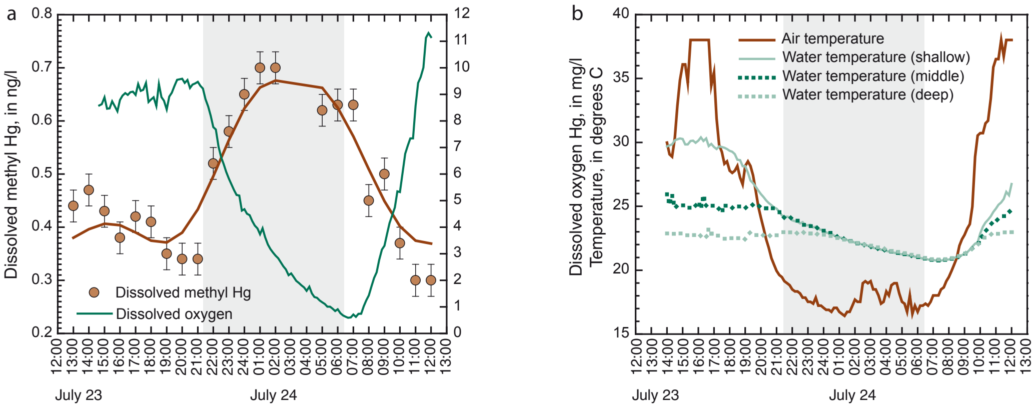

Fig. 1. Changes in dissolved methyl Hg and dissolved oxygen concentration (A) and changes in air and water temperature (B) with time at the outlet of Howard Slough wetland, Utah. Shaded areas indicate non-daylight period.

Emissions of Hg from Soil due to Forest Fire in central Europe - Czech Republic

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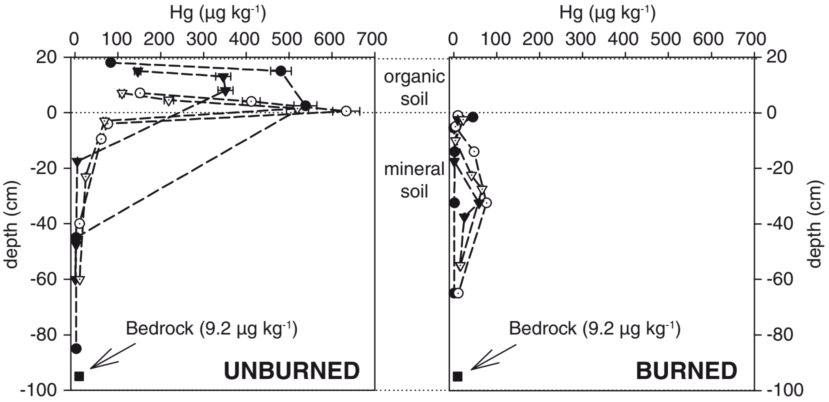
Mercury is nowadays considered as a global pollutant that has been released into the atmosphere by both natural and anthropogenic sources. Anthropogenic Hg emissions have been fairly well quantified. On the contrary, natural emissions have not been as well characterized especially in Europe. Natural Hg emissions originating from forest fires have been accounted as one of the important Hg non-point sources.

Recent studies in North America indicate that wildfires may provide a significant flux of Hg from terrestrial ecosystems to the atmosphere. During the forest fires previously deposited Hg is released primarily from the biomass and organic-rich soil horizons to the atmosphere.



We investigated emissions of Hg from a single fire event and effect of fire on soil Hg pools in forest located in central Europe, Czech Republic (CR). Area of 17.9 ha in hardly accessible part of Bohemian Switzerland National Park was burned during one-week long forest fire in 2006. Severity of the forest fire was extreme due to previous long period of drought. Total burnout of the organic soil horizons (4039 t) was reported from the burned area. We estimated Hg emissions from the burned organic soil to be 1.34±0.07 kg and Hg emissions from burned area thus amounted 75.1 g ha^{-1}.

Using total area (53 ha) of burned forests in CR during year 2006 we estimated annual Hg emissions from soils during forest fires in CR to be 3.98 kg in 2006. Total anthropogenic emissions in CR reported for year 2006 reached 3.7 t. Therefore natural Hg emissions from soils burned during forest fires in CR in 2006 were 0.1% of the annual anthropogenic Hg emissions. It should be noted that area of the burned forest in 2006 was the lowest annual value since 2000. The average burned area of forests in CR for period 2000–2006 was 356 ha with Hg emissions 26.7 kg, while the average anthropogenic emissions in the same period amounted 3 t yr^{-1}. Estimated mean Hg emissions from burned soil in period 2000–2006 reached 1% of annual anthropogenic Hg emissions.

Modelling of aluminium transport in forest soil profiles in the Jizera Mountains

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Soil acidification (due to acid deposition, acid parent rocks, high precipitation, and specific vegetation) presents a serious problem mainly in forest soils. It can result in a release of potentially toxic Al forms. To predict potential Al leakage into the groundwater, soil water regime and substances transport may be simulated using the numerical models. Typical acid soil profiles (Podzols, Cambisols) present in the Jizera Mountains under various plant cover (spruce forest, beech forest, grass) were chosen to asses potential groundwater contamination in this area. Soil hydraulic properties and properties affecting dissolved substances transport of all diagnostic horizons were studied in the laboratory. The wet precipitation and wet atmospheric deposition were measured at grass location. Throughfall and stemflow were monitored in forests. The numerical model HYDRUS-1D was applied to simulate water and Al transport within the soil profiles. Soil water regime and Al transport reflected various retention ability and different sorption properties of studied soils, which were significantly affected by organic matter origin (plant cover). The impact of various plant cover were documented.

Effects of acid sulfate and sea-salts on aluminium solubility and speciation: potentially contradictory effects in organic and mineral soils

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In many, but not all, surface waters in Europe and North America, aluminium concentrations have declined in line with reductions in sulfur deposition. The significance of Al declines to recovery of freshwater ecosystems depends on how much of the toxic inorganic (labile) form is present rather than the total Al concentration in stream water, and it is important that we understand how Al speciation responds to changing environmental conditions. The mobility of Al is strongly linked to that of DOC in upland soils, and many researchers have shown that the organic matter matrix exerts a significant control on overall Al solubility in organic soil horizons, whereas pH-mediated dissolution of secondary Al minerals may be more important in subsoil horizons. Potentially then, declines in sulphur deposition may have contradictory effects on Al solubility – causing an increase in monomeric Al in DOC-rich waters and a decline in monomeric Al in waters draining mineral soils. These dual controls on Al solubility likely explain why freshwater declines in Al have not been universally reported. In some freshwaters, there is evidence of a long-term switch from inorganic monomeric (toxic) forms to organic (non-toxic) forms, coincident with increases in DOC during the last 20 years (UKAWMN, 2007). Long-term increases in DOC in northern Europe have been attributed to declines in marine derived chloride in the last decade, and to longer-term declines in pollutant sulphate deposition (Monteith et al., 2007). Episodic increases in Al concentrations have also been attributed to high sea-salt events (UKAWMN, 2007).

To investigate the effect of sulfur and sea-salt deposition on Al solubility and speciation in organic and mineral soils, we conducted fully replicated laboratory batch experiments on soils collected from O and B horizons at five acid-sensitive upland sites in the UK (Clark et al., 2008). Soils samples were homogenised, standardized for moisture content, and shaken for 20 hours with 100ml of treatment solution containing either acid SO_4 (range 0–24 mg/L) or 'sea-salts' (SO_4 range 0–24 mg/L; Cl range 0–171 mg/L) in concentrations chosen to reflect those recorded in rainfall. Preliminary data for O horizons show that low concentrations (0.5–2 mg/L) of acid sulfate added to O horizon soils cause a small increase in total and organic monomeric Al, but that organic Al concentrations decline with sulfate additions greater than 2–4 mg/L. The changes in Al concentrations track changes in DOC concentrations. This inhibitory effect of SO_4 on Al solubility is counterintuitive, but provides experimental support for a long-term change in Al speciation in some drainage waters and a possible explanation for a lack of a long-term improvement in Al concentrations in some upland freshwaters.

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Climatic control on the coupled export of sediments and metals from erosion-susceptible watersheds

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Soil erosion from steep mountainous watersheds is vulnerable to increasing rainfall intensity as a consequence of climate change. To investigate short-term responses of soil erosion during intense or extreme rainfall events and their off-site environmental impacts, we compared the responses of hydrologic export of sediments and metals from an erosion-susceptible mountainous watershed in northern South Korea to varying degrees of rainfall duration and intensity over two summer monsoon periods. Six storm events were monitored every two hours for concentrations of suspended sediment, dissolved organic matter, and dissolved and particulate metals in a forest stream and a downstream agricultural stream. During two intense rainfall events the distribution of particulate metals among three sediment size ranges was examined using serial filtration and subsequent metal digestion.

Sediment export from both steep forest hillslopes and downhill croplands rapidly increased in response to increasing rainfall and runoff during each storm event, with larger responses observed in the agricultural stream and during more intense events. While suspended sediment measurements in combination with real-time turbidity monitoring in the forest stream also showed a non-linear increase in sediment export from small to extreme events, suspended sediment concentrations were much higher in the agricultural stream. For all measured metals except Sr, concentrations of particulate metals were much higher than the dissolved phase and particulate metal concentrations peaked during the peak flow. During the most extreme event (total precipitation over 400 mm in 3 days), the highest concentrations of particulate metals in both streams were associated with silt-size sediments (2–60 μm), followed by sand (> 60 μm) and clay (0.4–2 μm). Silt-associated metals comprised the bulk of metal concentrations in the agricultural stream, pointing to the dominance of silt-size sediments eroded from the agricultural fields (Fig. 1). These results suggest the significance of understanding short-term changes in stream chemistry during rainfall events combined with knowledge of soil characteristics of potentially erodible soils in controlling soil loss and sediment-associated metal export from erosion-susceptible watersheds in response to intense monsoon rainfalls.

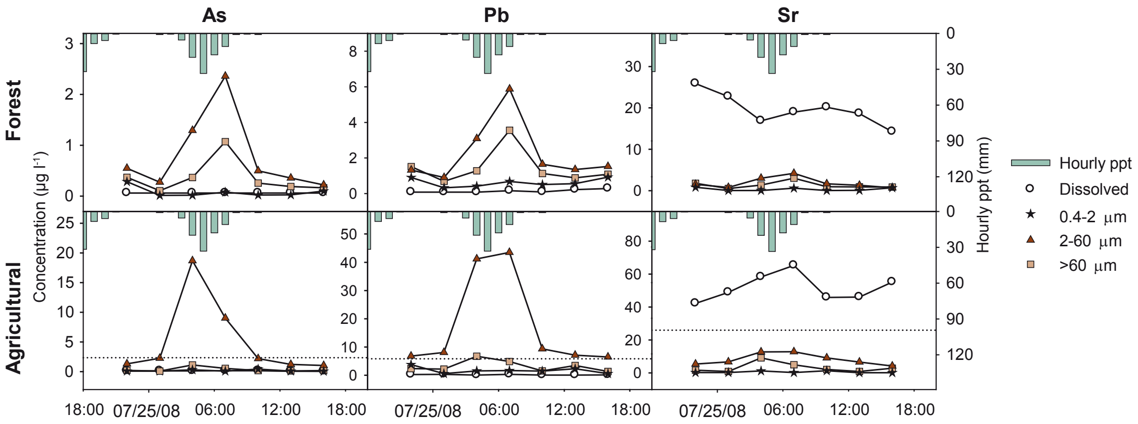

Fig. 1. Short-term variations in concentrations of dissolved and particulate phases of 3 selected metals in a forest & a downstream agricultural stream during an extreme rainfall event. Particulate metals were fractionated into 3 particle size groups (0.4-2 µm, 2-60 µm & >60 µm). Dotted lines in the bottom panel represent the maximum concentration observed in the forest stream.

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Experimental dialysis technique applied to the measurement of trace elements association with organo-mineral colloids in natural water

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Quantification of the association between trace elements and colloids in natural waters is one of the major issues for modeling of trace elements migration and bioavailability in continental waters. It is generally recognized that, in continental waters, most trace elements do not present in the form of ionic species but rather associated with organic and organo-mineral colloids (Ingri et al., 2000). This is especially true for boreal regions, where the presence of wetlands, abundant precipitation and sufficient plant production creates favourable conditions for formation of organic rich soils and provides high concentrations of organic matter in surficial waters.

A new method for quantification of the association between trace elements and colloids in natural waters is developed which is based on conducting the equilibrium dialysis (1-kDa porous membrane) in 0.45 μm filtered water sample at different pH adjusted by addition of acid or base. We tested this technique on seven contrasting, colloid-rich surface waters collected in the boreal zone of NW Russia belonging to the White Sea basin. We selected two rivers draining glacial acid rocks deposits and basic intrusive rocks (r. Palajoki and r. Ruiga), the swamp creek over ultramafic rocks, groundwater and swamp water in the Northern Karelia, river Peschanaja and soil peat water at the White Sea coast.

Equilibrium dialysis procedure was used to assess the distribution coefficients of ~50 major and trace elements between colloidal (1 kDa – 0.22 μm) and dissolved (< 1 kDa) forms. For this, Spectra Pore 7® dialysis membranes filled by deionized water were placed in large volume of natural filtered water and the pH of solution was varied between 3 and 8. After achieving the equilibrium (min 24 hrs), concentrations of trace elements were measured both inside the dialysis bag and in the external solution using ICP-MS. These measurements allowed quantification of both TE distribution coefficients and proportion of colloidal forms as a function of solution pH. Two groups of elements can be distinguished according to their behaviour during dialysis: i) those exhibiting significant increase of proportion of colloidal forms with pH increase (Mn, Cr, Co, Ni, Cu, Zn, Sr, Y, Cd, Ba, REEs, U, Pb, Ga, Hf) and strongly associated with colloids (Al, Fe, Th, Zr), and ii) elements weakly associated with colloids whose distribution coefficients are not significantly affected by solution pH (Li, B, Na, K, Ca, Mg, Si, Ti, V, Rb, Nb, Mo, Sn, Sb, Cs, W, Tl). Element speciation was assessed using the Visual MINTEQ computer code with an implemented database for binding of metals to discrete carboxylic sites (Allison and Perdue, 1994). The model reproduces quantitatively the pH-dependence of colloidal forms for some elements (Mn, Co, Ni, Cd, Sr, Ca, Pb) whereas for other elements (i.e., Th, U, Cu, Cr, Mo, As, Zr, V, Fe, REEs) adjustment of stability constants is necessary. The results from this work suggest that Visual MINTEQ, incorporating NICA Donnan humic ion binding model, can predict the distribution of the dominant species of trace metals in freshwaters with reasonable accuracy. However, the lack of laboratory data for trivalent and tetravalent elements binding to metal oxides and organic matter preclude quantitative comparison of apparent complexation constant of natural water colloids obtained in this work with their end member constituents (fulvic acids, Fe and Al hydroxide). The main significance of this work is that it allows direct empirical prediction of most TE speciation in natural organic and Fe-rich boreal waters under condition of aquifers acidification induced by global warming.

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Trace element transport and colloidal speciation in European subarctic rivers in different seasons

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In order to improve our understanding of colloidal transport and speciation of organic carbon and related trace and major elements in the boreal region, the chemical status of approx. 40 major and trace elements (TE) and organic carbon (OC) in large and medium size boreal rivers draining granitic moraine, carbonate and gypsum sedimentary deposits of Arkhangelsk region (NW Russia) have been investigated using filtration and dialysis. To this end, samples were filtered in the field through a progressively decreasing pore size (5 μm, 2.5 μm, 0.22 μm, 100 kDa, 10 kDa and 1 kDa) using the frontal filtration and ultrafiltration technique and in-situ dialysis through 10 kDa and 1 kDa membranes with subsequent analysis by Shimadzu TOC 6000 Analyzer. The size separation procedure revealed strong relationships between concentration in ultrafiltrates and dialysates of TE and that of colloidal Fe and, in a lesser degree, organic carbon. According to their partition during filtration and association with colloids, two groups of elements can be distinguished: i) those weakly dependent on ultrafiltration and that are likely to be present as truly dissolved inorganic species (Li, Na, K, Si, Mn, Mo, Rb, Cs, As, Sb) or, partially (20–30%) associated to small size Fe- and Al-colloids (Ca, Mg, Sr, Ba) and to small (< 1–10 kD) organic complexes (Co, Ni, Cu, Zn), and, ii) elements strongly associated with colloidal iron and aluminum in all ultrafiltrates largely present in 1–100 kD fraction (Ga, Y, REEs, Pb, V, Cr, Ti, Ge, Zr, Th, U). We did not observe any statistically significant difference in the colloidal distribution pattern of TE and OC in rivers draining various types of rock lithology (granite silicate moraine, carbonate and gypsum deposits), although the absolute concentrations of colloidal and dissolved metals and organic carbon are 2–3 times lower in rivers draining sedimentary watersheds compared to those located on silicate terrain. The seasonal observations of OC, TE and colloidal substances in winter, spring and summer period allowed concluding on the permanent presence of colloids during all seasons. The total dissolved concentration of colloidal TE correlates with that of OC, being the highest during the spring flood and the lowest in winter time. At the same time, relative proportion of colloidal (1 kDa–0.22 μm) organic carbon increases from 20–40% during summer and winter baseflow to 70–80% during spring flood independent on the lithology of the watershed. It is possible that the contribution of large-size allochtonous soils organics, most pronounced during the spring flood, decreases at the expense of autochthonous organic matter of planktonic origin during summer base flow. Iron remains in essentially colloidal form (1 kDa–0.22 μm) over the full period of observation. On the silicate (moraine) watersheds, > 95% of Fe is in colloidal form whereas on carbonate/gypsum watersheds, proportion of colloidal iron decreases to 70-90%. Based on seasonal observation of dissolved and suspended matter in Severnaya Dvina River, we evaluate the relative fluxes of suspended, colloidal and truly dissolved (potentially bioavailable) trace elements and conclude that the typical feature of most insoluble trace element fluxes is high proportion of total dissolved form (< 0.22 μm) compared to particulate forms due mostly to the contribution of colloids.

Heavy metals in topsoils of woody habitats around a former lead smelter in the North of France

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During more than a century and up to its closure in 2003, the former Metaleurop Nord lead smelter rejected in the atmosphere considerable quantities of pollutants. This smelter situated in the North of France was the most important lead producer in Europe. In the course of time, its atmospheric emissions engendered a strong contamination of soils in the surroundings. Previous works showed, on the agricultural soils of the sector affected by these fallouts, that the contamination although very high was limited to the ploughed horizon. The concentrations of Trace Elements (TE) were also strongly related to the distance to the smelter (Sterckeman et al., 2000). The urban soils used as kitchen gardens or lawns in the surroundings of the former smelter showed a very great spatial variability of their physicochemical parameters and especially a very strong contamination in particular for Cd, Pb and Zn. The studies showed that this topsoil contamination exceeded that of the agricultural soils located in the vicinity, and could sometimes exceed 1.50 m of depth (Douay et al., 2008). Contrary on the agricultural context, the spatial distribution of TE in the urban soils does not seem directly related to the distance to the source of contamination. Concurrently to these two types of ecosystems, the soils of the woody habitats were studied only recently in the neighbourhood of Metaleurop Nord, although they are largely present in the landscape (Scheifler et al., 2008). Indeed, taking into account the high level of contamination of the agricultural soils, measurements of management were undertaken since the beginning of the 90th in order to exclude the most contaminated soils of agricultural production. Tree plantations were carried out and constitute to date a green belt. Concurrently to these relatively recent woody spaces, thickets, woods, poplar plantations and a state forest are also present. Previous works on various tree species and herbaceous planted on an old agricultural plot located near the smelter (Bidar et al., 2007) showed a considerable transfer of TE from the soil towards the roots and foliar parts of the plants, being able to generate visible toxic effects (chlorosis, oxidative stress, slowed down growth). With these physiological disorders are also added dysfunctions in the recycling of the organic matters in the contaminated forest soil which can be explain by both the complex biogeochemistry of these mediums and the absence of certain organisms of the soil fauna whose biodiversity is particularly disturbed in the most contaminated habitats. The goal of this work is to characterize the pedological and physicochemical parameters of woody habitat soils on the area affected by the atmospheric emissions of the former lead smelter. It more specifically aims in three points: (i) to evaluate the degree of contamination in Cd, Pb and Zn into the principal soil horizons of these woody habitats; (ii) to connect the behaviour of the pollutants to the physicochemical characteristics of these soils in order to contribute to a better comprehension of the biogeochemistry of the TE in these complex mediums and (iii) to understanding the ecological disturbances observed on this area. In addition this work should contribute to a better evaluation of the environmental and health risks in an area very highly populated and where the human pressures are very strong.

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Fate of metals in frequently flooded soils

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Frequently flooded soils often function as sinks of pollutants (e.g. Devai et al., 2005, Overesch et al., 2007, Rinklebe et al., 2007). Thus, concentrations of metals in bulk soil, soil solution, and groundwater are elevated at many riverine sites world-wide. Floodplain soils are underlying large fluctuations in water table resulting in frequent drastic changes in Redox- (E_H) and pH- conditions, soil matrix potential (ψ), soil temperature, dissolved organic carbon (DOC), concentrations of NO_3^-, PO_4^{3-}, and SO_4^{2-} as well as kinetics of metals (e.g. Du Laing et al., 2008). However, a sufficient understanding of biogeochemical processes in such ecosystems is still missing. Thus, an appropriate technique which enables mechanistically studies of the main processes is a need for a better understanding and an adequate prognosis of the biogeochemical processes occurring in these ecosystems. Our approach - combining both - field and laboratory studies - aimed to elucidate the fate of metals and their relationships to E_H, Fe^{2+}, DOC, and several substances in frequently flooded soils.

In the laboratory we simulated flooding in biogeochemical microcosm systems (Yu et al., 2007) which enable to control E_H over a wide range. Using the automatic biogeochemical microcosm system on flooded soils and sediments is capable of assessing the mobility of hazardous materials released into the environment and mechanistically studies of pollution control processes such as kinetics and dynamics of metals and other hazardous substances in soils and sediments. We brought the E_H stepwise from a high (approx. +500 mV) down to a low level (-100 mV) and increased E_H progressively again while measuring pH, metals, DOC, and anions. Generally, E_H, DOC, soil water content, Fe^{2+}, and pH are the most important factors controlling the mobilities and dynamics of many metals; they explain 90 to 98% of the variability of metals in soil solid phase.

In the field we used soil-hydrological monitoring stations and measured metals in soil solution in three depth and three replications every 2 weeks over several years at various sites at several German rivers as well as in groundwater and in precipitation. Furthermore we observed water level, E_H, ψ, soil water content, and temperature in three depth and three replications every two hours with data loggers. During flooding periods we detected peaks of DOC and metals, while E_H and ψ were in minimum and moisture in maximum. Multiple regression analyses allow to determine controlling factors and to quantify relationships between them.

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Influence of Cu, Ni and Cd on the exudation of organic acids by *Halimione portulacoides* in freshwater from Cávado River

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Salt marshes are complex coastal ecosystems. When located within urban estuaries, they receive important inputs of pollutants, including trace metals from industrial and transportation activities (Mucha et al, 2005,. Reboreda et al, 2007) Several studies have revealed that salt marsh plants can accumulate trace metals in their roots and other tissues, being useful for phytoremediation/phytostabilization in estuarine environments. Differences in metal concentration and their chemical speciation in the vicinity of the roots of salt marsh plants have also been demonstrated. The processes by which the plants modify metal speciation in the rhizosphere include exudation of organic substances capable of complexing metals (Mucha et al, 2005). There are some studies that demonstrate that salt marshes plants are capable of exuding complexing ligands as, for example, low molecular weight organic acids. However, knowledge about the nature and concentration of exudates from salt marsh plants and their role on trace metals bioavailability in the rhizosphere is still scarce (Mucha et al, 2005, Mucha et al, 2008).

The main goal of this study is to investigate, in controlled environmental conditions, the influence of Cu, Ni and Cd on organic acids exudation by *Halimione portulacoides* roots (a plant commonly found in Portuguese salt marshes). In this study, it will be identified which organic acids are liberated and in which amount in order to plan future experiments. For this purpose, roots of groups of *H. portulacoides* (grown in a greenhouse), in freshwater from Cávado River, were exposed during 2 hours to: 100 $\mu g\ L^{-1}$ and 10 $mg\ L^{-1}$ added Cu concentrations, 50 $\mu g\ L^{-1}$ and 5 $mg\ L^{-1}$ added Ni concentrations, 10 $\mu g\ L^{-1}$ and 1 $mg\ L^{-1}$ added Cd concentrations and a mixture of Cu, Cd and Ni. Before and after exposure, Cu, Ni and Cd were determined in freshwater from Cávado River and in plant tissues (by atomic absorption spectrometry after high pressure microwave digestion). The dissolved organic acids were determined by high pressure liquid chromatography after their pre-concentration by solid phase extraction.

Experiments are in progress and the results will be presented and discussed in this communication.

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Permafrost thawing: effects on mire structure and possible implications for trace elements such as mercury

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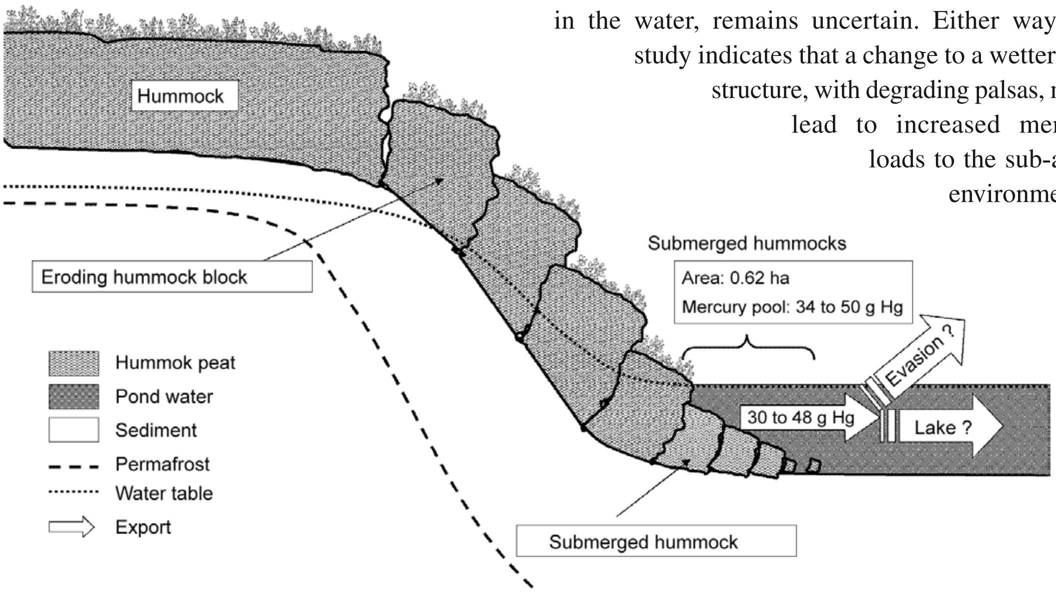
Mires store about 20–30% of the terrestrial pool of carbon. The fate of this carbon in a changing climate has frequently been debated because of its possible influence on the global carbon cycle. However, in addition to carbon peatlands also store large quantities of organically bound elements, e.g., bromine, lead, sulphur, arsenic and mercury (Biester et al. 2004; Bindler 2006). Of these elements mercury is of particular interest because of its toxicity and ability to bioaccumulate in the environment.

Sub-arctic mires are sensitive to climate change, because even small changes in temperature will have large effects on permafrost distribution and water balance. In the Stordalen mire (68º20’N 18º58’E) thawing of permafrost is already changing the structure of the mire. Wetter areas are increasing in extent, while raised hummocks are decreasing (Malmer et al. 2005). In our study we investigate what might happen to mercury currently stored in the mire when peat from hummocks is re-deposited into wetter areas (Klaminder et al. in press). We sampled peat cores representing stable hummocks, eroding peat blocks, hummock blocks re-deposited on hollow peat, hummock blocks submerged by water and hollow peat. Our results indicate that mire structure plays an important role in determining whether mercury is released from the peat or not. If an eroding hummock block is re-deposited on top of hollow peat (i.e. remains relatively dry) no large loss of mercury is observed. However, if hummock peat is re-deposited into water a substantial amount of the mercury previously bound in the peat will be lost (Fig. 1). Whether the released mercury is transported to downstream lakes, where it might enter the food-web, or if it is re-emitted as gaseous mercury to the atmosphere, due to photo-reduction in the water, remains uncertain. Either way, our study indicates that a change to a wetter mire structure, with degrading palsas, might lead to increased mercury loads to the sub-arctic environment.



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Trace element biogeochemistry of lichens in the Northwest European Russia

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Lichens absorb substances, including trace elements, through dry and wet deposition, and have been widely used as biomonitors. We studied multi-element composition of terricolous (mostly of genera *Cladonia* and *Cetraria*) and fruticose epiphytic (mostly of genera *Alectoria*, *Usnea* and *Bryoria*) lichens collected in 2004–2008 in Kola Peninsula, Karelia and Arkhangelsk Region of NW Russia. About 90 samples were analyzed. The unwashed lichen samples were air dried and homogenised to a fine powder in an agate crusher. Samples were treated in a four-step chemical digestion procedure (full dissolution via acid attack) for inductively coupled plasma spectrometry. Major element concentrations were determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES), and trace element concentrations by inductively coupled plasma-mass spectrometry (ICP-MS). Parts of dry samples were analyzed by instrumental neutron activation analysis (INAA). An enrichment factor (EF) was calculated for each element (X) relative to the composition of earth's crust: EF = ((X/Al) in lichen) / ((X/Al) in the earth's crust). Al was used as a crustal indicator. In most samples contents of Ti, V, Cr, Mn, Fe, Co, rare earth elements (REEs), Th, U are at the background level and their EFs are less than 10. These low EF values indicated that, relative to average values for crustal rocks, there was no enrichment of these elements in the lichen concerned. For some elements (Se, Cd, Zn, Sb, Pb, As, Ni, Cu) consistently higher EF values were obtained. These higher values were interpreted in terms of sources of both anthropogenic and natural sources other than crustal rock and (or) soil. These elements could be derived by long-range atmospheric transport. Highest concentrations of Cu, Ni, Pb in lichens and EF by these elements were registered in Lovozersky Tundry (Kola Peninsula) and in Paanayarvi area (NW Karelia) due to pollution from Monchegorsk and Nickel Cu-Ni smelters. In the vicinity of Kostomukshsky Ore-dressing Mill lichens are enriched by Fe. In lichens collected at the White Sea coast, high Na content and EF values were revealed. In general, elemental composition of lichens in the Northwest European Russia reflects complex influence of atmospheric deposition of aerosols from both natural and anthropogenic sources.

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Iron and aluminium phases in softwater lakes: identity and significance for copper binding

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Aluminium and iron have been found to compete with copper for binding sites to dissolved organic matter (DOM) in soil systems and when using geochemical modelling. However, the knowledge of the phases of Al, Fe and DOM in natural waters is uncertain. The aim of this ongoing work is to advance the knowledge on the geochemistry of iron and aluminium so that the speciation of copper in lake water can be more accurately assessed. Water samples from three softwater lakes in Tyresta (Stockholm) (Fig. 1), Sweden, are filtered using 0.45 µm and using 1 kDa cross-flow ultrafiltration. The particles on the filters and the colloidal phases of iron are investigated by extended X-ray absorption fine structure (EXAFS) spectroscopy. Aluminium phases are investigated by Fourier transform infrared (FTIR) spectroscopy. Field-flow fractionation (FFF) is used to study the colloidal composition of iron, aluminium and DOM. The competition of Al and Fe with Cu on binding to DOM is explored with Cu titrations using an ion selective electrode. The results will be used to improve geochemical modelling.

Preliminary results from EXAFS spectroscopy for an acid lake rich in DOM (Lake Trehörningen; pH 4.8, DOC = 22 mg/l) indicate that Fe is not present as a mineral in the colloids, instead it is bound as monomeric Fe(III) complexes to organic matter, which means that it probably competes with Cu for binding sites on DOM. Additional results will be presented at the conference.

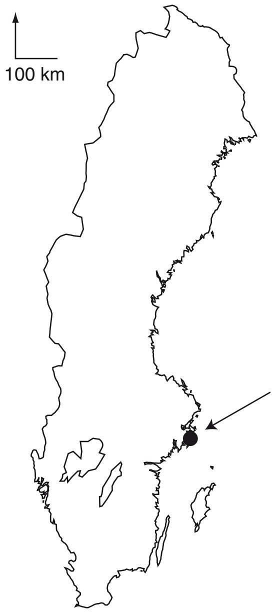

Fig. 1. Map of Sweden with Tyresta.

Seasonal variation of water extractable forms of aluminium in different forest soil locations affected by acidification

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Aluminium is a potentially toxic element; Al occurs in more toxic forms due to soil anthropogenic acidification. In the most toxic forms, Al is present as Al^{3+}, which is in fact Al^{3+} and transformed hydroxyl Al polymers.

The researched area is located in the naturally acid Jizera Mountains (Czech Republic), which was further affected by acid deposition and improper forest management. Soil samples were collected in different areas located nearby monthly (spruce a beech forest) and bimonthly (clear-cut area). In each sampling period, well developed horizons (organic Oe and Oa horizon, organomineral A horizon and spodic or cambic B horizon) were sampled individually for three dug soil profiles.

Total amount of Al, Al species and anions (SO_4^{2-}, NO_3^-, Cl^-, F^-) were analysed in aqueous extract. Al species were measured by using HPLC/IC method. Additional soil properties (moisture, DOC, pH, Cox) were also determined.

The effect of seasonal variability (growing and cold season) on contents of most toxic Al^{3+} and less toxic $Al(X)^{1+}$ species was observed. The amounts of total Al and Al^{3+} were higher in organic Oa horizon and spodic or cambic B horizon of spruce forest compared to corresponding horizons in beech forest and clear-cut area. Seasonal variability was also observed in the amounts of main anions (SO_4^{2-}, NO_3^-).

Application of DGT –method for determination of phosphate and trace element bioavailability in forest soil

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There are significant gaps in the knowledge on environmental chemistry of many nutrients and trace elements in forest soils. In particular, their bioavailability in the soil- plant system is not fully understood and cannot be accurately measured by current methodology in standard use. The aim of this project is to study the suitability of DGT –techniques (Diffusive Gradients in Thin films) for estimating the bioavailable and/or mobile pools of elements in forest soil by comparing results obtained by DGT (e.g. Hooda et al. 1999) to those obtained by more traditional soil extraction techniques and to the element uptake of test plants. The DGT -technique uses a chelating resin separated from the soil by diffusive gel, so that metal uptake by the DGT –device is controlled by diffusion. The chelating resin absorbs selectively the element under interest, e.g. chelex bounds many trace metals, iron-oxides phosphates and AgI suphates.

Peat cores were sampled from a forested site at Sotkamo in northern Finland and subsamples were analyzed by wet digestion for the total amount of metals and phosphorus. A phosphate diffusion method using iron-oxide paper (Saarela 1992) was performed for a series of peat sub-samples, as well as a diffusion method using commercial DGT –device for parallel set of sub-samples. Results obtained by diffusion techniques were compared with those obtained by applying traditional water extraction and NH_4Ac-EDTA (pH 4.65) extraction method.

The phosphorus concentrations obtained with the DGT –method correlated with the water extracted (1:200) concentrations. Also a high correlation was found between the DGT – and iron oxide paper diffusion methods. The concentrations of trace metals accumulated by DGT were below detection limits except for zinc. Further work will be needed for the validation of the method in the laboratory. The phosphate uptake by plants will be tested by an experimental set-up, in which seedlings will be cultivated in a series of a peat sub-samples.

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Trace elements in sediments from constructed wetlands treating municipal wastewater

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During last two decades the constructed wetlands with horizontal sub-surface flow have increasingly been used in the Czech Republic to treat municipal wastewater. The first constructed wetland was put in operation in 1989 and at present, there are about 300 systems in operation. Trace elements are usually not the target of the treatment of municipal wastewater but their concentrations in the sediments within the filtration bed may be the concern when the filtration bed would need to be excavated and disposed. Seven constructed wetlands with horizontal sub-surface flow with length of operation varying between 2 and 16 years were sampled in 2008 in order to evaluate the amount of sediment in the filtration beds and concentrations of 26 trace elements in the sediment. In each constructed wetland samples were taken in inflow, middle and outflow zones (3 samples in each zone). Samples were divided into surface (0–20 cm) and bottom sections (20–60 cm), cleaned from roots and analyzed using the ICP-MS after mineralization. Mercury was analyzed using the direct cold vapor method without mineralization in order to prevent evaporation.

The amount of sediments in the wetland beds increased with the length of operation with the lowest values of < 1.0% (on dry mass basis) found in systems which have been in operation for two years and the highest value of 12.6% found in the system which have been used for 16 years. In Table 1, the average concentrations for selected trace elements in sediments of monitored constructed wetlands are given. The data indicate that the average concentrations are well below the limits for both “light” and “other” soils with the exception of zinc. However, the concentrations listed in Table 1 are given for sediments only. Taking into consideration that sediments comprise between 1–13% of the dry mass of the filtration material even the concentrations would meet the limits for land application in case of filtration bed material disposal. The results reveal that the filtration material of the constructed wetlands treating municipal sewage may not be treated as hazardeous material which needs to be treat with special attention.

Table 1. Concentrations of selected trace elements in sediments (mg/kg dry mass) from CWs and comparison with legal limits. Selected are those elements which concentrations are limited in the soil.

	Hg	Cd	Mo	Be	As	Co	Pb	Cu	Ni	V	Cr	Zn
Mean (n=21)	0.13	0.32	0.96	1.69	4.59	10.2	25.6	27.2	36.9	38.8	63.3	277
Median	0.09	0.21	0.71	1.66	3.65	8.7	17.0	18.2	37.9	34.2	38.0	87
SD	0.08	0.20	0.53	0.61	1.91	3.9	15.5	18.5	14.9	16.0	40.2	273
Maximum	0.36	1.14	2.42	3.15	10.2	23.5	94.8	78.6	69.1	79.7	172	1681
limit for light*	0.60	0.40	5.0	7.0	30.0	25.0	100	60	60	150	100	130
and other soils	0.80	1.00	5.0	7.0	30.0	50.0	140	100	80	220	200	200
% of limit*	21.5	80.5	19.2	24.1	15.3	40.8	25.6	45.3	61.5	25.9	63.3	213
% of limit	16.1	32.2	19.2	24.1	15.3	20.4	18.3	27.2	46.1	17.6	31.7	138

Effect of characteristics of humic acids derived from lake sediment and mountain soil on sorption of toluene

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BTEX compounds including benzene, toluene, ethylbenzene, and xylenes are notorious due to the contamination of soil and groundwater with these compounds. Shih and Wu (2002) concluded that partitioning is believed to be the major mechanism of the sorption of toluene to humin. In this study, humic acids (HAs) were extracted from Chengching lake sediment and Meifeng mountain soil and then purified according to the method recommended by International Humic Substances Society (IHSS). The purified HAs were subjected to elemental and ^{14}C dating analyses and Fourier transform infrared (FTIR) and ^{13}C nuclear magnetic resonance (^{13}C NMR) spectroscopic analyses. In addition, each humic acid (HA) suspension was adjusted pH 4.00, 6.00, or 8.00 and then diluted to volume with a concentration of 200 mg L^{-1}. Subsequently, each HA suspension or solution was subjected to particle size analysis using high performance particle sizer (HPPS). Except for some differences revealed by various analyses, the mean residence time of HA extracted from lake sediment was 2980 y while that from mountain soil was modern product. Moreover, the particle size of HA extracted from lake sediment was around 1000 nm while that from mountain soil was 200 nm at suspension pH 4.00. Kinetic study showed that the best fitting for toluene adsorption by the two HAs was first order kinetics at initial concentration of 2 mg L^{-1}. Moreover, the sequence for the rate constant was at pH 4.00 > pH 6.00 > pH 8.00. This indicates that flocculation of HA molecules increased the rate constant of adsorption. At suspension pH 4.00, Freundlich adsorption isotherm model describes the best fitting for the adsorption of toluene by the two HAs. Moreover, the adsorption capacity of lake sediment HA was significantly larger than that of mountain soil HA (Fig. 1). This is probably because particle size of lake sediment HA was larger than that of mountain soil HA.

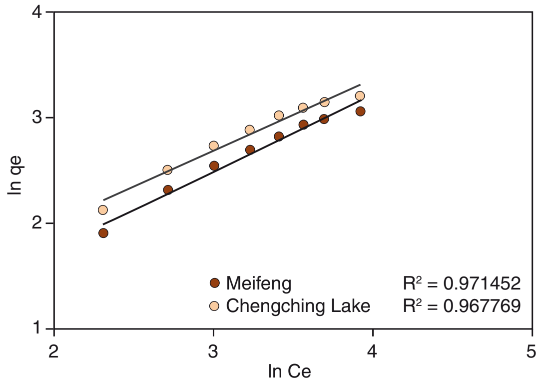

Fig. 1. Adsorption isotherm of toluene by HAs extracted from Meifeng mountain soil and Chengching lake sediment (Freundlich plot fitting).

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Trace metal biogeochemistry in southern Ontario

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Anthropogenic activities have resulted in local, regional and global trace metal contamination and southern Ontario is no exception. In order to evaluate the potential risk of chronic low level metal contamination and the potential for interactions between stressors such as acidification and climate change, intensive studies on trace metal cycling have been conducted at Plastic Lake and these data have been augmented with findings from regional surveys. Regionally, concentrations and pools of several metals including Pb, Cd, Zn, Cu and Mn in the forest floor are greatly elevated in the cooler, northern part of the region with acidic soils and more remote from emission sources due to a combination of slower litter turnover and greater litterfall inputs. In mineral soil, partitioning (K_d) of many metals is strongly related to soil pH and is independent of forest cover, although uptake of some metals vary considerably among tree species. Canopy condition of sugar maple (*Acer saccharum*) is negatively correlated to concentrations of several metals in the forest floor and foliage. Isotopic studies demonstrate that the majority of Pb currently cycled within these forests is anthropogenic in origin, with two distinct anthropogenic signatures recorded in lake sediment.

At Plastic Lake, metals that were enriched in bulk deposition (As, Cd, Pb, Zn) were generally enriched in the forest floor and upper lake sediment. While the metal pool in vegetation is small compared with soil, internal cycling of metals via litterfall is comparable to other fluxes within this catchment. Mass balance calculations show that for most metals, the mineral soil and lake sediments were net sinks while the wetland exported metals during this drought year. Overall, lithogenic metals (Al, Ba, Co, Fe, Mn, Rb, Zn) that are released by weathering processes generally exhibited net release from the catchment, while metals that have substantial pollution sources (As, Cd, Cr, Cr, Ni, Pb) exhibited net retention. Despite the acidified nature of the catchment, it appears to function as an environmental filter by retaining many pollutant metals. However, metal, DOC and SO_4 concentrations demonstrate seasonal patterns in the streams, and temporal coherence is observed among metal, DOC and SO_4 concentrations in the LFH soil solution and the wetland-draining stream (PC1). In the wetland-draining stream, the highest DOC, Cr, Cu, Fe, Pb and V concentrations occur in the summer, whereas concentrations of SO_4 and most other metals peak in the fall during this drought year. Despite the rural location, provincial water quality objectives were exceeded for many metals when the peak fall values occurred.

Uranium associations and migration behaviour at the Needle's Eye natural analogue site in SW Scotland

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As a result of nuclear activities around the world over the past ~60 years, nuclear waste containing U has been discharged to soils and groundwaters, e.g. authorized discharges from nuclear fuel reprocessing at Sellafield,,NW England (Gray et al. 1995). More recently, depleted uranium (DU), a byproduct from the production of nuclear fuel has been used for armour-piercing munitions. Munitions testing, leading to the localized contamination of soils, has been carried out at MoD sites in SW Scotland and NW England (Oliver et al. 2007). The environmental fate of U is of particular concern because of its longevity, chemical toxicity and, in some cases, radiological risk to human health. An understanding of U migration behavior in both soil and aquatic systems is therefore of fundamental importance.

The Needle's Eye natural analogue site, SW Scotland, provides a unique opportunity to study U associations and migration behavior as there is a mineralization in a rocky outcrop that has elevated amounts of natural U, a small amount of which is leached by oxic groundwater which then passes through highly reducing organic-rich soils. Previous results have shown that 80–90% of the U has been retained in the organic-rich soil (Jamet et al. 1993). The processes controlling U migration in the groundwater and the nature of U interactions with both the soils and the groundwater are the primary focus in this research because they can be applied to predict the U behavior in the far-field environments of nuclear waste repositories and in areas where DU-munitions have been used or tested.

It is generally considered that humic substances play an important role in controlling the migration behaviour of U at Needle's Eye, described as a process with kinetically controlled association/dissociation of U onto humic colloids and subsequent sorption of the U-humic colloids onto solid phase soils/sediments. However, the relationship between the dissolved and/or colloidal U species in the aqueous phase and solid phase species is still unclear. This may involve different mechanisms such as complexation, filtration, remobilization, and matrix diffusion of colloids. The nature of the colloids at this site is also uncertain, including the size distribution of colloid-bound U and the composition of the colloidal material.

The initial stage of this research has involved ultrafiltration in conjunction with ICP-MS to characterize the colloids in terms of their composition and metal binding behaviour (Graham et al. 2008). Porewater profiles revealed that transportation of U is probably being controlled by smaller colloids since the small colloids in the soil porewater become more important with increasing distance from the U mineralization and with greater soil depth. Model polyacrylic acid-coated alumina colloids are being used to study metal sorption/desorption behaviour, the preliminary results of which will be presented. It is hoped that the methods can be applied to further investigate the 'real' humic colloidal material from solid and aqueous phases of Needle's Eye soil.

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A new strategy to conserve *Acacia tortilis* subsp. *raddiana* in South Sinai, Egypt

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Acacia tortilis subsp. *raddiana* is one of the most useful trees in the Egyptian desert especially for the local Bedouins in Southern Sinai. This tree is subjected to various threats such as cutting, grazing, seed infection by insects and fungi as well as unmanaged developmental projects. Recently high mortality and low juvenile recruitment has been reported leading to a decline in population size and number of this species. Fifteen survey trips were conducted to different *Acacia* sites in South Sinai Egypt during the period from May 2007 up to November 2008.

The most common causes of *A. tortilis* diseases are fungi and insects which may infect the trees through wounds. The aim of this work was to develop a new strategy to conserve *Acacia tortilis* in South Sinai. This strategy divided into two main components, one to treat infected trees through isolation and identification of cultivable or uncultivable fungal pathogens. The other was directed to propagate multiple shoots from shoot tip explants derived from in *vitro* seedlings and/or mature plants on modified MS medium.

A complete strategy to treat infected trees was applied by application of “Bordeaux” solution and paste as well as the application of “Bio-Katherine” as a new developed biocide. Furthermore *A. tortilis* plantlets produced by micropropagation were supplemented with spores of mycorrhizal fungi and rhizobacteria isolated from *A. tortilis*, which also received gel as soil conditioner.

Results showed that plantlets transplanted on soil enriched with gel and microbiota produced the highest values of leaflets, shoot height and vitality in comparison with control plants. Treatment of mature plants by “Bio-Katherine” and “Bordeaux” proved to be a promising solution to control *A. tortilis* threats.

Microbial C, N and P in a Mediterranean oak forest soil: influence of abiotic conditions and canopy composition

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Soil microbial populations influence the pool of nutrients available for plants, immobililizing inorganic resources in their biomass and releasing them when population declines. The asynchrony between these nutrient retention-mobilization cycles and plant resources demand could derive in a plant-microbial nutrient competition and further nutrient loss, rendering negative effects on plant productivity (Jonasson et al. 1996). Microbial biomass varies seasonally and is controlled by regional and local factors such as climate, soil properties and plant community composition (Jürgen et al. 2006). Under a global change scenario, understanding the specific role that these factors have on microbial population becomes of major importance in nutrient limited systems.

We studied the dynamics of microbial populations and nutrient availability in soils of a Mediterranean mixed oak forest in southern Spain. Two forest stands of different structure, growing in contrasted climatic conditions were selected. Soil samples were seasonally collected in four microsite types i.e. beneath the canopy of one evergreen (*Quercus suber*) and one winter-deciduous (*Q. canariensis*) oak species, under dense canopy of mixed shrurb species and in forest gaps, which have different soil characteristics influenced by vegetation cover type. We used the fumigation-extraction method (see Jonasson et al. 1996) to determine the microbial C and to estimate the N and P soil microbial and inorganic pools.

Preliminary results showed spatial patterns of microbial variability consistent across sampling dates, with soil under oak trees harbouring the highest microbial biomass. Differences were observed between the two forest stands which could be related to their differing abiotic conditions. Maximum biomass C, N and P values were obtained for the wet seasons- spring and autumn- when a noticeable high proportion of the nutrients pool was retained as microbial biomass.

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Root dynamics and nutrient uptake during future climate change

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The last decade's discussion about the increasing atmospheric CO_2 concentration and its effect on climate change, have lead to the *in situ* multifactor manipulation experiment CLIMAITE. CLIMAITE is a Danish multidisciplinary national research initiative, studying the biological effects of the changing climate. Within the CLIMAITE project a common large scale experiment was established in 2005 with realistic manipulations according to a Danish climate scenario anno 2075; Elevated atmospheric CO_2 concentration (510 ppm), passive night time warming by approximately 2 ºC air temperature and an extended summer drought period from approximately May to June, or until soil water content is 4–5%. The project is located in a Danish heathland/grassland ecosystem dominated by two plant species; the grass *Deschampsia flexousa* and the evergreen dwarf-shrub *Calluna vulgaris*.

The objective of the study is to investigate root dynamics in a changing climate and we show results from two years of root studies. We have investigated below-ground root production, input of root litter to the soil and root litter decay rate in response to simultaneous changes of temperature, precipitation and CO_2.

To investigate root biomass, dynamics and turn-over rate we use minirhizotrons, root in-growth bags, sequential soil sampling and root litterbags. Furthermore we have bioassays of N-uptake in fine roots of the two dominant species, and plan to do P-bioassays as well.

Minirhizotrons are used to examine the distribution and dynamic of fine roots <2mm and to estimate fine root length and root turnover/survival. The minirhizotrons is a non-destructive method and are useful in monitoring the same root over a long time period through repeated sampling.

Sequential soil coring is used to estimate root biomass, and nutrient contents. Soil cores from spring, summer and autumn to a depth of about 15 cm was sampled and divided by horizons. The below ground biomass harvested from spring, responded to increasing temperature with a decrease in biomass, while the root biomass was increased under elevated CO_2 concentrations. Further results will show if this pattern continues throughout the growing season.

In-growth cores are used to obtain relative growth and to observe the effects of experimental manipulations on root growth. The in-growth cores were placed in the field and were taken up after 6 months and after 1 year, and the one-year old roots was used for bioassay of N uptake.

Root litter decay rate was assessed by the use litterbags, taken up after 6 months, one year and 1.5 years.

With this presentation, the CLIMAITE project is described as well as the methods we use to study belowground plant dynamics in a heath land with climate manipulations. We will further show results of below-ground responses from the first two years of climate manipulations.

Mycorrhizal diversity on two shrub species from the upper forest border

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High montane and sub-alpine areas at the upper forest border are influenced by summer and winter ski tourism, pastures can either be abandoned or their capacities are insufficient for changed cattle demands, several areas have been or are about to be changed into ski resorts. Such extreme ecosystems are vulnerable to erosion processes, soil water retention properties change and above- and below-ground diversity is diminished and unified. Several shrub species can influence soil aggregate stability and prevent soil erosion, and could be applied in biotechnical engineering for stabilization, remediation and conservation of mosaic high pasture and forest ecosystems.

We have concentrated our studies on two shrub species, occurring in the Julian and Kamnik & Savinja Alps (*Dryas octopetala* L.) and a relict species from the Dinaric Alps (*Sibiraea altaiensis* var. *croatica* (Degen) Beck.). Roots and mycorrhiza from both species can influence soil aggregate stability, and Sibirea has been used in the past centuries for stabilization of river banks in the Volga district (Ballian et al. 2006). Our approach is first to analyze mycorrhizal diversity on roots and the rhizosphere from both species, and then to apply them in rhizotron studies in experimental conditions.

Morphological and anatomical characteristics of mycorrhiza have been studied, ectomycorrhizal roots were differentiated into anatomo- or morpho-types, and identifications were done through single tip (classical ITS-RFLP and sequencing) and community structure (DGGE and sequencing) analysis. Roots which did not show ectomycorrhizal characteristics have been submitted to the same molecular identification procedures, while all staining for anatomical identification of other forms of mycorrhiza are still under way. Among other forms of mycorrhiza occurring on roots and in the rhizosphere of Sibirea we found ectomycorrhizal and ericoid mycorrhizal isolates, some reported previously as endophytic (including dark-septate endophytes), 'root-associated fungi' and as orchidaceous fungi.

The array of root-associated and mycorrhizal fungi of the two plants from the family *Rosaceae* can be linked to their pioneer characteristics, stabilizing the pastures and ski slopes at the upper forest zone. Therefore their potential use as biotechnical stabilizers could be predicted and will be studied next.

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Afforestation, microbial metagenomics, and biogeochemistry in Southern South American Grasslands

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Soil biogeochemical functions and ecosystem processes are closely tied to the soil microbial community composition and function; however, the majority of soil microorganisms are difficult if not impossible to grow in culture. New methods adapted from molecular biology have begun to shed light on the diversity and function of many of these previously uncultureable microbes. In this study, a new molecular technique, functional genomic microarrays, was utilized in conjunction with measures of soil biogeochemical pools to examine how the soil microbial community links with biogeochemical processes.

We used the conversion of native grasslands to exotic *Eucalyptus* plantations (i.e. afforestation) to study how changes in plant inputs to soil alter the function of soil microbes and their associated biogeochemical functions. Afforestation represents a major shift in vegetation cover in most ecosystems and is increasing in area globally. Plantations already cover 140 million ha globally, and 2.8 million hectares more are afforested annually; this rate is likely to increase as demand for wood products and the use of plantations as carbon offsets grows.

Afforestation provides a good opportunity to examine how the soil microbial community responds to altered quality and quantity of plant matter inputs. We tested the functional genomic and community structure response of soil microbes using DNA microarrays that simultaneously quantify >27,000 genes with ecological functions. Responses to afforestation in soil pools of carbon and nitrogen were also measured.

We found that changes in plant input change soil microbial community structure and function, as well as pools of different forms of soil carbon and nitrogen. Afforestation lead to changes in the composition of microbial species with important roles in the degradation of carbon substrates, ammonification, and nitrogen fixation. The change in plant structure also lowered the quantity of carbon degradation, nitrification, N mineralization, and urease genes across all microbes. This alteration of carbon and nitrogen cycling genes shifted the distribution of pools of soil carbon and nitrogen. We conclude that afforestation's combined effect on grassland soil microbes was to alter functional genomic capacity and decrease the soil microbial biomass, which decreased the microbial community's cycling of carbon and nitrogen.

Seasonal variation of the abundance and carbon assimilation activity of rhizosphere soil microbial communities in a temporal wetland

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Fluctuating hydrology in wetlands regulates the availability of oxygen in the soil, thus creating spatio-temporal variations in aerobic and anaerobic conditions, and consequently affecting the abundance and activity of soil microbial communities. In this study we investigated the seasonal variation of the abundance of rhizosphere soil microbial communities and their carbon (C) assimilation activity in a temporal wetland. The study site was characterized by a year-round shallow ground water table, which fluctuated within 75 cm below surface in summer and reached the ground surface in October, before winter inundation. This hydrological variation affected the oxygen content in the upper soil layer with aerobic conditions in summer and anaerobic conditions in winter. Vegetation growth followed a sigmoidal pattern, with a rapid increase in late spring that levelled off during summer. The abundance and activity of soil microbial communities were investigated by a combined approach of $^{13}CO_2$ pulse labelling followed by compound-specific analyses of phospholipid fatty acids (PLFA) (Balasooriya *et al.*, 2008) on three different occasions, i.e., April (spring), June (summer), and October (Winter). This method allowed identifying the microbial groups actively involved in the assimilation of newly photosynthesized, root-derived C. The relative abundance of gram-positive communities increased in October, when the groundwater table was high and anaerobic conditions prevailed, while the relative abundance of saprotrophic fungal and methanotrophic bacterial communities decreased under these conditions. The C assimilation activity of saprotrophic fungi decreased in October, while that of gram positive communities increased following their relative abundance. However, despite their decreased abundance, the net labelling of methanotrophic bacterial communities increased in October, suggesting that these microbial groups were more active under the prevailing methanogenic conditions.

Table 1. Relative abundance (mole %) and net increase of ^{13}C isotopic composition ($\Delta\delta^{13}C$) in selected PLFA biomarkers 24 hours after $^{13}CO_2$ pulse labelling in the 0–10 cm soil layer in April, June, and October 2007.

PLFA	Relative abundance (mole %)			$\Delta\delta^{13}C$ ($\delta^{13}C_{\text{post-labelled}} - \delta^{13}C_{\text{pre-labelled}}$)(‰)		
	April	June	October	April	June	October
i 17:0	3.07 (0.0) ^{a}	2.54 (0.1) ^{a}	4.46 (0.7) ^{b}	-6.34 (3.2) ^{a}	9.91 (2.4) ^{b}	4.35 (3.2) ^{b}
cy 17:0	2.05 (0.2) ^{a}	2.11 (0.1) ^{a}	2.74 (0.2) ^{b}	-5.96 (5.4)	-1.61 (4.9)	-1.55 (1.1)
10 Me 18:0	3.01 (0.2)	3.38 (1.1)	3.22 (0.4)	-2.42 (1.6) ^{a}	1.75 (0.8) ^{b}	-0.39 (1.7) ^{ab}
18:2ω6,9c	6.71 (0.6) ^{a}	7.83 (1.1) ^{a}	0^{*}(0) ^{b}	2.04 (4.3) ^{a}	6.89 (3.1) ^{a}	0^{*} (0) ^{b}
16:1ω7c	9.56 (0.6) ^{a}	8.65 (0.8) ^{a}	6.22 (0.6) ^{b}	13.73 (5.4) ^{a}	17.57 (4.6) ^{a}	35.48 (8.4) ^{b}

Different characters (a, b) indicate significant differences between time periods at $p<0.05$ (n=3). *Below the detection limit.

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Effects of arbuscular mycorrhizal fungi on grassland CO_2 fluxes and productivity under elevated temperature and CO_2

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Arbuscular mycorrhizal fungi (AMF) play a key role at the soil-root interface, influence plant physiology and ecosystem composition and are responsive to many perturbations such as climate change. Therefore, their responses to climatic factors as elevated temperature and CO_2 concentration may have a substantial impact on plant productivity, community composition, CO_2 fluxes and nutrient cycling.

In this study we examined whether the presence of AMF changed the CO_2 fluxes and the productivity of grassland communities under a future climate scenario. For this purpose, newly established grassland communities were grown either at ambient temperatures with 375 ppm CO_2 (*Amb*) or at ambient temperatures + 3°C with 620 ppm CO_2 ($T+CO_2$). The following plant species were used: *Poa pratensis* L., *Lolium perenne* L., *Trifolium repens* L., *Lotus corniculatus* L., *Plantago lanceolata* L., *Rumex acetosa* L.. Communities were planted on pasteurized soil, inoculated with the AMF *Glomus fasciculatum* and *Glomus intraradices* (*AM*) or not inoculated (*NM*). Each community was combined with a soil compartment in one container. Both compartments were separated from each other by a 25 µm nylon mesh, allowing AMF to grow through and blocking roots.

The communities were established in June 2008 and kept until the beginning of November of the same year. At four different times throughout the duration of the experiment CO_2 fluxes were measured at ecosystem level on a subset of ecosystems. Net ecosystem exchange (NEE) was measured at different light intensities, total ecosystem respiration (TER) and soil respiration (R_{soil}) under dark conditions. From NEE and TER gross primary productivity GPP) was calculated. After each period of flux measurements the subset of ecosystems was harvested to obtain above-ground and below-ground biomass. Frequency of root colonization by AMF was determined. Hyphal length was measured in soil samples from both plant and soil compartments.

The presented poster will discuss the obtained data on CO_2 fluxes, biomass, colonization and hyphal length putting them in a framework of ecosystem carbon balance and productivity under climate change.

Production of dissolved organic carbon in forest soils along the North-South European transect

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The aim of the study was to estimate a carbon loss from forest soils due to the production of dissolved organic carbon (DOC) along the N-S European transect. Dissolved organic matter (DOM) was extracted from the forest soils incubated at the defined temperature and water content. Soils were sampled from forest plots from Sweden to Italy. The plots represent monocultures of spruce, pine and beech and 3 selected chronosequences of spruce and beech spanned over range of mean annual temperature from +2 to +14°C. The DOM was characterized by its DOC/DON ratio and the carbon isotope composition $\delta^{13}C$. In addition to DOC production, heterotrophic respiration and nitrogen mineralization were measured on the incubated soils. The DOC production was described by the first order reaction kinetic, the heterotrophic respiration by the zero order reaction kinetic. The kinetic analysis of the experimental data yielded the mean annual DOC and respiration productions with respect to sites.

Carbon pool size and carbon quality affect the DOC and CO_2 production. The DOC mineralization is derived from the availability of labile forms of DOC. Production of CO_2 increases with the litter pool size and decreases with the size of carbon pool in subjacent mineral layers. Residual DOC does not correlate with the size of carbon pool. Only soils very rich in organics produced higher DOC concentration.

The CO_2 production is a function of carbon mean residence time. The CO_2 production exponentially decreased with carbon age. The residual DOC is not affected by the carbon age. According to this difference, DOC originates from the decomposition of complex structures, whereas CO_2 is produced from easily degradable labile components.

An increase in mean annual temperature (MAT) increases (DOC+CO_2) production from the litter, with MAT higher than 10°C the production has not increased. Soils with extreme accumulation or loss of carbon do not correlate.

Tree age does not affect the (DOC+CO_2) production. Carbon pool size had the major effect on the (DOC+CO_2) production.

Linking microstructural and spectroscopic analysis of biological soil crusts – investigation of organo-mineral interactions

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Cyanobacteria and green algae present in biological soil crusts are able to colonize mineral substrates even under extreme environmental conditions. As pioneer organisms, they play a key role during the first phases of habitat colonization and often initialize biochemical weathering of minerals. We combined FTIR and REM/EDX microscopy to study the contact zone of algal and cyanobacterial mucilage with quartz, spars and mica on a ≥40 µm scale in undistrubed biological soil crusts on the first millimeters of the surface of a sandy substrate. REM/EDX microscopy was used to determine the spatial distribution of elements in the profiles, organic compounds were identified using FTIR microscopy. We found accumulation of Al and K in microbially derived organic matter indicating capture of weathering products of feldspars and mica by microbial exsudates (Fig. 1). These exudates served as cementing material between sand particles. FTIR spectra recorded in the contact zone showed typical bands for quartz, phyllosilicates and carbohydrates (Fig. 2). It can be concluded that a combination of analytical microscopic and spectral techniques gives valuable insight into microbially induced organo-mineral interactions on a microstructural level.

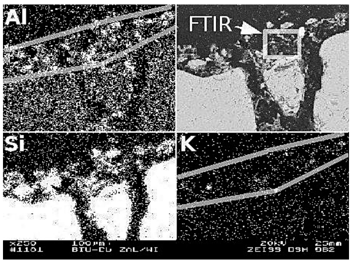

Fig. 1. BSE-signal (top right) and REM/EDX mapping of aluminum (top left), silicon (bottom left), potassium (bottom right)

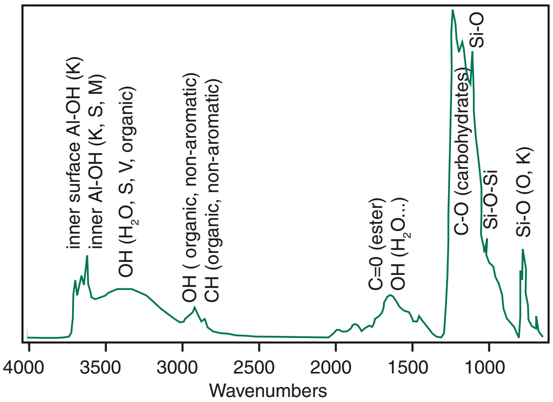

Fig. 2. FTIR-spectrum taken from indicated region (cf. Fig. 1, K – kaolinite, M – clay mica, S – smectite, V – vermicullite, Q – quartz)

The carbon balance of Scots pine, Norway spruce and silver birch in changing climate: the effects of temperature and ectomycorrhizal fungal communities

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The climate change will most probably change the boreal forest soil temperatures and cause changes in biological activities and microbial communities in soils. In most models, the soil respiration originating from the decomposition of organic matter is assumed to be directly correlated with temperature and humidity. Ectomycorrhizal fungi (ECM), which are mostly dependent on plant-derived carbon and photosynthesis, are abundant in boreal forests and they are of key importance for plant nutrient uptake and stress resistance. Also, their contribution to soil respiration is high. Therefore, the relation of ECM to the carbon balance of a tree and its temperature sensitivity is of major importance, if boreal forest soil CO_2 balance will be estimated.

We conducted a series of experiments using Scots pine, Norway spruce and Silver birch seedlings, temperature controlled custom-made microcosms, CO_2 gas exchange measurement system, $^{14}CO_2$-pulse-chase labelling and archaeal as well as ECM identification by DGGE or morphotyping and DNA sequencing. The aim was to determine the allocation pattern of assimilated carbon between tree biomass, above- and belowground respiration and soil as well as the associated microbial populations. In the experiment 1, we measured the carbon balance of these three tree species in constant temperature conditions in order to compare their carbon uptake, light response and allocation patterns in standard growth conditions. From these results, the differences in carbon economy and allocation patterns of the tree species studied can be estimated. In experiment 2, the effect of ECM communities on carbon allocation patterns in Scots pine seedlings was studied. From this experiment, we can estimate the effect of fungal symbionts to tree's CO_2 assimilation, carbon allocation and belowground respiration. Also, the turnover rate of CO_2 and its dependency on ECM fungi can be estimated. In experiment 3, the tree species were grown in three different soil temperatures and in the end their ECM communities were described. The ECM community was compared with the photosynthesis and respiration data in order to estimate the effects of soil warming on the communities and tree seedlings' carbon balance. In addition to ECM communities, the archaeal (*Crenarchaeota* and *Euryarchaeaota* that include methane producers) communities were described and their dependency on tree species and temperature was estimated.

The different tree species had clear differences in their carbon economy i.e. photosynthetic activity, carbon allocation pattern and turnover rate. Some members of ECM community modified the carbon allocation patterns in Scots pine seedlings and the turnover rate increased when ECM biomass increased. Soil temperatures had effects on CO_2 exchange: e.g. for Norway spruce, the increase in soil temperature seemed to increase soil respiration but also photosynthesis. Scots pine had more ECM per root length in cold than in medium and warm temperatures whereas for Norway spruce in medium temperature there seemed to more ECM per cm root than in cold or warm. The diversity of *Euryarchaeaota* tended to increase along with the increasing temperature while the case was opposite for *Crenarchaeota*. All the results of the three experiments and their interdependency are discussed in detail in the conference presentation.

Microbial community functioning drives nitrogen biogeochemistry in drought stressed pastures

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Microbial community composition is rarely considered in soil nitrogen (N) biogeochemistry. Rather, it is believed that microbial functioning is a ‘broad’ process, i.e. the operations of a certain microbial community are easily interchangeable between functional microbial groups without showing adverse effects on bioavailable N production. This hypothesis has recently been questioned, especially when the ecosystem is subjected to environmental stress (Allison and Martiny, 2008).

We studied N biogeochemistry in relation to microbial community composition in four pasture ecosystems (varying in plant species composition and fertilization history) located on a volcanic soil in south Chile (Experimental Research Station ‘Santa Rosa’, 39°47 S, 73°14 W). Phospholipid fatty acid biomarkers were analysed as an indicator for microbial community composition, while a combination of enzyme activity measurements and ^{15}N isotope dilution techniques was used as an indicator for biogeochemical N cycling. In order to evaluate the effect of drought, N transformation fluxes and enzymatic activities were determined at a well watered and drought stressed condtions. Biochemical analysis of bulk soil samples served as an indicator for soil organic matter quality. A combination of statistical analysis methods (principal component analysis, multiple response permutation procedure, Dufrene-Legendre indicator species analysis, co-inertia analysis) was used to assess the complex relationships between the studied indicators.

Volcanic soils are characterized by a tightly bound organic N that is mainly transformed into bioavailable N via microbial enzymatic reactions (Allison, 2006). Drought imposes physiological stress that might force microbes to shift resource allocation (e.g. from resource acquisition into survival) a process which alters bioavailable N production in the soil (Schimel et al., 2007). In our study, statistical analyses revealed a clear link between microbial community composition and biogeochemical N cycling. We indicate that (1) microbial acclimatisation processes in response to drought stress differ substantially between microbial groups, (2) more diverse microbial communities adapt better to abruptly changing environmental conditions such as drought stress, and (3) microbial functioning should explicitly be considered in ecosystem N cycling models.

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Nutrient enrichment in tropical wetlands: plant C partitioning and biological availability of C released from roots

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Herbaceous wetlands of northern Belize are part of a phytogeographically related group of limestone-based marshes that cover extensive areas of the Yucatan Peninsula, Caribbean islands and South Florida.

We used these oligotrophic, P-limited marshes to assess how changes in nutrient availability impact species composition and ecosystem processes. In 2001, P, N, and NP enrichment plots were established in 15 replicated marshes. The addition of P or combination of N and P resulted in rapid switch from a microphyte (cyanobacterial mats, CBM) to macrophyte *(Eleocharis*) domination**,** while N addition did not have any impact (Sirová et al. 2009). In 2005, +P plots in a subset of six marshes were split into two halves, each dominated by *Eleocharis cellulosa* and *Typha domingensis* to document the impact of dominant macrophytes on sediment microbial processes. There were significant differences between *Eleocharis* and *Typha* biomass changing the quality and stoichiometry of the organic C input, and, consequently, sediment chemistry and microbial activity (Rejmánková et al. 2009).

We assumed that these differences are accompanied by different plant C partitioning and C release from roots, as well as by different biological availability of released C. To verify these assumptions, *Typha* and *Eleocharis* were grown in the interstitial water from the studied marshes, with and without P addition, for four days. Pulse ^{13}C labelling was used to follow distribution of assimilated ^{13}C to leaves, roots and interstitial water. The biological availability of C released from roots to water was determined at the end of experiment using respiration response approach. Water was filtered (2μm), inoculated with sediment and kinetics of respiration was measured for ten days.

The content of ^{13}C in leaves of *Eleocharis* and *Typha* rapidly decreased in the first two days in all treatments and declined to about 10% of the total assimilated ^{13}C till the end of experiment. The ^{13}C.content in roots increased to about 10% of total assimilated ^{13}C during the first day and stayed stable afterwards. .*Eleocharis* grown in high phosphorus released nearly 60% of the assimilated ^{13}C from roots, while only 30% were released by *Eleocharis* from low-phosphorus. As compared to *Eleocharis*, the amount of ^{13}C released by roots of *Typha* was roots lower (15% to 20% of the total assimilated ^{13}C); and no significant effect of P addition was found. On the contrary to *Eleocharis*, *Typha* released higher amount of biologically available C. The role of nutrients was unclear.

The two dominant macrophytes differed in amount and quality of organic compounds released from roots indicating different impact on composition and activity of microorganisms in the vicinity of roots.

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Study on the Decolorization and Degradation of Textile Dyes Commonly used in the Textile Industry District of Tamil Nadu, India

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Textile dyes are one of the most prevalent type of chemicals in use today. Around 10,000 different dyes with an annual production of more than 7×10^5 metric tons worldwide are commercially available. Two percent of dyes that are produced are discharged directly in aqueous effluent and 10% are subsequently lost during the textile coloration process. Some of the azo dyes, xanthene dyes and anthroquinone dyes are known to be very toxic and mutagenic to living organisms. With the increasing use of a wide variety of dyes, pollution by dye-waste water is becoming increasingly alarming. The two major sources of release of dyes into the environment are the textile and dye stuff manufacturing industries. The present study was carried out in an attempt to decolorize seven commonly used textile dyes such as Reactive Back HFGR, Reactive Red, Reactive Yellow I, Reactive Yellow II, Reactive Blue and Reactive Black and Colonial Red. Soil sample from the sludge waste was taken for the isolation of microorganisms and 24 bacteria were isolated. All these were screened for the ability to decolorize all seven dyes and were found to be encouraging. Experiments were carried out to understand the role of Sources of Carbon, Nitrogen and their composition on the decolorizing ability and their synergistic relationship/role of the bacterial species in decolorization process. Results reveal the existence of wide variety of organisms capable of decolorizing a wide range of dyes and it is worth investigating further into the molecular details of the phenomenon.

Ectomycorrhizal community structure on roots of trees planted in the mixture of soils and ashes from the thermal power plant

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Degraded soils or substrates formed from mine wastes and ashes can remain unproductive for decades or stay bare forever in unfavourable site conditions. Mycoremediation technologies were tested in the area covered with contaminated substrates deposited from the Coal (lignite) mine and Thermal Power Plant Šoštanj in Slovenia. The development of the rhizosphere ecosystem was monitored with the analysis of the ectomycorrhizal (ECM) community structure which developed on the roots of Scots pine, aspen and willows planted into shallow mineral soil layer mixed with ashes 15 years before our study. Soil cores were taken from the upper 20 cm of the substrates, all roots in the 30 cores (up to 270 ml each) were carefully washed, counted and types of ectomycorrhiza identified after anatomical and molecular characteristics (using standardized protocols, the ITS-RFLP database of the SFI, sequencing and GenBank or UNITE comparisons). ECM root tip density (ECM root tips 100cm^3 soil) was calculated from the total number of ectomycorrhizal tips in soil sample and diversity indexes were calculated. Also, the fungal community structure in the soils and ashes from the deposits and from two control plots, planted with pines, was analysed (DGGE protocols & UPGMA clustering). All short roots of aspen, willow and pine were colonized by mycorrhizal fungi. Old and non-turgescent mycorrhizas persistently made up ca. 60% of the root tips and did not differ significantly between tree species from all sites. In total 9 571 root tips were examined for ECM type identification (1893, 6474, 1204 for aspen, willow, and pine, respectively). Based on morphology, structure of mantle and emanating elements in total 35 ECM types were distinguished (16 for aspen and willow together, 21 for pine). Fungal communities on roots from all tested plots were characterized by one very abundant species, two or three moderately abundant species, and a few species of low abundance. We conclude that the rhizosphere development was successful and the revitalization technique could serve as a control for the new mycoremediation technologies, using a mix of wood chip, inoculated with white-rot fungi, and ashes, which have been tested in the past few years at the site.

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Fine root biomass and depth distribution in different developmental stages of Norway spruce stands

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Fine root biomass and depth distribution were studied in pole (28yr) and mature (84yr) Norway spruce stands on Gleyic Podzol in South-Estonia. Stand density, mean height, mean diameter at 1.3 m, and basal area were in pole stand: 2315 stems ha^{-1}, 8 m, 8 cm, and 15.5 m^{2}ha^{-1}, respectively and in mature stand: 698 stems ha^{-1}, 24 m, 26 cm 29.0 m^{2}ha^{-1}, accordingly.

The aim was to analyze the factors affecting the fine root biomass and depth distribution in soil cores and in 3rd year ingrowth cores in similar soils at different stages of Norway spruce stand development. The depth distribution of fine D< 2mm roots and belowground part of understorey was studied in 10 soil cores per pole and 15 cores per mature stand, and in seven 3rd year ingrowth cores per stand. Soil cores and ingrowth cores were divided in soil layers: O-horizon, 0–5, 5–10, 10–15, 15-20 and 20–30 cm, and 0–5, 5–10, 10–15, 15–20 and 20–30 cm respectively.

Table 1. Norway spruce fine root (D<2 mm) biomass in pole and mature stand

Method	Soil cores	Soil cores	Ingrowth cores	Ingrowth core
Stand age (years)	28	84	28	84
Biomass, gm^{-2} (mean±SE)	930±100	870±60	1220±110	720±60
Biomass per tree, kg	4.0	12.5	5.3	10.3

The depth distribution of living fine roots of Norway spruce was shallower in pole than mature stand. According to soil cores most of the spruce fine roots were situated in O-horizon, 82% and 52% in pole and mature stand, respectively. The possible reasons of different depth distribution are the temporally raised level of groundwater and higher nitrogen availability in topsoil of pole stand and effect of stand age. Higher fine root increment during 3 years in ingrowth cores and higher value of fine root biomass in soil cores was in accordance with higher soil respiration and needle production (estimated on basis of annual needle litter flux) in pole stand vs. mature stand.

Higher ratio of fine root biomass in ingrowth cores vs. soil cores in pole stand indicates the higher root production in pole stand.

The main possible reason of higher productivity in pole stand vs. mature stand may be different developmental stage of the stands.

Searching for connections between land use, plant composition and soil aggregate stability at the ski resort Krvavec

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Mountain space comprises special ecosystems, where flora and fauna is adapted to harsh conditions. The presence of ski resort in alpine space is a further disturbance for these ecosystems. Therefore land use at ski resort must be considered with special attention.

The influence of soil structure on plant growth as well as plant effects to soil structure have been well described (e.g. Angers and Caron, 1998). The aim of our study is to analyse whether land use has a significant impact on plant composition and soil aggregate stability. We selected four research plots on the ski runs and one control plot in the nearby forest (20 × 20 m each) at the ski resort Krvavec (46° 18' N, 14° 32' E, 1650 m a.s.l.). Two plots are located on a graded ski slopes, while the other two are on a relatively undisturbed pasture. Within the plots additional subplots (2 × 2 m) were set on which phytocenological survey has been carried out. Additionally, soils were screened using a soil probe. The preliminary results showed a high plant and soil diversity. At each research plot the following soil units were determined according to WRB (2006): Lithic Leptosol, Haplic Leptosol, Rendzic Phaeozem and Haplic Cambisol. There were no big differences among the plots concerning the number of plant species (about 100) excluding one plot on the graded ski slope (64). After the winter season (next year) soil aggregates from each plot will be taken using cylindrical probe in order to evaluate the stability of water-stable aggregates following the protocol of Frei et al. (2003). Soil and root measurements include root length density, dry volume weight, soil humidity and porosity. Root indices will be calculated using WinRhizo® Software, types of ectomycorrhiza differentiated and statistics will be applied to distinguish differences among the plots.

Keywords: water-stable aggregates, roots, plants composition, land use, ski resort

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Simulation of mycorrhizal contribution to forest C- and N-cycling

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The importance of mycorrhiza for the vitality of forest ecosystems has been shown in numerous field and laboratory experiments. Especially on nutrient poor sites, mycorrhiza contribute significantly to plant N nutrition and ecosystem C cycling since up to 30% of plant photosynthates are transferred to the fungal network. Irrespective of the importance of mycorrhiza, existing biogeochemical models on the ecosystem scale do not explicitly consider the symbiotic feedbacks between fungi and plant roots and, thus, may miss an important mechanism to describe plant-fungal competition for nutrients in the rooting zone and adaptation to environmental changes. Therefore, we developed a simple dynamic feedback model simulating the symbiosis between tree roots and ectomycorrhizal fungi. This model captures the main C- and N- flows between fungus and tree root and considers the impact of environmental factors like N availability and temperature. The model is applicable to test the sensitivity of the system fungus-tree to changes in N availability and temperature and aims to quantify the potential significance of mycorrhiza for forest ecosystems with regard to N nutrition.

Sensitivity tests carried out showed that the model responses to changes in various parameters correspond to observations from field and laboratory studies. E.g. fungal contribution to tree N nutrition ranges between 21% and 99% for a variation of total soil N between 0.006 kg-N kg soil and 0.018 kg-N kg soil. The model will be linked to a biogeochemical model that includes plant photosynthesis, C-allocation, and nutrient demand as well as dynamic physical and chemical soil properties in order to simulate the influence of mycorrhiza on forest stand growth and vitality in dependence on varying environmental factors.

Modeling of the mineral nutrient uptake of forest tree roots as affected by the ion dynamics in the rhizosphere

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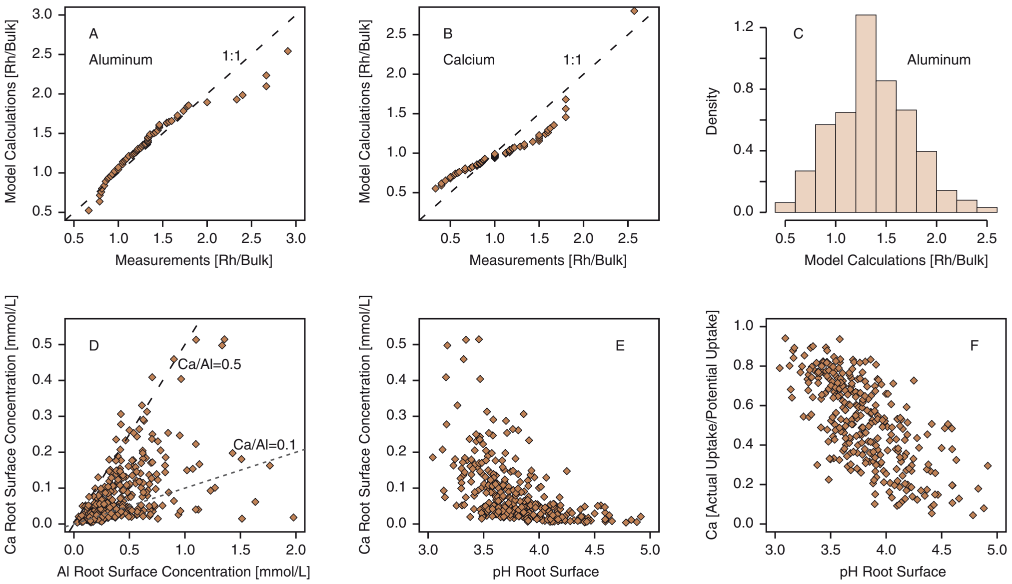
The conditions of mineral nutrition of forest trees growing in acid soil stands are not well understood. Especially, nearly all previous investigations do not consider the root-induced ion concentration changes in the rhizosphere.

In this study it is hypothesized that the acquisition of mineral nutrients is explainable only in terms of the ionic dynamics in the rhizosphere. For understanding the feedback-reactions in the rhizosphere a multi-species model has been developed which simultaneously calculates the rhizosphere concentration changes and root influxes/effluxes of all essential ions (H, Al, Mn, Fe, Ca, Mg, K, Na, H2PO4, NO3, SO4, Cl) thereby taking into account interactions among them. The objectives of this study is to present model results of actual root uptake rates of all relevant mineral nutrients as affected by the dynamic of ionic interactions in the rhizosphere. The heterogeneity of model parameter values (e.g. ionic bulk soil concentrations) are represented by probability density functions which are derived from measurement data (F1-plot in Solling, Germany). A Monte-Carlo uncertainty analysis has been made. A validation of the model results is given by comparisons with rhizospheric measurements (X-ray micro analysis) via equivalence testing (Robinson and Froese,2004); comparisons between model and measurement values may also be demonstrated via qq-plots (Fig. A, B). Results are presented separately for non-mycorrhizal long roots (Nietfeld et al., 2008a/b; Fig. A-F) and mycorrhizal roots (in prep.). Around long roots depletions and accumulations of Al and M_b cations have been measured and modelled (Fig. A, B, C). Low Ca/Al ratios on the root surface have been calculated at both, low and high Al^{3+} concentrations (Fig. D). Hydroxyl ion root excretions do not lead to substantial pH increases due to buffering via cation exchange. Root surface concentrations and potential root uptake rates of M_b cations are reduced with increasing pH (Fig. E, F). Assessments are given with regard to root nutrient acquisition and risk of Al toxicity.



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Mycorrhizl Work in Turkish Forest

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Mycorrhizal study in Turkey started in 1995. Since than several works had been done to understand the role of mycorrhizal fungi in forest development. The mycorrhiza, rhizosphere and soil quality research group in Turkey who are studying mycorrhizae for high plant root. Mainly we are interested with producing mycorrhizal inoculated agro forestry seedling production. Turkey has more than 21 million ha forest area that has been covered the 27.2% of Turkish land. All over the Turkey, there are 110 forest nurseries and every year nearly 425 million seedlings are produced. It is important to produce mycorrhizal inoculated forest seedling for better establishment. Also it is important to understand the influence of mycorrhiza in soil and plant management related with mycorrhizae. It is very important to work agro forestry plants for better establishment and growth.

Major plants species seedlings are grown in Cost of Mediterranean are were searched in term of root colonization and seedling development were analyzed. In our previous studies agro forestry plant roots were worked and root colonization were determined that vascular plants have shown high mycorrhizal root infection. Root and shoot weight and ratios were calculated. Non mycorrhizal plant have high ratio of root: shoot ratio. Mycorrhizal dependent plant has fewer ratios.

In the seedling stages, the order of effectiveness of species was as follows: Root colonization level for *Nerium oleander* (89%), *Rosmarinus officinalis* (64%), *Acer negundo* (45%), *Laurus nobilis* (37%), *Eucalyptus grandis* (35%), *Eleagnus angustifolia* (17%), *Ceratonia siliqua* (7%) respectively. Only *Ceratonia siliqua* has less root colonization.

Also seedling establishment ratios under field condition without mycorrhizal inoculation were determined. It has been found that naturally well inoculated seedlings are successfully established under field condition compare to naturally less inoculated ones. For further work we are planning to study how mycorrhizal inoculation can successfully apply to seedling establishment under field condition.

Microbial, chemical and geotechnical characteristics of tropical heterogeneous soil

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Despite the presence of relevant biomass in the subsurface, soil microbiology has traditionally focused on superficial soils, where plant roots grow and microorganisms thrive, because of the importance of microbial processes in the maintenance of soil fertility and life on our planet. The vadose zone has been less studied and processes are still poorly understood, especially concerning tropical soils. Given the recent advances in environmental sciences, the relevance of interfaces between different areas of expertise must be evaluated. Also, some important phenomena of geotechnical engineering demands a better understanding of the role of biology and chemistry in soil properties and behaviour, and of the extension and usefulness of biological processes in geo-engineering. Subsurface soils present greater heterogeneity in the distribution of nutrients, carbon, water and oxygen, which leads to a greater variability in microbiota composition and activity. Besides, Brazilian residual soils present different characteristics from those from the Northern hemisphere, where most of the studies have been conducted to date; they frequently preserve the structure of the mother-rock and are very heterogeneous when not submitted to important weathering.

Environmental microbiota is the main regulator of soil processes, being responsible for the degradation and cycling of natural and anthropogenic compounds. Therefore, evaluating its metabolic state and composition allows assessing its biodegradation potential as well as monitoring biodegradation processes. However, environmental conditions, regulated by soil composition and structure, are determinant for these populations' distribution, composition and activity, hence the need to assess soil as a support for microbial growth and activities. Inter-disciplinary and multi-parametric studies analyse diverse parameters, providing different views for a better understanding of environmental processes.

This study has focuses a young residual soil from Rio de Janeiro, describing its main facies (one silty and one sandy) from a mineralogical, chemical and geotechnical point of view, relating these characteristics to those of the soil microbiota. Data show how microbial biomass and activity relate to carbon content, availability and use, as well as the relation between their distribution and soil characteristics. The sandy facies, despite a lower degrading activity, less carbon and water contents, supports a more efficient microbiota in carbon incorporation. In fact, soil carbon appears relatively more available than in the silty facies, and is allocated in more important amounts to the biomass. Those factors seem to be related to a better distribution of air, water and nutrients because of soil higher porosity due to its grain size distribution. Also, the sandy facies is a better drained soil where microbial activity is not disrupted by high rainfall, which seem to impact the microbiota in the silty facies because of higher water retention.

More powerful techniques will deepen this knowledge and different soils will be contemplated, seeking for comparative studies to validate this approach. The innovative integration of different areas contemplating environmental issues is thus highly emphasised by the pioneering combination of Geotechnical Engineering, Soil Microbiology, Geology, Chemistry and Agronomy.

Fungal species-specific impacts on ectomycorrhizal root traits in Alnus

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Ectomycorrhizal (EcM) fungi provide mineral nutrition for the dominant boreal forest trees. Much of the nutrient uptake and exchange depends on morphology of EcM short roots. The effect of ectomycorrhizal fungal taxa and community on these parameters has remained poorly understood.

Morphological parameters - mean diameter (D, mm), length (L, mm), mass (W, mg), specific root length (SRL, m g^{-1}), specific root area (SRA, m^2 kg^{-1}), root tissue density (RTD, kg m^{-3}), root tip frequency per dry weight (RTFW, n $_{DW}mg^{-1}$) and length (RTFL, n mm^{-1}) of EcM roots were measured in ectomycorrhizal anatomotypes of *Alnus incana* and *A. glutinosa* in relation to the effects of host species, soil moisture and soil nutrient concentrations in seven forest sites.

Redundancy analysis revealed that anatomotype, alder species, site and soil parameters (N, P, K, pH_{KCl}, Ca, Mg, organic content) accounted for 42.3 % ($p<0.001$) of the total variation in EcM root morphology. The extent of described variation in EcM root morphology decreased in following order: anatomotypes (27.9%) > soil parameters and sites (19.9%) > alder species (5.1%).

EcM fungus affected primarly independent variables of EcM roots: D, L and W of ectomycorrhizal root tip. EcM roots of dominating anatomotype, *Alnicola* spp., had the highest SRA and SRL in both *A. incana* and *A. glutinosa*. Short root morphology depend most strongly on fungal taxa involved, indicating that mycobionts may play an important role in their functional properties.

Direct effect of fertilization on anaerobic carbon and nitrogen transformation in two different wet meadow soils

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Effect of eutrophication on wetlands has been often studied however information about direct effect of added nutrients on microbial processes and C and N transformations in wetland soil, especially under anaerobic conditions, are scarce. The aim of our study was to show direct effect of fertilization on microbial processes and C and N transformations in two different wet meadow soils under anaerobic conditions.

Soils were sampled from two oligo-mesotrophic wet meadows located in the Trebon Basin Biosphere Reserve (South Bohemia, Czech Republic) which are representative of two main types of temperate wet meadows. The first, Záblatské Louky is a sedge meadow on silt-loam peat soil (Histosol), dominated by Carex acuta and Carex vesicaria. The second site, Hamr, lays on a mineral, silt-loam alluvial substrate, classified as Gleysols and is co-dominated by the mixture of Glyceria maxima and Carex acuta. Laboratory experiment was established using homogenized soil samples. Two treatments were established: soils fertilized with commercial NPK fertilizer and soil without addition of fertilizer (control soil). The samples were incubated under anaerobic conditions for three weeks. During this period CO_2 and CH_4 production were analyzed regularly. At the end of experiment, concentration of soluble organic carbon (SOC), soluble nitrogen (SN) and particular N forms (soluble organic N, SON; ammonium, $N\text{-}NH_4^+$; nitrates $N\text{-}NO_3$), microbial biomass C and N (Cmic and Nmic), DNA amount, potential denitrification activity (DEA) and the number of denitrifiers were determined. Then acetate was added to the soil samples and CO_2 and CH_4 production were measured.

After three weeks incubation, Cmic and Nmic was not different in fertilized soils and in unfertilized ones whereas SOC was slightly lower in fertilized soils than in unfertilized ones. CO_2 production was slightly lower in fertilized soil as compared to control one. Nitrates disappeared from both fertilized soils and also ammonium concentration decreased significantly during three weeks of anaerobic incubation. However, nitrogen was not found in Nmic and, moreover, C to N ratio of microbial biomass even increased in fertilized soil as compared to control soil. Although DEA was not affected by fertilization, number of copies of nirK enzymes was much higher in fertilized soil as compared to unfertilized one, what indicates increased activity of denitrifying microorganisms. Methane production was negligible in all samples during three weeks incubation. However, later, after acetate was added to the soil, methane was produced in both soils and in both fertilized and unfertilized variants, respectively. Methane production started later in fertilized soils as compared to unfertilized ones.

Rhizosphere, fine-root, and soil parameters in a silver birch stand chronosequence on reclaimed oil shale mining area

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Opencast oil-shale mining creates substantial areas of alkaline (pH~8) wasteland that require reclamation. As a result of mining, the relief is rugged, and the soil heterogeneous and extremely stony; N and organic content of oil-shale mining spoil is low. Planting of trees, especially fast-growing deciduous species as silver birch (*Betula pendula*) on abandoned opencast oil shale mining area (OSMA) is the best means to accelerate the development of a new forest ecosystem in such harsh conditions. A chronosequence of silver birch stands of different ages (1, 2, 4, 7, 31, 43) on reclaimed OSMA was investigated to reveal changes in activity of microbial communities in the soil root interface (Rhiz) and in the bulk soil (Bulk), and in short root morphology during stand development. Biolog Ecoplates were used to determine summed activity (SA) of cultivable bacteria in Rhiz and Bulk. Active microbial biomass in Bulk was determined using substrate-induced respiration (SIR). Short root morphological parameters were measured using WinRHIZO^{TM} Pro.

Soil pH decreased and N% as well as organic matter (from 1.8% to 15%) increased logarithmically with increasing stand age (Fig. 1A). SIR was positively correlated both with soil N% ($r=0.97$, $p<0.01$) and stand age ($r=0.91$, $p<0.05$). SA ratio Rhiz/Bulk, indicating the plant support of rhizosphere microbial communities, was low after planting, reached the maximum after four years and decreased thereafter hyperbolically with age (Fig. 1B). During the first 30 years of stand development SIR increased an order (from 0.18 to 1.90 mg C g^{-1}). Mean short root mass (W), diameter (D), and tissue density (RTD) increased, and short root length (L), specific length (SRL) and specific area (SRA) decreased according to a power function with stand age ($0.85<r<0.98$, $p<0.05$). Soil N% was negatively correlated with SRA, SRL and L ($-0.92<r<-0.86$, $p<0.05$) and positively with D and W ($r=0.94$ and $r=0.90$ respectively, $p<0.05$). In conclusion, silver birch on reclaimed OSMA supports rhizosphere microbial communities in order to improve mineral nutrition and changes short root morphology according to soil development stage. Rhizosphere processes have an important role in soil development and improvement in OSMA.

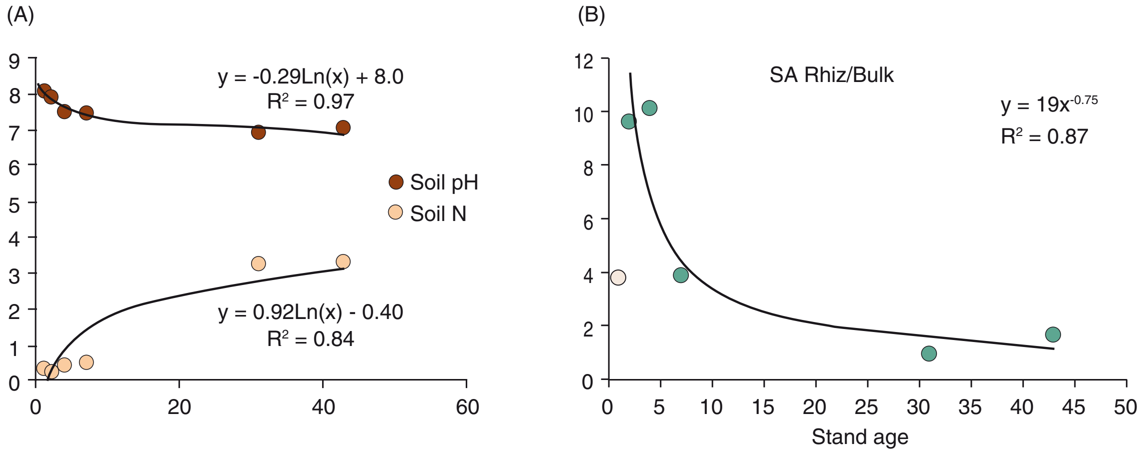

Fig. 1. (A) Dynamics of soil pH and N %, and (B) of summed bacterial activity (SA) ratio SA_{Rhiz}/SA_{Bulk} in chronosequence of silver birch stands growing on abandoned oil shale mining area.

Tree and understorey fine root growth and longevity in a Norway spruce stand in northern Finland

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Tree and understorey fine root growth and longevity was determined by minirhizotrone research in northern Finland. The study was made in a 70-year-old Norway spruce stand, growing on a mesic mineral soil site in the Kivalo experimental forest. Three replicate plots were established, and three vertical minirhizotron tubes installed in June 2003 in soil of each of the three plots. The images were taken at monthly intervals (altogether 11 sessions) during the growing seasons 2004, 2005 and 2006. The lengths, diameters and status (new, living, dead, disappeared) of Norway spruce and understorey (mainly shrub) fine roots were recorded, and statistical analyses carried out.

Our data indicates that there were more new roots growing in the upper soil depths (the organic layer) than in the lower soil depths (mineral soil). The growth rate seemed to be highest in late summer (August). Regarding root longevity, both trees and understorey showed the same trends by months and soil depths; root longevity was found to be greater for those roots which were born late in the growing season (August) relative to roots born early in the growing season (June). Furthermore, monthly trends of new roots born versus their death and disappearances by soil depths are also discussed.

Biogeochemistry of tropical benthic microbial mats: diurnal changes in phosphorus partitioning and availability in mat vertical structure

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Belizean wetlands are part of a phytogeographically related group of limestone-based marshes that cover extensive areas of the Caribbean. Apart from sparse stands of macrophytes, these systems are dominated by benthic cyanobacterial mats, in which a variety of microbial functional groups forms a structural and physiological unit. We chose cyanobacterial mats from a shallow freshwater location in northern Belize as a model system for studying processes related to P cycling in microbial consortia. The mats at our study site covered more than 80% of sediment surface and were up to 5 cm thick. Three conspicuous layers were distinguishable optically in the mat vertical profile. Microscopic and pigment analyses revealed that cyanobacteria dominated the upper yellow and middle green layer, while most of the chlorophyll *a* was concentrated in the topmost 8 mm. The bottommost red layer, in contact with sediment surface, constituted mainly of anoxygenic phototrophs. Microbial cells were embedded in a matrix of extracellular polymeric substances (EPS) and autigenic crystals. *In-situ* microelectrode measurements showed marked diurnal changes of dissolved O_2 concentration, redox potential, and pH. During the day, O_2 penetrated the first 25 mm and the entire yellow mat layer (top 15 mm) experienced oxygen supersaturation. The entire mat turned anoxic during the night. The pH ranged between 7 and 9.5 diurnally in the top two layers, the red layer remained at approximately neutral values.

The concentration of P and main ions was measured in mat pore water (PW) and particulate matter. In the latter case, sequential chemical fractionation of twelve (4 mm thick) vertical layers was employed, with the following steps: 1M $MgCl_2$ (exchangeable and loosely bound inorganic P), 0.1M Bicarbonate Dithionate (BD – Fe-bound/ redox labile P), 0.1 M NaOH (organically bound P), 1M Na-Acetate (autigenic apatite), 0.5 M HCl (detrital apatite), 1M NaOH 85°C (refractory organic P). Total P (TP) content was extremely low and ranged between 0.025 and 0.1 mg P g DW^{-1}, depending on mat layer. Soluble reactive P (SRP) constituted 58% and the non reactive P (NRP) 42% of this amount. The three optically distinguishable layers corresponded well with diurnal partitioning of P forms. In contrast to the rest of the mat, no differences in P partitioning were detected within the red layer, probably due to the absence of diurnal pH and O_2 changes and low microbial metabolic activity (microscopic evaluation revealed an abundance of *Rhodocista* sp. resting stages or cysts). Exchangeable and loosely bound P ($MgCl_2$ fraction) constituted the largest proportion of P pool during both day and night (28% and 35% of TP respectively). This fraction also exhibited largest diurnal changes: day TP_{MgCl2} conc. (0.016 mg g DW^{-1}) increased more than twice (0.04 mg g DW^{-1}) in the yellow layer; on the contrary, day TP_{MgCl2} concentration decreased markedly from 0.018 to 0.005 mg g DW^{-1} in the green layer during the night. Similarly, diurnal changes affected the composition of $MgCl_2$ fraction: The SRP concentration increased from 72% to 90% of TP_{MgCl2} during the night in the yellow layer, while a decrease from 96% to 30% was observed in the green layer. Na-Acetate fraction contained 25–30% of TP on average, during both day and night. Although the mats were found to be low in Fe content (0.64–2.28 mg g DW^{-1}), the concentration of Fe-bound P was not negligible (8% TP during the day and 13% during the night). Total organically bound P increased by 8% during the night, which indicates increased microbial P uptake. The HCl and NaOH 85°C fractions did not show any diurnal changes. Phosphorus partitioning and its potential availability for microbial uptake seem to be determined by diurnal changes of physicochemical gradients. Largest shifts of P among the different fractions were detected in layers experiencing largest pH fluctuations and at the oxic/anoxic boundary. EPS likely plays an important role in release/retention of inorganic and organic loosely bound P and hence may significantly influence its availability for microbial uptake.

The curious effects of mycorrhizas on the plants of the unique Jarrah forests of Western Australia

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Mycorrhizas are a vital symbiosis for many plants of the mega-diverse western Australian Jarrah forests. The soils of the Jarrah forest are ancient and phosphorus is the key limiting nutrient because it is sparingly available in the highly weathered (Fe/Al rich) regolith. Despite the P-fixing nature of many WA soils, phosphorus can become toxic to some functionally important native (and endemic) Australian trees, including the Jarrah tree itself (Eucalyptus marginata). Mycorrhizas seem to have a curious and sometimes unexpected effect on the nutrition and growth of their host plants in these soils and ecosystems that will be reviewed in my paper.

Many Western Australian tree species form dual symbioses with both ecto- and arbuscular mycorrhizal fungi, with AM relationships being prevalent in seedlings. In this presentation I will explore recent evidence that arbuscular mycorrhizas have an important role in regulating plant P uptake in the early stage of tree growth and that managing soils for early AM symbiosis may be important for some P sensitive plants.

An ecologically important aspect of arbuscular mycorrhizal symbiosis is the proliferation of mycelial networks that colonise the roots of more than one plant, thereby forming a belowground network linking (potentially) numerous plant roots with common fungal hyphae. In this presentation I will examine whether the presence of an established network of common mycorrhizal hyphae would affect the emergence of seedlings of key species from the Jarrah forests. I will also examine the capacity of mycorrhizas to both enhance P uptake in low P soils and protect against toxicity in high P soils.

Multi-level effects of increased ammonium fluxes in peatlands: a rhizotron approach

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An increased influx of ammonium (NH_4^+) is known to affect a number of different important biogeochemical and ecological processes in peatlands. Firstly, nitrogen is an important nutrient for plant growth, potentially limiting biomass production. Therefore, increasing concentrations can lead to the outcompetition of slow growing or small plant species by a few fast growing species. Secondly, NH_4^+ may become toxic for sensitive plant species at high concentrations in soil pore water. In addition, the decomposition of peat can be influenced by NH_4^+, as a higher nutrient availability often leads to increased decomposition rates. The aim of this study was to investigate the effects of increased availability of NH_4^+ at these different levels in a peatland ecosystem, and the interactions between these levels.

To be able to study these effects under controlled conditions, a large-scale rhizotron experiment was set up to investigate the effects of a high or low NH_4^+ concentration on plant species differing in functional traits and their interactions with peat biogeochemistry. By using rhizotrons (each with a volume of 175 L) it was possible to study the interactions between aboveground vegetation and root growth, peat biogeochemistry, rhizosphere and atmosphere (Fig. 1). At the start of the experiment, *Juncus acutiflorus* and *Carex disticha*, separately or in a mixture, were grown on waterlogged peat soil, with or without added NH_4^+. A similar set-up, without plants, was used as a control. From earlier experiments it was known that *J. acutiflorus* has strong Radial Oxygen Loss (ROL) from its roots, which enables this species to survive under anaerobic conditions, while *C. disticha* has much lower ROL and periodically needs aerobic conditions.

It was expected that the differences in the capacity and pattern of ROL will strongly influence NH_4^+ levels in the sediment by stimulating microbial NH_4^+ oxidation and coupled denitrification, and thus in higher nitrogen loss. In addition, both aerobic and anaerobic decomposition may be stimulated at high ROL and increasing NH_4^+ levels. It was additionally hypothesized that in mixed cultures, plants with high ROL can facilitate species with low ROL by preventing adverse anaerobic conditions and potential toxic levels of NH_4^+.

Fig 1. The rhizotron set-up

The first results showed that both in the non-vegetated rhizotrons and in those including low ROL plants, NH_4^+ accumulated to high levels, while NH_4^+ levels stayed low in the high ROL vegetation and the mixed vegetation. The growth of *C. disticha* appeared to be N-limited in contrast to that of *J. acutiflorus*, without signs of potential toxicity. In addition, the carbon flux to the atmosphere was stimulated at high NH_4^+ levels, increasing the net carbon source the *Juncus* vegetation already was and converting the *Carex* vegetation from a net carbon sink to a net carbon source.

Stable carbon and oxygen isotopes as an indicator for soil degradation

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Analyses of soil organic carbon content (SOC) and stable carbon and oxygen isotope signatures ($\delta^{13}C$) of soils were assessed for their suitability to detect early stage soil erosion. Results were validated with Cs-137 measurements. We investigated the soils in the alpine Urseren Valley (Southern Central Switzerland) which are highly impacted by soil erosion. Hill slope transects from uplands (cambisols) to adjacent wetlands (histosols and histic to mollic gleysols) differing in their intensity of visual soil erosion and reference wetlands without erosion influence were sampled. Carbon isotopic signature and SOC content of soil depth profiles were determined. A close correlation of $\delta^{13}C$ and carbon content ($r > 0.80$) is found for upland soils not affected by soil erosion, indicating that depth profiles of $\delta^{13}C$ of these upland soils mainly reflect decomposition of SOC. Long term disturbance of an upland soil is indicated by decreasing correlation of $\delta^{13}C$ and SOC ($r \leq 0.80$) which goes parallel to increasing (visual) damage at the site. Early stage soil erosion in hill slope transects from uplands to adjacent wetlands is documented as an intermediate $\delta^{13}C$ value (-27.5‰) for affected wetland soil horizons (0–12 cm) between upland (aerobic metabolism, relatively heavier $\delta^{13}C$ of -26.6‰) and wetland isotopic signatures (anaerobic metabolism, relatively lighter $\delta^{13}C$ of -28.6‰). Cs-137 measurements confirmed stable isotope analysis.

Stable oxygen isotope signature ($\delta^{18}O$) of soil is the result of a mixture of the components within the soil with varying $\delta^{18}O$ signatures. Thus, $\delta^{18}O$ of soils should provide information about the soil's substrate, especially about the relative contribution of organic matter versus minerals. As there is no standard method available for measuring soil $\delta^{18}O$, the method for measurement of single components using High Temperature Conversion Elemental Analyzer (TC/EA) was adapted. We measured $\delta^{18}O$ in standard materials (IAEA 601, IAEA 602, Merck Cellulose) and soils (organic and mineral soils) in order to determine a suitable pyrolysis temperature for soil analysis. We considered a pyrolysis temperature suitable when the yield of signal intensity (mass 28 per 100 µg) is at a maximum and acquired raw $\delta^{18}O$ signature is constant for used standard materials and when the quartz signal from the soil is still negligible. After testing several substances within the temperature range of 1075 to 1375 °C we decided to use a pyrolysis temperature of 1325 °C for further measurements. For the Urseren Valley we have found a sequence of increasing $\delta^{18}O$ signatures from phyllosilicates to upland soils, wetland soils and vegetation. Our measurements show that $\delta^{18}O$ of upland soil samples differ significantly from wetland soil samples. The latter can be related to changing mixing ratio of mineral and organic constituents of the soil. For wetlands affected by soil erosion, we have found intermediate $\delta^{18}O$ signatures which lie between typical signatures for upland and wetland sites and give evidence for input of upland soil material through erosion.

To conclude, carbon isotopic signature and SOC content are found to be a sensitive indicator of short and long term soil erosion processes. Regarding stable oxygen isotopes, we consider $\delta^{18}O$ to have potential as a suitable tracer for soil erosion in transects from upland to wetland soils. However, soil erosion detection with $\delta^{18}O$ needs to be verified at other sites with differing geology, climate, altitude and vegetation to acquire an even broader understanding of $\delta^{18}O$ of soils.

Complex responses to dissolved organic carbon dynamics to acidification in organic soils

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Organic soils represent an important store of carbon; recent work suggests these stores may be destabilising, with an increase in dissolved organic carbon (DOC) in (European) surface waters over the last few decades. Whilst increased global temperatures, CO_2 and drought frequency are likely to be producing an increase in primary productivity and organic matter decay in organic soils, these hypotheses cannot quantifiably account for the measured increases in DOC. Rather a coincident decline in acid sulfate deposition across parts of Europe may influence an important control on the solubility of DOC, yet little attention has been given to the apparent inverse trends in sulfate and DOC concentrations in some organic soil systems. Here, we describe laboratory experiments, which use $^{34}SO_4$ tracer techniques to better understand sulfur biogeochemistry and constrain the relationship between sulfur and DOC cycles in organic soils.

Long-term laboratory mesocosms are ongoing; living peat and organic podsol cores from Plynlimon, Wales, have been kept under controlled conditions (10ºC, 12 hour artificial sunlight) and treated with artificial rainwater solutions for 18 months. Triplicate cores were treated with (1) control rainwater (based on modern deposition data); (2) high acid sulfate rainwater (based on peak acid sulfate deposition, 1989); (3) high acidity rainwater (as for 2, additional sulfate omitted). All rainwaters contained a 99.9% pure $^{34}SO_4$ tracer as part of the basic chemistry. Regular sampling of peat and podsol soil waters allows a comparison of the soil biogeochemistry under varying acid (and acid sulfate) loadings.

Data suggest that acid deposition does affect the release of DOC to soil water, with higher acid loadings inhibiting DOC release (treatment 2); but that this effect is moderated by the activity of sulfate reducing bacteria where acid inputs are associated with sulfate (treatment 3). Reduction of sulfate to sulfide during bacterial sulfate reduction attenuates acidity, provided that sulfur can be permanently stored in reduced form (e.g. FeS). ^{34}S analyses show that physical removal of acid sulfate by conversion to sulfide and precipitation at depth occurred during the experiments, with the ^{34}S tracer detectable in inorganic sulfur phases.

The effect of enhanced bacterial sulfate reduction under acid sulfate treatments on DOC dynamics is both chemical, with the attenuation of acidity during bacterial sulfate reduction increasing DOC solubility, and biological, through stimulation of the wider microbial ecology and further production of DOC. This has important implications for the assumption that acidification has had a negative chemical effect on DOC solubility, and the prediction of future DOC trends under recovery from acidification.

Partitioning sources of respiration in peatlands cultivated with a bioenergy crop

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Climate warming due to increased amount of radiatively active atmospheric greenhouse gases is among the most serious problems linked to anthropogenic activities and future of the globe. One of the strategies to reduce CO_2 concentrations is to increase the use of renewable energy. In Finland, the cultivation of reed canary grass on cut-away peatlands for bioenergy use is expanding exponentially. To estimate the true value of reed canary grass as a bioenergy crop, the greenhouse gas dynamics of the ecosystem have to be known.

The greatest part of CO_2 fixed through photosynthesis eventually returns to the atmosphere through respiration. Ecosystem respiration consists of plant-derived and soil-derived respiration (autotrophic vs. heterotrophic respiration). The major challenge is to differentiate the CO_2 released from soil from that associated with root respiration. Estimating the amount of CO_2 released from soils is crucial since soils, especially organic ones like peat soils, store huge amounts of carbon and are thus especially critical for soil carbon losses under cultivation.

In 2006, we applied two partitioning approaches to separate sources of respiration in a cut-away peatland cultivated with a bioenergy crop located in Eastern Finland: component integration (including root trenching), and carbon isotopic (^{13}C, ^{14}C) methods (Kuzyakov 2006). Component integration revealed that the largest portion of ecosystem respiration is derived from the plants (> 50 %), while soil respiration component is smaller. The contribution of old peat in respiration was assessed by radiocarbon dating of CO_2 respired. It was varying over the season with relatively higher contribution of peat decomposition at the end of the growing seasons. Cultivated cut-away peatlands offer a unique possibility to study the fate of old peat, since the surface soil is very old and the plants carry a modern ^{14}C signature. Since CO_2 emissions were also measured in unplanted bare peatlands, the priming effect (increased/decreased decomposition of organic matter as a result of plant establishment) was studied. By applying a ^{13}C approach we also calculated that in 2006, after a liming event, about 5 % of the annual CO_2 losses from soil originated from abiotic lime (Biasi et al., 2008). In the presentation, the advantages and disadvantages of the different partitioning approaches, results on respiration components and implications for the priming effect will be discussed.

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New isotopic approaches to understanding aquatic carbon release from northern peatlands

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It is now known that significant amounts of carbon are released from peatlands in the form of DOC and evasion CO_2 and the inclusion of both flux terms can have a significant affect on the sink/source relationships of the peatland C budget. The same also applied to POC in highly impacted systems. Recent developments in the use and application of C isotopes, now means that the age and source of C released via surface waters draining peatlands (as evasion CO_2 and DOC) can be measured routinely. We present dual isotope ($\delta^{13}C$ and ^{14}C) data from both UK and contrasting forested Finnish peatlands, which shows significant differences in the source and age of carbon released from peatlands to the aquatic system.

Whilst the isotopic measurement of DOC (and POC) in freshwaters presents few methodological challenges, determination of the isotopic composition of CO_2-C in surface waters has in the past relied upon indirect methods. These make a number of underlying assumptions about the equilibrium dynamics of DIC in surface water. We have developed a new, direct, field-based method, using a molecular sieve trapping system attached to a floating chamber, to collect sufficient evasion CO_2-C for AMS radiocarbon analysis (Billett et al. 2006). This allows us to measure the isotopic composition of both these important flux components (DOC and evasion CO_2) of the peatland C budget.

Data from four UK peatlands show that while the age of DOC released in the drainage system of peatlands is consistently young (modern to 202 years BP), the age of CO_2 lost by the evasion flux pathway is often much older, varying from modern to 1449 years BP (Billett et al. 2007). $\delta^{13}C$ data also suggest that the sources of DOC and CO_2 are different. In contrast, recent isotopic measurements in the Välipuro (pristine) and Suopuro (partly drained) forested peatland catchments in Eastern Finland during the spring 2008 snowmelt event, show that both DOC and CO_2 are relatively young. However, there is some evidence to suggest that older CO_2-C is being released from the partly drained peatland during the low flow periods at both the beginning and end of the snowmelt event.

In summary, the development of new isotopic methods and their deployment in a range of peatland systems has produced evidence of clear differences in the internal cycling of C. Isotopic measurements also provide significant insight into the inherent stability of these important carbon repositories.

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Insights into sulfur cycling in lowland peats from novel sulfur isotope tracer experiments

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Six mesocosms were isolated in a lowland peatland with historically high pollutant S inputs (Thorne Moors, UK). A ^{34}S-sulfate tracer was regularly added to the surface of each mesocosm and mesocosms were sacrificed in pairs at 12, 24 and 48 weeks to determine distribution of tracer in solid phase components of the peat. In a second experiment triplicate mesocosms (21 total, including controls) were treated with the same ^{34}S-sulfate tracer but different acid supplements to recreate former pollutant loadings. The chemistry and tracer content of surface water and pore-water (sulfate and sulfide) were also analyzed.

The ^{34}S-sulfate tracer was rapidly removed from surface waters, though there was mass transfer both into and out of this sulfur pool at different times. The ^{34}S-sulfate tracer content in both sulfate and sulfide in pore-water from 25–35 cm depth shows near-continuous increase over the 48-week monitoring period. Deeper in the peat, pore-water sulfate shows a similar concentration of ^{34}S-sulfate tracer, but no migration into sulfide. This implies that bacterial sulfate reduction is highly suppressed at these depths in the peat. The chemistry of pore-water showed clear response (versus controls) to acid loading treatments. Results from these mesocosms (which will terminate in January 09) will also be presented.

The most significant uptake of ^{34}S tracer (5.7 to 33% of tracer added, mean 17.6%) was into vegetation. This occurs rapidly, as there was no trend to increased tracer in vegetation between 12 and 48 weeks during the experiment. There was also significant uptake of ^{34}S tracer (up to 25.6% of tracer added) into the organic fraction of shallower (<20 cm depth) peat. There was no uptake into the peat organic fraction below 20 cm depth despite penetration of ^{34}S-sulfate tracer to 55–65 cm depth. Sulfur reservoirs in the deep peat remain unreactive on timescales of 1 year.

Deducing climate signals from hydrogen and oxygen isotopes in *Sphagnum*

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Stable isotopes from precipitation are powerful proxies for climate reconstruction. However, they are difficult to assess, since unambiguous recorders are lacking. Many climate factors play a part in isotope fractionation: temperature, amount of precipitation and seasonality affect the isotope ratio's in precipitation. After fall out, isotope ratio's can rise through evaporation driven by temperature, humidity, cloudiness and wind. Furthermore, biochemical processes during the synthesis of different plant tissues may cause fractionation in the isotope ratio's.

Isotope ratio's from precipitation as registered in *Sphagnum* mosses from peatlands are a valuable, but highly complex signal. Detailed understanding and quantification of the factors that cause isotope fractionation is of great importance for application of stable isotopes in palaeoclimate studies. Developing a proxy for Holocene precipitation, we have studied the contribution of humidity to stable isotope fractionation in *Sphagnum* in detail.

In a greenhouse experiment, different species of *Sphagnum* were grown under controlled climate conditions. Fractionation of hydrogen and oxygen isotopes in the cellulose, lipids, and bulk material was determined for the *Sphagna*. Remarkably, hydrogen fractionation in the lipids significantly differs among the species. Differences are up to 50‰, which is as large as the difference in δD between precipitation from Holland and southern Sweden. On the other hand, oxygen isotope fractionation in cellulose is equal among all species, indicating that biochemical pathways diverge among the compounds of one single plant. Here, we shall present a comparison of the compounds and discuss their advantages and disadvantages for palaeoclimate reconstruction.

Furthermore, we have collected a set of *Sphagnum* field samples from European bogs with a large geographical spread. The isotope ratio's in the *Sphagna* are a fine record of the isotopes from precipitation: both show a decreasing gratient from south west to north eastern Europe. These isotope data were correlated to meteorological data. δD in *Sphagnum* appears to be a moderate proxy for precipitation. By new greenhouse experiments we shall try to calibrate and refine this proxy further.

Soil microstructure and the temperature response of soil respiration: a novel investigation using stable carbon isotopes and matric alteration

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Soil respiration represents a large (68 Pg C y^{-1}) (Raich and Schlesinger 1992) and temperature sensitive source of CO_2. Many regional soil carbon stocks have declined over the past decade, reflecting an increase in soil respiration relative to inputs and a net efflux of CO_2. Estimates of the potential positive feedback between soil carbon and climate change are largely based on measurements from disturbed bulk soils covering landscape-scale heterogeneity. However, most soils are also highly heterogeneous on a micro scale, and soil organic matter (SOM) consists of several different pools, cycling at different rates. Slow-cycling (decadal to millennial) soil organic carbon (SOC) make up an estimated 98% of total SOC (Jones et al. 2005), and any increased temperature sensitivity in these pools could be critical for establishing the magnitude of the soil carbon climate feedback loop. SOM stability is described in the literature as a combination of chemical recalcitrance, mineral interactions and physical protection. We focus here on the relationship between temperature sensitivity and physical protection of SOM, which is determined by the physical structure of pores and aggregates on a micro scale. We used soils from an agricultural site at Invergowrie, UK, with a known history of C3/C4 crop transitions, leaving a natural $\delta^{13}C$ tracer for SOM age. Intact soils were incubated under controlled pore saturation by matric alteration using pressure plates to isolate the temperature responses of SOM situated in micro-, meso- and macropores. 3-dimensional visualisations of soil structure were produced using x-ray micro-tomography, allowing estimation of size distribution of colonisable pore space. Fluxes and isotopic composition ($\delta^{13}C$) of CO_2 during incubations were measured using tunable diode laser adsorption spectroscopy.

This paper reports on preliminary findings of soil incubation studies examining spatial patterns in the temperature sensitivity of CO_2 evolution on a micro scale. The contribution of different ages of SOM to respired CO_2 at various temperatures and from a range of micro-spatial locations will also be considered. Overall the influence of soil structure and temperature on gaseous emissions of CO_2 will be evaluated.

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Assessing sources of nitrate in the Bow River, Alberta, Canada using hydrological, chemical and isotopic techniques

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The Bow River in Alberta is a major tributary to the South Saskatchewan River in western Canada. The river provides drinking water for many cities and municipalities as well as irrigation water for agriculture in the Bow River Basin. Urban development and agricultural activities including feedlot operations within the Bow River Basin can potentially impact the river water quality by elevating nitrate concentrations. Treated sewage effluent, storm water and agricultural return flows constitute potential sources of nitrogen input to the Bow River and agricultural return-flows via tributaries and irrigation canals may have significant impact on water quality. Although the importance of protecting the Bow River is acknowledged by the government and citizens of Alberta, concerns about a future deterioration of the quality of the Bow River cannot be effectively addressed without a conceptual understanding of the sources and processes that control potential water contaminants. In this project, we combined hydrological, chemical and isotopic techniques with the objective to identify sources of nitrate in the Bow River.

The study area stetches approximately 570 km along the Bow River from Lake Louise in the Rocky Mountain headwaters in the west to about 20 km upstream from its confluence with the Oldman River in the prairie region of southeastern Alberta. Between June 2007 and July 2008, monthly samples were taken from the Bow River for major ion chemistry and stable isotope ratio measurements of H_{water}, O_{water}, C_{DIC}, N_{NO3}, O_{NO3}, S_{SO4} and O_{SO4}. Flow data from Alberta Environment were used in combination with chemical analyses to estimate fluxes of nitrate and other ionic solutes at six sampling sites along the river. The isotopic composition of nitrate was used to identify the sources that caused significant increases in riverine nitrate fluxes in the basin.

Preliminary results show that background nitrate fluxes in the pristine headwaters of the Bow River near Lake Louise are typically below 700 kg/day (as NO_3). Samples obtained from the Bow River near Lake Louise were characterized by $\delta^{15}N$-NO_3 values between -0.4 and 2.1‰ and $\delta^{18}O$-NO_3 values between 7.5 and 11.3‰ falling within the range typical for nitrate produced by ammonification and nitrification in natural forest ecosystems. Leaching from the organic rich top soil horizons particularly during snowmelt periods appears to be the preferred pathway by which soil-derived nitrate is introduced to the Bow River in the headwater region. Between Lake Louise and Calgary, the Bow River flows through a number of municipalities and towns in the Rocky Mountains and foothills region. Within this 200 km stretch the nitrate fluxes are somewhat elevated with typically less than 10,000 kg/day, while $\delta^{15}N$-NO_3 increased to values between 3.5 and 7.4‰, and $\delta^{18}O$-NO_3 decreased to values as low as -1.5‰. Below the two waste water treatment plants of Calgary, a city with 1 million inhabitants, and in the irrigation districts of the prairie region, further increased nitrate fluxes between 10,000 and 30,000 kg/day were observed with $\delta^{15}N$-NO_3 values ranging between 6.0 and 11.4‰ and $\delta^{18}O$-NO_3 values varying between 0.0 and -12.0‰. Elevated $\delta^{15}N$-NO_3 values and low $\delta^{18}O$-NO_3 values indicated a mixture of manure and waste water derived nitrate, with nitrate in effluents from Calgary's major waste water treatment plant having the lowest $\delta^{18}O$ values. In order to better delineate urban and agricultural sources of nitrate and their fate within the Bow River, other stable isotope tracers are currently being used since they can further assist in tracing important hydrogeological processes, sources of the riverine water, and biogeochemical reactions.

Zinc Isotopic Ratios as Tracers of Zn Biogeochemical Cycle

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Excessive Zn uptake from polluted substrates is the first step for foodweb contamination. Plant roots absorb zinc as an essential nutrient from their aqueous environment. Zinc speciation in solid and liquid phases could supply more information about contamination risk for plants. Zinc isotopic ratios are a new and sensitive tool to trace the Zn biogeochemical cycle

This study focuses on zinc isotopes in the solid and liquid phases of three polluted substrates: (1) a slag deposit (SD) from a metallurgical industry, (2) a calcareous soil (CaS) and (3) a shale-derived soil (ShS), the last two both contaminated by aerial fallout. Fine earth fractions (fef, < 2 mm) were obtained by dry sieving. Solutions were collected *in situ* under organic (O) and organo-mineral (Ah) horizons. Shoots of plants growing on those substrates were also sampled. After zinc purification by a novel chromatographic method performed on micro-columns (Zn blanks ≤ 2ng), the values of the Zn isotopic ratio (δ^{66}Zn) were measured on a Nu Plasma MC-ICP-MS.

Determination of the isotopic ratios on fef showed that SD was richer in heavy isotopes (0.35–0.60 ‰) than soils contaminated by aerial fallout (0.09–0.34 ‰), in agreement with the known effect of the industrial Zn extraction process. In soils, enrichment in heavy Zn isotopes was observed from O horizon (0.09–0.18‰) to Ah horizon (0.18–0.34‰), suggesting a larger mobility of light isotopes in O horizons than in Ah horizons. Exchange processes induced light Zn isotopes enrichment in soil solution, especially in solutions leached from O horizons. Plant uptake involved mainly heavy Zn isotopes and was therefore associated with depletion of heavy Zn isotopes in soil solutions. Finally, isotopic ratio of bedrocks influenced δ^{66}Zn in fef of deep soil horizon. In CaS, there was a transfer of heavy Zn isotopes from bedrock to deepest soil horizon; whereas in ShS, there was transfer of light Zn isotopes.

Zn isotopic fractionation is highly useful to study the mobility of zinc in the soil-plant cycle.

Role of calcium-oxalate in controlling calcium isotope fractionation in plants

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Ca isotopes ($^{44}Ca/^{40}Ca$) are increasingly being used to understand forest Ca cycling, although there remains much to learn about processes controlling Ca isotope fractionation in plants. For this study, we hypothesized that the formation of Ca-oxalate in foliar tissues fractionates Ca isotopes and contributes to Ca isotope variation observed in plants. We first synthesized Ca-oxalate from an aqueous solution in the laboratory and determined a fractionation factor ($\alpha_{\text{Ca-oxalate-aqueous Ca}}$) ~ 0.998 to 0.999 (Fig. 1), confirming that Ca-oxalate is isotopically light relative to coexisting aqueous Ca. We then sampled Douglas-fir (*Pseudotusga menziesii*) needles at two sites in the Coast Range of Oregon that differed in Ca-oxalate concentrations both among sites and across needle age classes, consistent with differences in soil Ca status. We used a chemical sequential extraction technique (water, 2*N* acetic acid, 2*N* hydrochloric acid) to isolate soluble-Ca, structural-Ca and Ca-oxalate foliar pools, respectively. We found that Ca-oxalate fractions contained isotopically light Ca relative to other pools, although the isotopic contrast decreased with increasing foliar age (Fig. 2). Moreover, isotopic mass balance calculations revealed that the high-Ca and low-Ca sites had similar bulk leaf $\delta^{44}Ca$, but that the isotopic contrast between the soluble-Ca and Ca-oxalate fractions was greater at the low-Ca site (Fig 2). These preliminary results suggest that foliar Ca oxalate dynamics are an important control of plant Ca isotope signatures, and may be useful in assessing Ca deficiency in plant-soil systems.

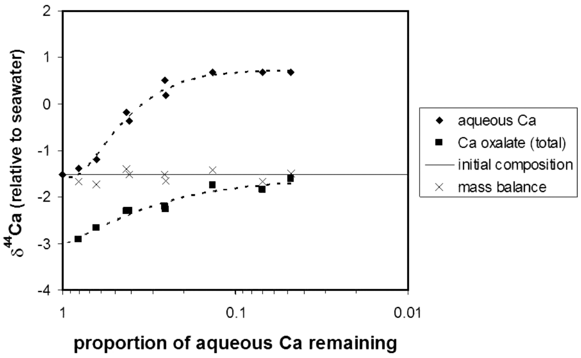

Fig 2. δ^{44}Ca of sequential extractions plotted versus foliar age for samples collected from high Ca (A) and low Ca (B) sites. Preliminary bulk-leaf isotopic mass balance compositions (X) were calculated using measured values for extraction components.

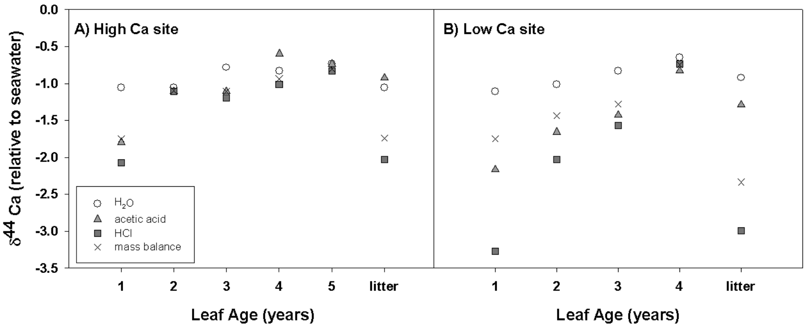

Fig. 1. Experimental precipitation of Ca-oxalate. δ^{44}Ca of filtered aqueous solution (diamonds) and total Ca-oxalate on filters (squares) is plotted versus proportion of Ca remaining in the solution, representing a 2880 minute time course. The system mass balance (X) at each time point, calculated using measured values for aqueous Ca and Ca-oxalate, is identical to the composition of the initial aqueous solution.

Use of lead isotopes as a marker for organic matter mobilisation

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Upland organic soils are sensitive to changes in management, climate or pollution (Holden et al., 2007). Mitigation of soil organic matter losses to surface waters requires sustainable solutions as part of management "best practice". Such losses impact on freshwater biodiversity and have economic consequences for potable waters (Dawson & Smith, 2007). Understanding of how hydrological and biogeochemical processes interact to underpin sustainable management strategies is often poor (Tetzlaff et al., 2007).

This study describes the development of a technique that exploits the use of naturally occurring lead isotope ratios as a tracer for organic matter transport from soils to surface waters as dissolved organic carbon (DOC) and particulate organic carbon (POC) at a managed peatland in upland Wales, UK. Two catchments with differing management regimes have been chosen: A) a treated site with drainage channels (grips) blocked with heather bales in spring 2008 and B) a control site with unblocked drainage channels.

Lead isotopic ratios change down peat profiles as a consequence of past deposition from a variety of sources such as leaded petrol, coal burning and metal smelting (Bacon & Hewitt, 2005). The majority of lead binds strongly to organic matter, which is subsequently exported to surface waters as DOC and POC. Thus lead isotopic ratios in the DOC and POC fractions of both soil and surface waters may provide a tool to ascertain the provenance of soil OM in fluvial exports.

During 2008, three separate visits to assess variability in organic matter transport under different hydrological conditions were undertaken. Soil cores, soil pore-waters at 10, 30 and 70 cm and contiguous downstream samples were obtained from the vicinity of moorland drainage channels on each occasion. The carbon content, isotopes of lead, total lead and other heavy metal concentrations were determined for each sample. Data will be presented from the two catchments to assess the applicability of the technique for describing organic matter losses under different hydrological and management regimes. This will aid understanding of environmental and management issues that control hydrologically mediated organic carbon losses implicated in (dis)colouration of water and diffuse pollution (heavy metals) enhancing sustainable use of natural resources and landscapes in the future.

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Seasonal stimulation of the decomposition of organic matter in tropical soils

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In tropical areas, the succession of dry and wet seasons drives the input of plant organic matter into soils. The beginning of rain seasons induces a large release of fresh and labile organic matter. This seasonality of inputs affects the activity of decomposers as it temporary enhances microbial activity and increases the decomposition of soil organic matter (SOM). We suspect this phenomenon to be extremely important in the coastal areas of Congo where eucalyptus are grown on very poor sandy soils. The mechanisms of the changes in SOM dynamics caused by discontinuous substrate input remain controversial. Some authors have suggested that decomposer activation would be sequential. Fast-growing species would first grown on easily available plant substrate whereas slow-growing communities able to use recalcitrant soil organic matter would benefit from the enhanced activity of the first ones and outcompete them in a later stage (Fontaine *et al*., 2003; Blagodatskaya *et al.,* 2007).

A laboratory experiment based on the natural differences in carbon isotopic composition between savannah and eucalyptus derived organic matter was designed and coupled innovative isotopic techniques so as to check this assumption of microbial community succession after substrate input. We sampled soil in 16 year and 8 year Congolese eucalyptus plantation and assumed that it was less easy for decomposers to feed on the savannah derived organic matter than the eucalyptus one. The soils were incubated after glucose substrate addition. Very high frequency measurements of the isotopic composition of the CO_2 were combined with specific compounds analyses so as to capture the potential succession of micro-organisms feeding on different quality substrates. The isotopic composition of the mineralised CO_2 evolving from the incubated soils was continuously monitored over 45 days with a tunable diode laser (TDL) beam. These high time resolution data allowed to quantify the increase in organic matter decomposition and to determine the savannah or eucalyptus origin of the mineralised organic matter. Stable isotope analyses of PLFA biomarkers were performed by gas chromatography-isotope ratio mass spectrometry (GC-IRMS) so as to related temporal changes in the nature of the decomposed organic matter to changes in the active microbial communities.

A transient acceleration of internal microbial metabolism based on cell-stored compounds was recorded during the first hours of the experiment. A switch of microbial metabolism on quickly utilisable organic carbon was then observed. After few days, when the most easily substrate was consumed the activated decomposers utilized soil organic compounds of lower availability, sequentially eucalyptus and then savannah derived. Thus, as a result of the marked seasonality, decomposition of SOM in Congolese Eucalyptus plantations appeared strongly controlled by the succession of contrasting decomposer activities.

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The fate of N_2O in a Norway spruce forest soil investigated by concentration and isotope profiles

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Nitrous oxide (N_2O) is a potential and long-lasting greenhouse gas of the atmosphere. The atmospheric N_2O concentration currently increases by about 0.3% per year and reached 319 ppbv in 2005. With a contribution of about 70% soils act as the main source for atmospheric N_2O. Soil N_2O emissions originate from microbial nitrification and denitrification, with the latter process also potentially being able to consume N_2O. Both processes are mainly driven by soil temperature, soil moisture and substrate availability. Changes in meteorological conditions as predicted for the future are, therefore, expected to affect N_2O emissions from soils.

In this study we investigated effects of experimentally induced drying/rewetting and freeze/thaw events on soil N_2O emissions in a mature Norway spruce forest in the Fichtelgebirge (NE Bavaria, Germany). Drought was induced by roof constructions and freezing by snow removal. The experiments were run in three replicates each. Non-manipulated plots served as controls. In addition to N_2O flux measurements between soil and atmosphere we analysed N_2O concentrations and stable isotope signatures ($\delta^{15}N_{N2O}$ and $\delta^{18}O_{N2O}$) in soil air collected along soil profiles. The latter approach provides information on localisation of N_2O sources and sinks as well as identification of N_2O production and consumption processes.

Drought reduced the N_2O emission from the soil or even turned the forest soil temporarily to an N_2O sink. N_2O emission peaks after rewetting could not compensate for the drought effect. Soil frost caused a burst of N_2O emission.

Soil air N_2O concentration and stable isotope profiles provide a new and hitherto scarcely considered mechanistic explanation for all of these observations. N_2O concentration in the soil air decreased in most cases exponentially from the subsoil to the soil surface. This observation identifies microbial activity in the subsoil as an additional source for N_2O and diffusion to the soil surface along a concentration gradient. A shift in the N_2O isotope signature along the concentration gradient towards increasingly positive δ values indicates, furthermore, a simultaneous microbial N_2O consumption (reduction to N_2). Drought reduced the source strength of the soil for N_2O while simultaneously the sink function of the topsoil for N_2O remained active. Both of these factors resulted in a temporary occurrence of below-atmospheric N_2O concentrations in the air of the topsoil and thus a soil sink function for atmospheric N_2O under severe drought. Frost in the topsoil was the only exception for these trends in N_2O concentration and isotope signature. Under conditions of soil frost the topsoil served no longer as a sink for N_2O, thus leading to the observed burst in N_2O emission.

The until now almost unconsidered sink function of soils for N_2O sheds a new light on the hitherto poorly resolved global N_2O budget. We suggest the consideration of a soil N_2O sink function for future model calculations on global N_2O budgets.

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Visualization and quantification of the C-N-S transfers by soil engineers using NanoSIMS

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Soil organisms, by changing soil physical properties, are efficient engineers that play a key role on the soil nutrient dynamics but their biological processes at the micrometric scale are still misunderstood. The nano-scale secondary ion mass spectrometry (NanoSIMS) is a new tool in the study of biophysical interfaces in soils. Its main advantage over other SIMS ion microprobes is its ability to operate at high mass resolution, while maintaining both excellent signal transmission and high spatial resolution (down 50 nm) (Herrmann *et al.*, 2007). Based on this new technology, the aim of this study was to visualize at the micrometric scale the soil biostructures that the engineers create, and to quantify the transfers of carbon (C), nitrogen (N) and sulphur (S) deriving from two soil engineers, *Eriophorum angustifolium* (a vascular plant) and *Lumbricus rubellus* (an epi-anecic earthworm).

Soil engineers were first triple labelled with isotopic tracers (^{13}C, ^{15}N and ^{34}S) prior to introduction into unlabelled peat mesocosms for 24 days. Then, the mesocosms were embedded in a polyester resin to carry out the NanoSIMS analysis (NanoSIMS 50™; Cameca, Gennevilliers, France).

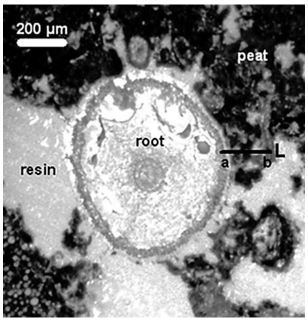

Fig. 1. Root and its rhizosphere embedded in the resin (image achieved by optical microscopy)

Representative peat samples of the plant activity (root pore-linings, Fig. 1) and earthworm activity (burrow-linings) which correspond to their functional sphere (rhizosphere and drilosphere, respectively) are currently under analyzes. We will thus visualize the extent the different tracers distributed across from the root pore-linings and the burrow linings to the surrounding bulk peat. We will also assess the linkage of both elements with the soil micro-architecture of these two biophysical interfaces by using the line-scan technique (Fig. 2). Isotopic compositions will be also determined by using image processing with the ImageJ software (W.S. Rasband, US National Institutes of Health) and thus enriched areas in the peat soil will be then identified.

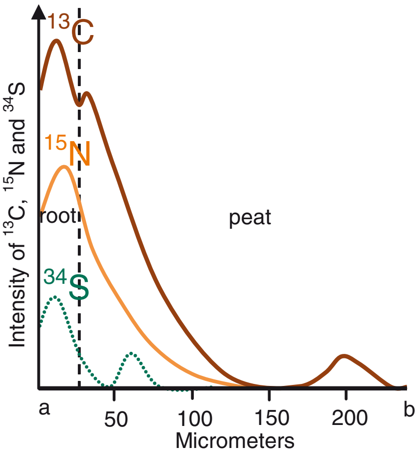

Fig. 2. Example of expected Line-scan data of ^{13}C-^{15}N-^{34}S. The trace of the line-scan (L) is depicted in Fig. 1

This study will show how the NanoSIMS tool coupled with isotopic tracers bring out new understandings of the impact of soil engineers on the nutrients and thus their ability in sustaining hot spots of microbial activity in peat.

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δ^{34}S-DOS as a tracer to separate different sources of DOM in freshwater and marine ecosystems

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The discharge of terrestrial dissolved organic matter (DOM) by streams is an important cross-system linkage that strongly influences the aquatic ecosystems. The identification of the different terrestrial landscape compartments and their relative influence on the DOM export is thus a key issue in understanding the export of DOM. Also, one of the big unsolved issues in global organic carbon budgets is the fate of terrestrial DOC in the oceans. Here we show that the use of δ^{34}S-DOM is a potential tool that can separate and identify terrestrial and marine end-members We present results on the spatial and temporal variation of δ^{34}S in DOM in ten boreal streams to test if it could provide new insights to the origin of DOM. We also show results from marine estuaries in Norway and Sweden on δ^{34}S values in DOM and POM. We found large variations in stream water δ^{34}S-DOM values ranging from -5.2‰ to +9.6‰ with an average of +4.0±0.6 (N=62; average and 95% confidence interval) (Giesler et al. 2009). Large seasonal variations were found in stream water δ^{34}S-DOM values with a shift of more than 10‰ during the spring snow melt in a wetland dominated stream. We also found spatial differences during the winter base flow with higher δ^{34}S-DOM values in the 4th order stream at the outlet of the 68 km^2 catchment compared to the small (<1 km^2) headwater streams. Variations in estuarine DOM and POM ranged between +9.3 and +17.6‰ and suggests mixing of terrigenous DOM with marine DOM (Alling et al. 2008). Our results allow us to quantify the terrestrial part of the bulk OM in estuaries, which is a prerequisite for future C budgets of key areas receiving vast amounts of permafrost derived C with global warming. Our data also clearly shows that the δ^{34}S-DOM values have the potential as a tracer to identify and generate new insights to terrestrial DOM sources in the boreal landscape.

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Investigations of sphalerite oxidation mechanisms with oxygen and sulphur isotopes

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Weathering of the monosulphide mineral sphalerite (ZnS) does not produce protons but causes water and soil contamination due to the release of sulphate, zinc, and further toxic trace metals. Sphalerite oxidation and non-oxidative dissolution have been studied by several investigations. However, sphalerite oxidation has not been investigated by oxygen and sulphur isotopes yet, although they could be useful tools as shown by numerous oxidation studies of the disulphide pyrite (FeS_2). The oxygen isotope composition of sulphate should provide information about the incorporation of oxygen from atmospheric-derived molecular oxygen ($\delta^{18}O = 23.5‰$) and water ($\delta^{18}O < 0‰$) into sulphate and isotope fractionation effects that occur during these processes. Sulphur isotopes of sulphate should indicate possible isotope fractionation effects that occur during the incorporation of sulphur from the only source sphalerite into sulphate. Both the origin of oxygen isotopes of sulphate and oxygen and sulphur isotope fractionation effects may help to understand sphalerite oxidation mechanisms. Hence, batch oxidation experiments with varying parameters ($\delta^{18}O_{H2O}$ value, experiment duration, initial pH value) were carried out using an iron-rich sphalerite (8 wt.% Fe).

Our results confirm that the oxidation of the monosulphide sphalerite is not comparable to the oxidation mechanisms of the disulphide pyrite (Weisener et al., 2004). Experiments with different $\delta^{18}O_{H2O}$ values show similar $\delta^{18}O_{SO4}$ values. They indicate that almost no water-derived oxygen is incorporated into sulphate; otherwise $\delta^{18}O_{SO4}$ values should be different for experiments with different $\delta^{18}O_{H2O}$ values. This finding is consistent with the proposed overall oxidation reaction $ZnS + 2\ O_2 \rightarrow SO_4^{2-} + Zn^{2+}$ (Weisener et al., 2004). Thus, the difference between $\delta^{18}O$ values of sulphate and molecular oxygen represents the oxygen isotope fractionation that occurs during incorporation of molecular oxygen into sulphate. However, $\delta^{18}O_{SO4}$ values seem to decrease slightly with progressive oxidation and become more similar to $\delta^{18}O$ values of water. This would mean that water-derived oxygen is also incorporated into sulphate with progressive oxidation. Malmström & Collin (2004) proposed a parallel oxidation of sphalerite by molecular oxygen and ferric iron ($ZnS + 8\ Fe^{3+} + 4\ H_2O \rightarrow Zn^{2+} + 8\ Fe^{2+} + SO_4^{2-} + 8\ H^+$) which could explain decreasing $\delta^{18}O_{SO4}$ values when the oxidation by ferric iron becomes more dominant over time. However, the incorporation of water-derived oxygen in sulphate should be reflected in $\delta^{18}O_{SO4}$ values.

$\delta^{18}O_{SO4}$ values are independent of the initial pH (2 and 6) maybe due to the iron-rich composition of the oxidized sphalerite. Weisener et al. (2004) suggested that the oxidation of an iron-rich sphalerite produces polysulphides consuming protons, which is consistent with our results (increase of initial pH 2 to about 6 after 2 days). Thus, oxidation mechanisms of an iron-rich sphalerite are independent of the initial pH.

$^{34}S_{SO4}$ values show isotope fractionation effects compared to sulphur isotopes of sphalerite in some experiments. Probably, they indicate a significant amount of sulphur intermediate species (with specific ^{34}S values and fractionation effects) which are finally oxidized to the end product sulphate. The lack of correlation between $^{34}S_{SO4}$ values and sulphite and thiosulphate concentrations points to the formation of further sulphur intermediate species (e.g., polythionates).

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Carbon stable isotopic composition of CO_2 and CH_4 in a fen under different vegetation and moisture conditions

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Northern peatlands make up only ~3% of the Earth's land surface, yet they store ~30% of the global soil carbon stocks. Peatlands have thus acted as a significant sink for carbon from the atmosphere since the last deglaciation (Gorham, 1991). On the other hand, peatlands contribute 2–10% to the global release of methane into the atmosphere (Mikaloff Fletcher et al., 2004). Increasing temperatures and changes in the hydrologic regimes due to global climate change are likely to affect the carbon balance of peatlands (Moore, 2002). A thorough understanding of carbon turnover in peatlands is thus desirable.

The application of stable carbon isotopes is a tool to elucidate carbon turnover in peatlands, and has been applied to track formation, fluxes and consumption especially of methane (Hornibrook et al., 2000). Methane produced by acetate cleavage is generally not as depleted in ^{13}C as CH_4 from CO_2 reduction with H_2. Thus, typically observed fractionation factors of CO_2 and CH_4 have been applied to estimate the contribution of the individual pathways to overall methane production. This approach is yet constrained as methanotrophy shifts the apparent isotope fractionation factor of methane from CO_2 reduction in a range overlapping with that of the acetate pathway. Even less accurate is an interpretation of the isotopic composition of methane only, although typical ranges for both pathways have been reported (Conrad, 2005).

In a minerotrophic fen, we studied the isotopic composition of soil organic matter (SOM), soil CO_2 and CH_4 during an experimental water table manipulation *in-situ* and in a complementary laboratory approach. The isotopic composition of CO_2 (-26 to -15‰) and CH_4 (-35 to -65‰) was in accordance with previous studies for comparably moist plots with sedges and sphagnum present and less degraded peat. In highly degraded plots dominated by Poaceae but only few sedges and in absence of mosses, CH_4 was more depleted in ^{13}C ($\delta^{13}C$ up to -110‰). The two different sets of peat types showed distinct and different patterns of the depth distribution of the isotope fractionation factors $\alpha_C(CO_2/CH_4)$, although no differences in $\delta^{13}C$(SOM) existed. In the wet plots with sedges and sphagnum, α_C was around 1.05 regardless of depth, while in the degraded plots α_C increased with depth up to 1.09.

This study demonstrates that a comparison of isotope data obtained from different types of peatlands is not without caveats. Different substrates, moisture conditions, and vegetation lead to locally distinct isotope fractionation patterns, probably obscuring isotopic shifts solely related to methanogenic or methanotrophic activity. Such shifts of isotope fractionation factors may, however, be reasonably explained by thermodynamic arguments, by differences in predominant gas transport mechanisms and by the stimulating effect of aerenchymatic oxygen transport on microbial activity in the subsurface.

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Biogeochemical Cycling of sulfur and carbon in small river basins in SW China

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To understand the linkage between eco-environmental change and the bio-geochemical cycling of sulphur and its effects on those of other nutrients such as carbon and nitrogen in karstic region, southwest China, we studied rivers draining catchments with different lithology and ecological systems for their water chemistry, sulphur and carbon compositions of sulphate ion and dissolved inorganic carbon.

The chemistry of surface and epikarstic waters in karstic catchments is dominated by high concentrations of total dissolved solutes (ranging from 112 mg L^{-1} to 479 mg L^{-1}), of which Ca^{2+}, Mg^{2+}, SO_4^{2-}, and HCO_3^- account for more than 80%. On the other sides, the river and spring water collected from an area with high-vegetation and lithology characterized by slightly metamorphosed clastic sedimentary rocks has much lower contents of total dissolved solutes (ranging from 5 mg L^{-1} to 103 mg L^{-1}), which contains much more K^+ and Na^+. Sulphur isotopic compositions ($\delta^{34}S$) of river water draining karstic areas range from -9.4‰ to +3.3‰, and that draining clastic-rock terrain from -4.7‰ to +5.8‰. Among water draining karstic areas, the water draining karstic areas with heavy forest shows a smaller variation in $\delta^{34}S$ value (-9.4‰ ~ -2.5‰), different from the water draining karstic area facing ecological degradation. The carbon isotopic compositions ($\delta^{13}C$), like $\delta^{34}S$ value of water collected from karstic and non-karstic areas are also different: water draining karstic area has $\delta^{13}C$ values of from -15.13‰ to -7.76‰, and that draining clastic-rock terrains has $\delta^{34}S$ values of from -21.08‰ to -5.91‰.

It can be first concluded that the chemical and isotopic compositions of surface and spring water change in response to the changes in ecological and geological environments. The higher contents of total dissolved solutes in karstic water are ascribed to quick dissolution of carbonate rocks, as compared to those in the water collected from clastic-rock terrains. The oxidation of sulphide minerals in the catchment dominated by clastic rocks might have been the main source of sulphate ion, while the source of sulphate ion in karstic water is mainly of origin from oxidation of sulphide minerals in coal-containing strata and organic sulphur. In comparison with those of water draining karstic areas, the much lower and also higher $\delta^{13}C$ values found for dissolved inorganic carbon in water draining clastic rock-dominated area indicate a main source of carbon derived from oxidation of organic matter, and adsorption of CO_2 into surface water from atmosphere. Ecological factors show a control over geochemical characteristics of surface water, due to different biogeochemical cycling of nutrients in different ecological systems.

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The impact of land use on sources of riverine sulfate, nitrate and chloride in a large watershed in western Canada

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The South Saskatchewan River in western Canada is fed by three major tributaries: the Red Deer River, the Bow River and the Oldman River. These tributaries originate in pristine forested headwater catchments on the eastern slopes of the Rocky Mountains prior to flowing eastwards across the prairie provinces of Alberta and Saskatchewan, where the watersheds are progressively impacted by urban and agricultural land use practices. Hence, the South Saskatchewan River Basin provides an excellent opportunity to assess the cumulative impact of different land use along its tributaries on the quality of river water. The objective of this study was to combine hydrometric and chemical measurements to determine changes in element fluxes along the river and assess their relation to land use. Stable isotope techniques were used to determine the sources that contribute sulfate, nitrate and chloride to the rivers.

River water, sampled seasonally at 25 stations along the South Saskatchewan River and its key tributaries from the headwaters in Alberta to the mouth near Prince Albert (Saskatchewan), was analyzed for its chemical and isotopic composition (δ^2H, δ^{18}O, $\delta^{13}C_{DIC}$, $\delta^{15}N_{nitrate}$, $\delta^{18}O_{nitrate}$, $\delta^{34}S_{sulfate}$, $\delta^{18}O_{sulfate}$, $\delta^{37}Cl_{chloride}$). Sources and processes responsible for marked changes in riverine sulfate, nitrate and chloride fluxes were identified using stable isotope techniques. Geologic (evaporite) sulfate was the predominant sulfate source in the headwaters, while sulfate from anthropogenic sources in urban areas and from pyrite oxidation in the tills of agricultural regions caused markedly elevated sulfate fluxes with increasing distance. Nitrate fluxes in the headwater sections were low and N and O stable isotope data indicated that the nitrate was mainly derived from nitrification in forest soils. With increasing distance along the watershed, there was clear evidence of nitrate loading from municipal waste water sources and agricultural return flows. Riverine chloride concentrations progressively increased from the upper reaches of the basin at 0.5 mg L^{-1} to 10 mg L^{-1} Cl^- at the outflow primarily due to cumulative effects of urban waste water effluent inputs. Plotting Na/Cl ratios versus δ^{37}Cl values demonstrates this riverine progression of Cl^- chemistry toward Na/Cl ratios of 1 and δ^{37}Cl values towards zero (SMOC). This study demonstrates that stable isotope techniques are an effective tool for distinguishing natural and anthropogenic sources and the fate of sulfate, nitrate and chloride in large riverine systems with different land use, particularly if used in concert with hydrometric and complementary geochemical data.

Determination of biological cycling rates for sulphate in a small mountain lake, Flattops Wilderness Area, Colorado using natural ^{35}S

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The biological cycling of sulphate in watersheds is an important issue and may become more so with the possible switch to the use of more coal and oil shale due to fluctuating oil prices. Frequently tracer experiments are carried out by adding ^{35}S ($t_{1/2}$ = 87 days) to the watershed in various forms. Another option is the use of naturally-occurring ^{35}S which is produced by cosmic-ray spallation of argon in the atmosphere. This isotope has been used to follow the movement of atmospheric sulphate in watersheds where soil interactions are limited (Michel et al., 2000, Michel et al., 2002). In this study, natural ^{35}S is used to study the biological cycling of sulphate in two small lakes in the Flattops Wilderness Area, Colorado. The Flattops Wilderness Area is a high elevation mesa capped by fractured basalt with little soil development and limited buffering capacity. There are about 1000 small lakes and little or no overland flow. This study focuses on two lakes, Ned Wilson Lake and Upper Ned Wilson Lake, with areas of about 10000 m^2 and 2500 m^2 respectively. The main source of water for these lakes is snow melt and there is no observable surface flow into or out of them in the summer.

Sulphur-35 samples were collected several times during the summer of 1995 and 1996. Concentrations of snow-melt derived ^{35}S decreased much more rapidly during the summer than can be accounted for by decay alone. The drop in ^{35}S concentrations can not be explained by changes in sulphate concentrations and there was no accompanying change in sulphate stable isotope ratios. Influx of “dead” sulphate from groundwater is ruled out by other chemical data. The most likely cause for ^{35}S concentrations to decrease faster than decay is biological exchange with the biota in the lake. Sulphate containing ^{35}S is incorporated into the biota and sulphate containing non-radioactive sulphate is returned to the system, with little or no net change in sulphate concentration. This process entails no fractionation. Using the specific concentrations of ^{35}S (^{35}S/SO$_4$) we were able to estimate biological exchange rates on a lake-wide basis for these small lakes during the summers of 1995 and 1996. Estimates ranged from 2-10 microgms/L per day with the higher rates being found in Upper Ned Wilson Lake each year.

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Vertical changes in $\delta^{13}C$ of chemically separated carbon forms in peat cores from Central and Northern Europe: A temperature effect

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Peatlands accumulate one third of the world's soil carbon. During climatic warming, higher emanations of greenhouse gases, accompanying thinning of peat deposits, may lead to further temperature increases. We explored the relationship between C cycling in peatlands and climate by a downcore reconstruction of C isotope speciation in peat cores collected in the Czech Republic (Central Europe) and northern Sweden. The formation of CO_2 and CH_4 during peat decomposition depends on temperature, but also on organic matter quality. Preliminary data indicated that bulk C can become both isotopically lighter and heavier downcore, but it is not known which C species are responsible for these isotope shifts, which, in turn, could reflect climate change. We examined vertical changes in peat organic matter speciation at the warmer Velke Darko bog and the colder Stor Amyran bog. We sequentially extracted and quantified the following organic C forms in peat: soluble fats, oils and waxes; soluble carbohydrates; soluble phenolics; total hot-water solubles; holocellulose; α-cellulose; hemicellulose; lignin; and acid-soluble carbohydrates. Seven most abundant C forms were analysed also isotopically. Both examined sites had a positive downcore $\delta^{13}C$ shift in bulk peat. At Velke Darko (Czech Republic), three types of vertical $\delta^{13}C$ trends were observed when C forms were analyzed separately: throughout the profile, $\delta^{13}C$ of lipids was the lowest in the system, fluctuating around –30 per mil. At a depth of 30 cm, $\delta^{13}C$ of lipids was 8 per mil lower than that of cellulose. $\delta^{13}C$ of all forms of cellulose, carbohydrates and phenolics overlapped, increasing smothly downcore from –27 to –22 per mil. $\delta^{13}C$ of lignin, also increasing downcore, was off-set relative to cellulose by 2 per mil to more negative values, but never became as low as $\delta^{13}C$ of lipids. At Stor Amyran, a site located near the Polar Circle (Sweden), $\delta^{13}C$ of both lipids and lignin were more negative compared to Velke Darko. At the same time, $\delta^{13}C$ of cellulose at Stor Amyran was higher than $\delta^{13}C$ of cellulose at Velke Darko. Importantly, the northern site showed less steep increase in $\delta^{13}C$ of bulk peat and of cellulose with an increasing depth. We propose that this pattern is a result of slower peat decomposition at the northern site due to lower temperatures.

Lead isotopes in high-elevation environments near the state borders between the Czech Republic, Poland, Germany, and Austria

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Growth rings of hardwood plant species and vertical peat profiles are two possible archives of past changes in lead pollution. Whereas it is generally accepted that rain-fed peat profiles accurately record historical rates of atmospheric Pb deposition, due to immobility of buried Pb (e.g., Novak et al., 2008), the usefulness of tree rings as a dendrochemical archive has been questioned. Some studies have found indices of radial mobility of Pb in young tree rings, others have stressed the confounding effect of acidification on the bioavailability of Pb.

We present a comparison of Pb accumulation and isotope record in spruce tree rings and ^{210}Pb-dated *Sphagnum* peat at three sites in the Czech Republic. Similar to the entire Central European region, these sites exhibited antropogenic acidification, peaking in the 1980s. Two of the sites, JEZ and UHL, are situated in the northern Czech Republic, where massive lignite burning caused high Pb emissions. Since the 1980, the industrial pollution rates decreased by 90 %. The third site, LIZ, is located in the relatively unpolluted south of the country, 150 km from the main point sources of pollution. Three trees per site were studied.

We found that the southern unpolluted site LIZ lacked any peak in Pb concentration throughout the lifetime of the trees (1900-2007). Pb concentrations in LIZ tree rings were uniformly low (0.6 ppm). In contrast, Pb concentrations at the polluted JEZ and UHL were up to 10 times higher than those at LIZ. At both polluted sites, a large peak was seen with a plateau between 1960 and 1990. We conclude that spruce tree rings realistically reflect the known history of Pb pollution in Central Europe.

We further compared Pb concentrations in tree rings with annual Pb accumulation rates in peat from three nearby sites. At JEZ and UHL, the maxima in Pb content in tree rings and peat coincided. In contrast, peat LIZ showed a small 1980 maximum, not seen in the monotonous Pb content in LIZ tree rings. The Pb concentration peak in the southern peat was 4 to 8 times lower than in the northern peat. We conclude that spruce tree rings and *Sphagnum* peat may be equally reliable archives of past Pb pollution. There may, however be a pollution threshold, under which three rings are less sensitive to Pb inputs than peat.

Lead isotope systematics (^{206}Pb/^{207}Pb) did not show any change at the time of maximum pollution at any of the sites. Mean ^{206}Pb/^{207}Pb ratios in tree rings were relatively constant within each site, and decreased in the order JEZ > UHL > LIZ. The overall range of isotope data set was narrow (1.158-1176). The ^{206}Pb/^{207}Pb ratio of the lignite is relatively high (1.19) The highest Pb isotope ratios at JEZ were a result of the proximity of coal-fired power stations (6 km). The distance of UHL from the power stations is 60 km. The southern site LIZ with low Pb concentration in tree rings was still polluted: Its ^{206}Pb/^{207}Pb ratios close to 1.165 are consistent with constant pollution from historical Ag-Pb smelting. The Variscan Ag-Pb ores in Central Europe have the same ^{206}Pb/^{207}Pb ratio of 1.165 as LIZ wood. Lead isotope ratios may be useful in deconvoluting the relative contribution of bedrock and atmogenic Pb in three bimass, but more detailed study of Pb trends in the soil are needed.

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The provenance and fate of pollutants in remote mountain-top locations: A new network to monitor the chemistry of ice accretions in the Czech Republic

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Traditional and non-traditional isotope systems, such as Pb, Cr, Zn, and Cu can be used to apportion the sources of pollutants transported over long distances by wind. Small mass-dependent isotope fractionations of non-traditional isotope systems are caused by low-temperature industrial processing of ores rather than by high temperature processes of ore formation. In January 2008, a monitoring program was launched at 10 mountain-top locations near the state borders between the Czech Republic, Germany, Poland and Austria. The chosen sites are situated above an elevation of 1000 meters equidistantly along the state borders. Chemism and selected isotope compositions are determined for ice accretions (horizontal deposition), and snow (vertical deposition). The average age of the accretion/snow is 7 days. Precautions are taken to prevent contamination in the field, and clean lab procedures are employed during sample treatment and analysis.

The sampling methodology has been tested on one site in the Orlicke Mts. close to the Czech-Polish border (Dousova et al., 2007). Two similar sampling campaigns took place 20 years apart, in 1984 and 2004. This period of time was characterized by a sharp decrease in coal burning and industrial arsenic emission rates. The results showed that, over the 20 years, As concentrations in ice accretions decreased 16 times. Over the same 20 years, As concentrations in snow decreased 8 times. Arsenic concentrations in snow were generally lower than those in ice accretions during both observation periods. It is believed that horizontal and vertical deposition brings arsenic to a receptor site from different distances. Horizontal deposition tends to scavenge As originating at greater distances, whereas vertical deposition brings more local As. Our new monitoring network attempts to determine the origin of pollutants other than arsenic, using air-mass back-trajectories, and isotope determinations by means of multicollector ICP-MS (Pb, Cr, Zn and Cu). The paper will discuss data from the winter season 2008–2009.

One of the objectives of the project is also to follow the dispersion pathways of selected pollutants in mountain-slope forest ecosystems. We contrast mountain-top depositions with runoff fluxes in nearby head-water catchments, which are part of the national hydrogeochemical monitoring network GEOMON. Export of environmentally relevant substances from these catchments has been monitored since 1994. A comparison of sites in the industrial north of the Czech Republic with the less polluted south of the country in 2007 has shown the following systematics: the deposition rates weighted by the type of vegetation were higher in the north for all calculated substances. In the north of the Czech Republic, the atmospheric input amounted to 280, 1, 16 and 12 g.ha^{-1}.yr^{-1} for Zn, Ni, Cd and Pb, respectively. The deposition rates were 2.5 times higher, in case of Cd even 6 times higher, than in the relatively unpolluted south. Mass balances were calculated as differences between vegetation-type weighted input and output via runoff. The only net export was recorded in the north for Cd where output amounted to 110% of input. The input-output fluxes were similar for Cd in the south and Ni in the north. Zn and Pb accumulated in both polluted and unpolluted catchments in 2007.

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Stable isotope study of the River Sava watershed, a major tributary of the River Danube

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In this presentation the study on hydrogeochemical dynamics of the River Sava watershed, the main tributary of the River Danube using stable isotope approach is outlined. Although some data already exisists as a part of the monitoring programme in different countries, the present survey represents the first systematic study of chemical and isotopic composition of dissolved constituents for the entire riverine system and therefore provides the first comprehensive background database. The research was performed within the EU project SARIB – Sava River Basin: Sustainable Use, Management and Protection of Resources. On the basis of the data it was possible to identify locations (hot-spots) with higher anthropogenic influence in the studied riverine system.

Stable isotope measurements of oxygen and hydrogen ($\delta^{18}O$ and δD) were used to characterize spatial and temporal variation in $\delta^{18}O$ and δD values of the River Sava and River Danube and to preliminary estimate the mean residence time of runoff in the studied rivers catchments. Precipitation is of mixed Atlantic-Mediterranean origin which is also reflected in the isotopic composition of River Sava surface waters. Spatially, rivers water is ^{16}O-enriched in the high mountain areas due to higher amount of precipitation, lower temperature and higher elevation of the recharge area, while in the lower part of the River Sava catchments the $\delta^{18}O$ values are higher. It is also observed that the River Sava responds quickly to precipitation which is reflected in its $\delta^{18}O$ and δD values and the low residence time estimated in the river. The mean residence time (MRT) of stream water is similar for all sampling points with a mean value of 1.32 years and can be characterized as relatively short and the catchments as having not too much groundwater storage capacity.

The River Sava exported 1.9×10^{11} mol C yr^{-1} as dissolved inorganic carbon (DIC), and emitted 2.5×10^{10} mol C yr^{-1} as CO_2 to the atmosphere. Stable carbon isotope ratios indicate that up to 42% of DIC originated from carbonate weathering and ~23% from respiration. Loads of dissolved and particulate organic carbon increased with discharge and export rates were calculated to be 5.2×10^{10} mol C yr^{-1} and 4.3×10^{10} mol C yr^{-1}, respectively. Isotopic compositions ($\delta^{13}C$ and $\delta^{15}N$) and C/N ratios indicated that soil organic matter was the dominant source of particulate organic matter for 59% of the samples. 18% of the samples were dominated by plankton, 12% by periodic inputs of fresh terrestrial plant detritus with C/N > 15, and 11% of the samples were dominated by the contribution of aquatic vascular plants. Nitrate inputs were controlled by land use in the River Sava watershed. $\delta^{15}N_{NO3}$ values < 6‰ were found in predominantly forested watersheds, while values > 6‰ typically represented watersheds with a higher percentage of agricultural and/or urban land use. Elevated $\delta^{15}N_{NO3}$ values (up to +25.5‰) at some sites were probably due to the combined effects of low flow and inputs from sewage and/or animal waste.

The sulfur flux calculated at Belgrade (sampling location 33) was estimated to be 4.4×10^9 mol yr^{-1}. The sulfur isotopic mass balance calculation indicates that the relative contribution of tributaries, precipitation and other sources to this flux was 28:8:64% with the highest contribution coming from the industrial activity.

The study of the carbon soil dynamics at different forest ecosystems in Slovenia - stable isotope approach

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This presentation represents research on carbon soil dynamics performed in Slovenia at four different forest stands with soil texture on silicate bedrock at Kladje (KL) in Pohorje and carbonate bedrock in karstic-dinaric area in Kočevski Rog – Snežna jama (SJ), Rajhenav (RA) and Brdo (BR) during period 2005-2007. In addition spatial and temporal variability of soil respiration is presented together with stable carbon isotope data on soil CO_2 to determine abiotic and biotic sources of carbon effluxes.

The carbon and nitrogen isotope values of soil organic matter (SOM) increased with depth in all four investigated plots. Decomposition of SOM controlled by climate condition is the most probable explanation for ^{13}C and ^{15}N enrichment in SOM at locations RA, SJ and BR. On the other hand, the depth distribution in $\delta^{13}C$ and $\delta^{15}N$ values, organic carbon content and C/N ratios suggested that the soil microbial biomass could be an important source for SOM at location KL. The pCO_2 values in soil profiles were 6-100 times higher than atmospheric CO_2, with a maxima observed in the summer and a minima in the winter. It was found that isotopic composition of dissolved inorganic carbon ($\delta^{13}C_{DIC}$) in soil water was locally and seasonally dependent. At location KL where silicate weathering was dominant, soil CO_2 was the major source of soil water DIC, and atmospheric CO_2 contribution was insignificant. The higher $\delta^{13}C_{DIC}$ values of -19.4‰ in the shallow soil water observed during the summer were the consequence of isotopic fractionation induced by molecular diffusion of soil CO_2. In contrast, the soil activity is low during the winter and molecular diffusion and accompanying isotope fractionation were not present. $\delta^{13}C_{DIC}$ values in soil water were higher at locations SJ and RA compared to KL ranging between -16.5 and -11.7‰ due to carbonate mineral dissolution. In the deep soil zone, carbonates dissolve in a CO_2 open system, and saturation with respect to calcite and dolomite was approaching rapidly. The isotopic mass balance calculation indicated that ~ 45 % of DIC is coming from carbonate dissolution dominated by calcite in the deeper soil water, while in the shallow soil waters the soil CO_2 was the major source of DIC reaching up to 73 % of DIC in the summer.

Oxygen isotope of nitrate indicates how high the gross nitrification was in the forest floor in a temperate forest ecosystem in Japan

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Mineralization of organic matters and nitrification on the forest floor and in the organic soils are most important dynamics to determine the activeness and quickness of internal nitrogen cycling. Atmospheric inorganic nitrogen inputs may change the cycle structure and turn over velocity of intrinsic nitrogen cycling. In order to elucidate the intensity and mechanism of the impact of atmospherically derived nitrate on the soil nitrogen dynamics, dual isotope measurements on nitrate ($\delta^{15}N$ and $\delta^{18}O$) in soil waters were conducted in a forested watershed in central Japan.

Study site is in the Kiryu Experimental Watershed (KEW) located within the Lake Biwa Basin in the central part of the Japanese islands. Soil waters have been sampled from various horizons of the soil profiles to elucidate the vertical distributions of nitrogen transformation processes. NO_3^- concentration, $\delta^{15}N$ and $\delta^{18}O$ of NO_3^- were measured. Dual isotope measurements on NO_3^- was conducted using the denitrifier method (Casciotti et al., 2002). In general, the $\delta^{18}O$ of nitrate in rainwater is remarkably higher than that produced by nitrifying bacteria in soils. Accordingly, the $\delta^{18}O$ can often be used as an index of the impact of the atmospherically derived nitrate.

While $\delta^{18}O$–NO_3^- in soil waters in <20cm depth (-9 to 58‰) had a strong signal of the atmospheric nitrate, that in soil water decreased in the deeper soil horizons (-4 to 3‰), indicating that the dominant source of nitrate in this soil profile was nitrification. The net nitrate production of this soil profile was about 18 kg-N $ha^{-1}year^{-1}$, and deposited nitrate was about 6 kg-N $ha^{-1}year^{-1}$.

In nitrification process, oxygen atoms from soil H_2O and O_2 are used in proportion of 2:1 (Kendall, 1998). In KEW, average $\delta^{18}O$ of soil water was –8.45‰ (Kabeya et al., 2007). $\delta^{18}O$ of O_2 is generally about 23‰. Based on these facts, $\delta^{18}O$ of nitrified NO_3^- in soil can be estimated as ~0‰. Assuming that the annual mean $\delta^{18}O$ of deposited nitrate was 63 ‰, the average value for soil NO_3^- pool can be estimated as ~15‰ based on mixing of two sources (atmospheric and nitrified). However, the observed $\delta^{18}O$ of the soil and groundwater was 0–6‰ and was remarkably smaller than the estimation based on annual mass balance. This indicates that the major portion of NO_3^- derived by atmospheric depositions was immediately assimilated by microbes and/or plants. This also implies that the gross nitrification was much higher than net nitrification rate, and indicating a rapid turnover of a small but important NO_3^- pool in this ecosystem.

Previous studies in temperate forests have shown from laboratory experiments using isotope dilution method that gross nitrification in soils was several times greater than net nitrification (e.g Davidson et al. 1992). We could verify this phenomenon from our $\delta^{18}O$–NO_3^- measurements of the field samples.

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Sulfur isotopes as a tool to monitor the movement of a contaminated groundwater plume

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Twenty sampling sites surrounding an abandoned toxic waste repository in central Czech Republic were chosen to monitor the rate of movement of a contaminated groundwater plume. The landfill at Pozdatky was in operation between 1994 and 1997. Industrial and municipal toxic waste, rich in heavy metals, was deposited at the site along with 10 thousand tons of crystalline ferrous sulphate, soaked with concentrated sulphuric acid (15 wt. %). Following precipitation events, sulphuric acid was leached from the intercalations of $FeSO_4$ into deeper segments of the landfill while dissolving and mobilizing metals, such as Pb, Zn, Cu, Sn, W, Mo, Cr, but also As and V. State authorities twice (1997 and 2000) declared a state of emergency, because extremely high concentrations of toxic metals, sulphate and iron were found in a river near a downslope village. Between 2002 and 2009, the abandoned repository was covered by a sealed plastic sheet. At present, state authorities are financing dismantling of the entire body of the deposited waste, chemical neutralization, redeposition at a safe alternative site, and reclamation of the contaminated topsoil in the vicinity of the site.

Our hydrochemical and isotope research at Pozdatky started in 2005, and will be under way throughout the current reclamation effort. Isotope composition of sulphate S has been determined in 135 samples of shallow groundwater from monitoring wells surrounding the landfill, atmospheric deposition, streams draining the basin, a river, an abandoned spa spring 600 meters from the site, and private wells in the village of Dobra Voda.

The amount of anthropogenic sulfur leaving the landfill is ca. 14 kg per day. The highest measured concentrations of sulphate and Fe^{2+} were 72,000 and 28,000 mg L^{-1}, respectively, both in the disfunctional drainage system underneath the site. Spruce canopy throughfall and open-area deposition differ in sulphate concentration (throughfall richer in S), but show similar $\delta^{34}S$ values of ca. 4 per mil. In contrast, shallow groundwater near the landfill has higher $\delta^{34}S$ values of up to 9 per mil. A private well used for watering a vegetable garden in the village of Dobra Voda has low sulphate concentrations (40 mg L^{-1}), but its $\delta^{34}S$ value (6.2 per mil) is higher compared to the rainwater. Overall, a $\delta^{34}S$ vs. $1/SO_4$ concentration exhibits four mixing end members. Groundwater used by villagers plots near the field of contaminated landfill groundwater. Further monitoring will show whether or not the front of the contaminated groundwater plume reaches the village.

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Isotopic tracing of sulfur emissions from oilsand operations in Alberta (Canada): a feasibility study

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Fossil fuel energy will be required to supply society for at least another half century even under the most optimistic scenarios towards greener energy solutions. The oilsands in northeastern Alberta, Canada, constitute an enormous new energy source that will become increasingly important as the availability of more conventional energy sources continues to decline. The exploitation and processing of bitumen is, however, not only accompanied by significant CO_2 emissions, but also by significant anthropogenic nitrogen (N) and sulfur (S) emissions. There are increasing concerns regarding the environmental impact of Alberta's oilsands industry, including the cumulative impact of the N and S emissions from all currently operational oilsand projects on the surrounding terrestrial and aquatic environment. A quantifiable assessment of this impact would benefit from the ability to differentiate between natural and anthropogenic N and S contributions to the environment. Hence, the objective of this ongoing study is to evaluate whether stable isotope techniques can be used to trace the fate of anthropogenic N and S emissions from the Athabasca oilsands region in surrounding terrestrial and aquatic ecosystems.

In the summer and fall of 2008, bitumen from the Athabasca oilsands region and elemental sulfur from the Syncrude sulfur block were obtained to characterize the sulfur isotope ratio of the major S emissions sources. In addition, bulk precipitation was collected at various distances from the major emissions sources in order to evaluate whether background sulfate deposition is isotopically distinct from industrial emissions. Total sulfur in bitumen has an average $\delta^{34}S$ value of 4.3 ± 0.2‰ (n=14). This is similar to the average $\delta^{34}S$ value of elemental sulfur samples (5.3 ± 0.5‰, n = 10) from the Syncrude block and suggests that S emissions have likely a $\delta^{34}S$ value of ~5‰. Ongoing sulfur isotope analyses on atmospheric deposition will reveal in more detail whether industrial S emitted from the Athabasca oilsands region is isotopically distinct from sulfate deposition at background sites and whether stable isotope ratios constitute a suitable tracer for assessing the fate of emitted S in the environment.

Determining sources of groundwater and uranium downgradient from a uranium processing facility, White Mesa, Utah, USA

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A uranium mill, located on the White Mesa in San Juan County, Utah, 3 miles north of the Ute Mountain Ute Indian Reservation, has been extracting yellowcake (U_3O_8) and vanadium from uranium ores since 1980. Potential sources of uranium and other metals in ground water include (1) dissolution of airborne dust deposited on the soil from ore storage pads and trucks delivering ore to the mill, (2) leakage from the tailings ponds to the unconfined groundwater aquifer in the Dakota Sandstone and Burro Canyon Formation, and (3) natural sources in groundwater.

Sampling of bedrock, soil, and ground water up- and down-gradient of the mill suggest complex spatial variations in the concentration of uranium and other metals of environmental concern, redox conditions favorable for either uranium solubility or precipitation in ground water, and rock properties that can influence ground water residence times in White Mesa. Spatial variability of water quality complicates an assessment of the environmental impact of the mill. In this study we supplement ground-water concentration data with measurements of (1) hydrogen and oxygen isotopes to distinguish sources of ground water, (2) noble gases and tritium (^3H) to date ground water and estimate travel times from the mill to the reservation, (3) uranium isotopes and isotopes of oxygen and sulfur in sulfate to determine the distinctive isotopic signature of mill-derived solutes (liquid wastes and tailings liquids). Geochemical modeling is used to determine the mobility of uranium and other metals in the groundwater in White Mesa. Possible offsite dispersion of mill-derived dust is checked by trace-element analysis of <-200 mesh stream sediments from ephemeral drainages surrounding the mill.

Preliminary conclusions are summarized below (data collection ends in September 2009):

- There are two distinct sources of ground water on the White Mesa; one source originates directly east of the mill and flows east-northeast; and a second source that flows south from the mill toward the Ute Mountain Ute Reservation.
- Travel time of ground water over the 3 miles from the mill to the Ute Mountain Ute Reservation is on the order of hundreds to several thousands of years.
- Uranium isotope ratios (234U/238U and 235U/238U alpha activity ratios) indicate that mill wastes in the tailings ponds are not affecting the uranium concentration in ground water.
- Dissolved uranium concentrations in water samples collected from Entrance Seep, located directly east of the mill, are consistently above the USEPA MCL of 30 μg L-1. Uranium concentrations in all other sampled waters are consistently at or below 10 μg L-1.
- Relatively high uranium concentrations in Entrance Seep could result from contamination by wind or water-borne debris from the ore storage pads or from natural uranium leached from local Dakota Sandstone bedrock. In 2009 we will determine if the mixing of uranium ore derived from the mill's storage pads with uranium derived from natural sources can explain the concentration of uranium in Entrance Seep. This will be done by measuring uranium isotopic ratios in water that has been in contact with the ore and by sampling of Entrance Seep for uranium concentration and isotopic ratios on the rising limb, peak, and falling limb of the hydrograph during spring snowmelt.

A dynamic model to determine the $\delta^{15}N$ and $\delta^{18}O$ of source, dissolved and emitted nitrous oxide in aquatic ecosystems

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Nitrous oxide (N_2O) is a powerful greenhouse gas, a significant portion of which is produced in rivers and estuaries worldwide. As the various microbial pathways (nitrification, denitrification) of N_2O production have different isotopic enrichment factors, the isotopic analysis of N_2O is a useful tool to study these processes (Wada & Ueda 1996). While several studies have measured the isotopic ratios of N_2O produced in soil environments, only one published study has reported $\delta^{15}N$ and $\delta^{18}O$ of N_2O produced in a river (Boontanon et al 2000).

The isotopic ratios (^{15}N/` ^{14}N and $^{18}O/^{16}O$) of dissolved N_2O are affected by the isotopic effects of gas exchange. The isotopic composition of dissolved N_2O is not equal to the isotopic composition of the N_2O produced or the N_2O emitted to the atmosphere (Inoue and Mook 1994). Previous examinations of the isotopic composition of N_2O produced in aqueous systems have not considered the isotopic effects of gas exchange.

A simple box model (SIDNO, **S**table **I**sotopes of **D**issolved **N**itrous **O**xide) was designed in order to study the relationships between the isotopic ratios of dissolved, source, and gas exchange flux N_2O. This model is a loose adaptation of the PoRGy model (Venkiteswaran et al 2007), which simulates the stable isotope dynamics of dissolved oxygen in response to photosynthesis, respiration and gas exchange in aquatic ecosystems. One box in the model is used to represent the total mass of dissolved N_2O and two additional boxes in the model are used to represent the dissolved masses of the heavy isotopologues ($^{15}N_2O$, and $N_2{}^{18}O$).

SIDNO accurately reproduced stable isotopic ratios of equilibrating N_2O measured in laboratory. It was also used to examine the effects of variable and constant N_2O production rates and source isotopic composition, as well as the gas exchange coefficient in steady state and non-steady state production of N_2O.

The model can be used to determine the production rate and isotopic composition of the N_2O source and flux in aquatic environments by adjusting the source parameters to reproduce the measured field data (concentration, $\delta^{15}N$ and $\delta^{18}O$ of dissolved N_2O). The SIDNO model could easily be adapted to simulate the stable isotope dynamics of other dissolved gases, such as CH_4.

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The age of fine root carbon may not indicate the age of root

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The present paper deals with the root longevity estimation by bomb radiocarbon method. For this purpose, the fine root samples from ingrowth cores with known maximum root age (1 to 6 years) from the different Scot pine (*Pinus sylvestris*, L) stands from boreal forests of Finland were collected and analyzed. The stands selected were 1). Mekrijärvi, Ilomantsi, (maximum root age one year), 2). Jämijärvi, (Hämeenkangas) maximum root age one year, 3). Punkaharju, maximum root age six years. All the collected ingrowth core root samples originate from the years 1985 to 1993. Two root diameter classes of these root samples were selected; i). < 0.5mm, and ii). 1.5–2.0 mm. The overall goal of this study was to assess whether or not the root C age coincides with the root age? For this purpose, we analyzed their bomb root C age by bomb radiocarbon method and compared it with the known maximum fine root age. Since the structural carbon (cellulose) is not replaced once deposited in the root, the root cellulose C age should represent the real age of the root. Hence, the bomb ^{14}C was analysed both in bulk roots (i.e. without removing any structural and non structural compounds from the roots) and in only root cellulose (other root constituents removed).

For bulk roots of all stands, our present result on root longevity by 14C method corresponds to that of ingrowth core maximum root age range to a large extent. On the contrary, for the root cellulose (Punkaharju stand, 1987–89), we observed an older age (by 5–10 years) relative to their ingrowth core roots maximum age. This shows that the roots are getting a large amount of older stored carbon from other unknown sources rather than only atmospheric CO_2. Possible sources may be use of stored C, DOC (dissolved organic carbon) uptake or incorporation of soil respired CO_2 by mycorrhiza to root cellulose. We are still waiting for the results on root cellulose age for the other stands. After we have all the results, we would be able to give our conclusions on this. Our preliminary results are contradictory to some other ^{14}C- based root age studies.

Going down the river: Isotopes for biogeochemical cycling and ecology in an impacted river in southern Canada

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The river continuum concept was developed for the evolution of river ecology from the headwaters to the mouth in relatively unimpacted rivers. Many large rivers, however, are heavily impacted by agricultural activities, damming, flow augmentation and urbanization. Management decisions are typically enacted on a reach basis but effects often cross jurisdictional boundaries. Is the continuum or reach approach appropriate for science-based management of large heavily impacted rivers? Is there a continuum in impacted rivers or simply distinct reaches of heavy impact and recovery? The Grand River watershed in southern Ontario, Canada is home to 900,000 people. Projected population increase is 40% within 20 years. Currently, more than 500,000 people rely on the Grand River for drinking water, while there are 26 WWTPs located along the river. Point source N releases from WWTPs are large. Non point source nutrient loads are also extremely high, as agriculture (including large livestock operations) is the dominant land use (80%) in the watershed. To accommodate this new growth, billion dollar decisions for wastewater and drinking water treatment and agricultural land management have recently been taken.

Several approaches were used to study biogeochemical cycling and metabolism in the Grand river. Whole river surveys were conducted where 23 sites were sampled along the entire 300 km length of the river on the same day, once before sunup, once midmorning and once close to solar noon. To interpret the longitudinal sampling, full diurnal studies of 28 hours in duration were conducted at specific locations. In addition, the river was sampled biweekly over several years to understand the effect of seasonal changes in temperature, solar radiation and flow on biogeochemical cycling. WWTPs were sampled to obtain source signatures and biogeochemical processes in the river were followed in plume chasing studies. The relatively new technique of coupling $^{18}O/^{16}O$ in dissolved O_2 and O_2 concentrations was used to address the changes in photosynthesis (P), respiration (R) and gas exchange (G) along the length of the river. Diurnal amplitude of O_2 and $\delta^{18}O$-O_2 is high even in headwaters but the mean O_2 decreases and $\delta^{18}O$-O_2 increases below WWTPs. In the lower river, where the river is deeper and bordering wetlands interact with main channel, diurnal O_2 and $\delta^{18}O$ remains high. The observed *in situ* respiration fractionation factor differs from the main stem to the mouth.

Sources and cycling of nitrogen species were investigated using concentration and $^{15}N/^{14}N$ and $^{18}O/^{16}O$ of NH_4^+, NO_3^- and N_2O. A dynamic model for N_2O isotopes is used to correct for the effects of gas exchange enabling observation of diurnal changes in N_2O processes. Below the largest WWTP, NH_4 loss is due to a combination of volatilization, uptake and nitrification in the day. At night, nitrification can be limited by low O_2. Changes in $^{15}N/^{14}N$ and $^{13}C/^{12}C$ were observed in dissolved organic matter (DOM), macrophytes, benthic invertebrates and small fish along the length of the river and especially immediately below the WWTPs. Comparison to isotopic signatures of WWTPs and effluent plumes in the river shows that NH_4^+ is preferentially assimilated in comparison to NO_3^-. The river is always supersaturated in N_2O but the concentrations rise dramatically (up to 8,000% atmospheric) below the WWTPs at night. This diel cycle in N_2O is accompanied by a shift in $\delta^{15}N$ and $\delta^{18}O$ of N_2O. River methane concentrations are high and a diurnal variation in $\delta^{13}C$-CH_4 indicates the changing role of CH_4 oxidation. The relative importance of urban and agricultural impacts changes with season and discharge. Critical low flow periods occur both in summer and winter but are marked by differing rates of N removal by uptake, NH_4^+ volatilization and denitrification. Management scenarios must consider changing biogeochemistry with season and climate variability in the protection of aquatic ecosystem health and drinking water supplies.

Mapping Provenance of Organic Carbon and Nitrogen in Guanabara Bay by Means of δ^{13}C and δ^{15}N in Particulate Matter and End Members

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Guanabara Bay is circumscribed by the city of Rio de Janeiro (Brazil) and is dominated by seawater influence. This urban estuary for a number of low runoff rivers (total runoff of about 150 $m^{-3}s^{-1}$) receives large load of untreated sewage and industrial wastes, serving also as base for activities related to offshore petroleum exploration. In the photic zone limited to 0.5–2.5 m depth primary production can reach 2 g C m^{-2} day^{-1} while below that zone, in certain areas, oxygen concentrations are often under the limits requires by aerobic higher life (Rebello et al, 1988). Despite intense heterotrophic respiration carbon fluxes to sediments increased from 4.2 mol C m^{-2} $year^{-1}$ to 42 mol C m^{-2} $year^{-1}$ within the last 100 years (Carreira et al, 2002), partly due to high sedimentation rates. Due to the complex nature of this tropical marine system little is still known about the relative importance of different source of organic carbon to the bay and on the relevance of denitrification and nitrification reactions to the nitrogen cycle.

$\delta^{13}C_{(PDB)}$ and $\delta^{15}N_{(N2)}$ were determined in particulate organic matter (POM) collected in Guanabara Bay (15 stations in winter and 20 stations in summer), in some of the affluent rivers (6 stations), in mangrove sediment cores and leaves. δ^{13}C in *Laguncularia*, *Avicennia* and *Rhizophora* leaves ranged from - 27.3 to - 30.7‰ while in sediment organic matter values were heavier, in the range of - 24.1 and - 27.6‰, due to degradation processes and mixing with some fraction of aquatic biomass. In winter most POM showed

δ^{13}C below 19‰ but δ^{15}N varied from about -4 to +11‰ demonstrating the influence of different processes as nitrification (values around and below 0‰) or/and the presence of blue green algae. The N/P ratio in studied areas of the bay are below 10 indicating that the system is nitrogen limited, therefore nitrification may be expected. Denitrification contributes to the POM enriched in ^{15}N since in shallower areas of the bay bottom waters and sediments are suboxic or anoxic. In the summer only in the most sewage contaminated rivers POM showed δ^{15}N negative values, which may derive from ammonium assimilation in aquatic algae, and large shift in δ^{13}C compared to winter. Most POM samples from the bay had δ^{15}N in the range expected for phytoplankton and δ^{13}C below -19 ‰ that seems to be the lower limit for δ^{13}C in marine biomass in the area. Although winter is the driest season δ^{13}C more negative than -20‰ in several stations in the bay show that influence of terrestrial organic matter is more prominent in this season possibly because of the higher phytoplankton production in summer. The sewage influence on the carbon isotope ratio is not evident since the measured values are in the same range as those for terrestrial biomass.

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Bayesian isotopic mixing model to quantify NO_3^- input sources into surface water (Flanders, Belgium)

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Nitrate (NO_3^-) contamination in surface water in Flanders (Belgium) is a pressing environmental problem. These NO_3^- loads are attributed to intensive agriculture, use of fertilizers and manure and discharge of human sewage. The Flemish Environmental Agency (VMM) has an operational network for monitoring surface water quality. An apriori NO_3^- source classification has been provided based on NO_3^- concentration variation and land use. The 5 potential NO_3^- source classes are as follows: greenhouses, agriculture, agriculture with groundwater dilution, households and a combination of horticulture and agriculture. However, NO_3^- concentration data alone can not fully assess the extent of the input of various NO_3^- sources, which is a key aspect in monitoring water quality. Hence, this study will apply a dual isotope approach ($\delta^{15}N$- and $\delta^{18}O$-NO_3^-) and a Bayesian isotope mixing model (SIAR) (Parnell & Jackson 2008) to identify and quantify NO_3^- sources in surface water. Finally, the NO_3^- source classes will be relabeled based on SIAR output via k-means clustering.

Thirty sample points (6 sample points per apriori NO_3^- source class), distributed over the whole of Flanders, were selected for NO_3^- source identification and quantification based on monthly measured $\delta^{15}N$- and $\delta^{18}O$-NO_3^- data. So far (from October 2007 to September 2008) we observed isotopic values ranging from -5.6 to 28.0‰ for $\delta^{15}N$ and -9.1 to 40.2‰ for $\delta^{18}O$. The output of proportional NO_3^- source contributions via SIAR revealed that NO_3^- from manure or sewage contributes on average 40% during winter and 28% during summer. Mineral fertilizers contribute 29% in winter and 37% in summer. Contribution of NO_3^- from soil in winter is 24%, nearly equal to the contribution in summer (22%). NO_3^- precipitation contributes 7% in winter and 13% in summer. However, NO_3^- from manure or sewage needs to be further separated using $\delta^{11}B$, as $\delta^{15}N$ and $\delta^{18}O$-NO_3^- can not separate manure from sewage. Based on these NO_3^- source contribution values, apriori source classes were relabeled by applying a k-means clustering technique. Results suggest the optimum number of NO_3^- source classes is only 3, which are “greenhouses”, “agriculture” and “agriculture with groundwater dilution”.

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Soil biodegradation of aerial and underground litter of *Miscanthus*, a perennial energy crop

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The concerns of global fossil fuel depletion and environmental pollution from its combustion are driving the search for carbon-neutral, renewable energy sources. The use of ligno-cellulosic plant biomass as an energetic source is an alternative which is fully investigate nowadays. Substituting fossil fuels with crop biomass will require selection of the most suitable plant species and adequate management to meet the environmental constraints. Several species that produce high biomass from low inputs would be good candidates for energy production. Amongst these, the genus *Miscanthus*, which is a perennial rhizomatous grass, with a great adaptability to different environments and a high yielding potential (C_4-plant) appears as a good candidate. New practices and/or the development of new energy crops will also modify the quantity and quality of crop residues entering the soil system and therefore affect the nutrient cycles (mainly Carbon (C) and Nitrogen (N)). The aim of our study was therefore to establish the relationships between *Miscanthus* litter quality (aerial and underground) and their rate of decomposition in soil as a function of the agricultural practices (date of harvest and N fertilization rate).

Miscanthus sampling was realized at the INRA experimental station of Mons en Chaussée (North-East part of France). Plants were two years old, and two N treatments were selected (without [0N] and with N [100 kgN.ha^{-1}.year^{-1}]). Rhizomes and associated roots were sampled in the field at two stages: i) the first stage was in autumn before N remobilization from leaves to rhizome occurred and ii) the second stage was in winter at plant maturity, after N remobilization from aerial parts to rhizomes. Senescent leaves were collected between the two sampling stages.

Biochemical characterisation (Klason lignin, soluble content, sugars and C/N ratio) of the different plant parts was determined. An incubation experiment was performed to determine rates of decomposition and C and N mineralization. First results are shown.

Key words: *Miscanthus*, litter quality, soil biodegradation, carbon and nitrogen cycles.

Effects of increased biomass removal on the biogeochemistry of two Norwegian forest systems

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In Norway, it is planned to double the stationary use of bioenergy from all sources by up to 14 TWh before2020, with much of this increase coming from forest resources, including residues like branches and tops (which are not much used today) being removed after tree harvest. This removal will reduce the supply of nutrients and organic matter to the forest soil, and may in the longer term increase the risk for future nutrient imbalance, reduced forest production, and changes in biodiversity and ground vegetation species composition. However, field experiments have found contrasting results (e.g. Johnson and Curtis 2001; Olsson et al. 1996). Soil effects of increased biomass removal will be closely related to soil organic matter (SOM) dynamics, litter quality, and turnover rates. The SOM pool is derived from a balance between above- and below-ground input of plant material and decomposition of both plants and SOM. Harvest intensity may affect the decomposition of existing SOM as well as the build-up of new SOM from litter and forest residues, by changing factors like soil temperature and moisture as well as amount and type of litter input. Changes in input of litter with different nutrient concentrations and decomposition patterns along with changes in SOM decomposition will affect the total storage of carbon, nitrogen and other vital nutrients in the soil.

To quantify how different harvesting regimes lead to different C addition to soil, and to determine which factors have the greatest effect on decomposition of SOM under different environmental conditions, two Norway spruce forest systems will be investigated in the context of a research project starting in 2008/2009, one in eastern and one in western Norway, representing different climatic and landscape types. At each location, two treatment regimes will be tested: (1) conventional harvesting, with residues left on-site (CH), and (2) aboveground whole-tree harvest, with branches, needles, and tops removed (WTH). Input of different forest residues will be quantified post harvest. Soil water at 30 cm soil depth will be analysed for nutrients and element fluxes will be estimated to provide information about nutrient leaching. Soil respiration will be measured, along with lab decomposition studies under different temperature and moisture regimes. Long term in situ decomposition studies will be carried out in the WTH plots using three different tree compartments (needles, coarse twigs, fine roots) decomposing in litter bags, in order to determine their limit value. The structure of the fungal community will be determined by soil core sampling and use of molecular techniques allowing qualitative and quantitative estimation. Understorey vegetation will be sampled to determine the biomass, and the frequency of all vascular plants, bryophytes and lichens will be estimated. After harvesting, replanting will be carried out. Seedling survival, causes of mortality and potential damage, growth, and needle nutrients will be monitored. Results from these studies will be used to identify key processes explaining trends observed in two series of ongoing long-term whole-tree thinning trials. We shall combine knowledge obtained using field experiments with results of modelling and data from the Norwegian Monitoring Programme for Forest Damage and National Forest Inventory. This will help us to predict and map the ecologically most suitable areas for increased harvesting of branches and tops on a regional scale based on current knowledge, and to identify uncertainties and additional knowledge needed to improve current predictions.

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Approaches for the assessment of nutrient sustainability for different intensities of forest utilization

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Within the European Community the proportion of regenerative energies shall be increased to 12% until the year 2010. This aim, in combination with increasing prices for fossil fuel rises the pressure on forests to produce biomass for energetic use (“fuel wood”). However, forests in Europe often are growing on unfavorable sites which are too steep, too wet or too cold and in many cases too poor for agricultural use. Thus an intensification of forestry in large areas will be critical with respect to the sustainability of nutrient availability for the next forest generations. As shown in Table 1even on a well growing site like the Höglwald a whole tree harvest has to be seen critical, because more than one third of the currently available ecosystem pool of K, Mg and Ca would be removed and the loss of P and K would not be compensated by weathering. Even when only using wood, the total stock of Ca would be removed within 10 rotation periods, supposing a constant nutrient incorporation from generation to generation. This documents remarkable differences between nutrients, with P and K mainly limited by release from poorly available sources and Ca mainly limited by the total available stock.

There are two alternatives to guarantee a nutrient sustainable utilization of our forests. Either the export of nutrients by harvesting is restricted to a level which is compensated by weathering and input, or, when a maximum of biomass is exported, the losses of nutrients have to be compensated by fertilization. For both strategies it is essential to calculate site and tree species specific nutrient budgets, that include input and output of nutrients, weathering rates, allocation of nutrients in different tree compartments as well as different harvest scenarios. Such calculations are needed as a decision support system for a single forest enterprise, for regions or even countries, although the availability of the necessary data up to now is suboptimal.

Table 1. Three different ways to estimate nutrient related sustainability of forest utilization as calculated for two harvest intensities on the data basis of the Höglwald site; values estimated to be critical are shaded with gray.

	Nutrient export in % of easily available ecosystem pool		Nutrient release by weathering in relation to nutrient export		Number of hypothetically possible rotation periods until total storage is exhausted	
Element	Wood only	Whole tree	Wood only	Whole tree	Wood only	Whole tree
P	6	23	2,48	0,64	>100	25-50
K	15	40	2,08	0,69	>100	>100
Mg	13	35	2,72	1,94	50-100	50-100
Ca	22	72	3	1,18	<10	<10

Data from Ettl et al. (2007)

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Biomass removal from jack pine forests: impact of harvesting levels on nutrient pools across a gradient in site productivity

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Interest in forests as a source of bioenergy has increased as the human impact of fossil fuels on the earth's climate is realized and as supplies of non-renewable energy dwindle. In Ontario, Canada a newly-released biofibre policy emphasizes the utilization of woody biomass not usually removed from the forest during conventional logging operations. Concurrently, a specific objective of this directive is a commitment to forest sustainability as set out in the Crown Forest Sustainability Act, which requires forest management to ensure long-term forest health. One area of particular concern is the effect of greater biomass harvesting on long-term site productivity, especially on sensitive sites with naturally low fertility levels. There is a need to determine the contribution of potential biofibre to forest nutrient budgets and its impact on future stand growth.

We determined macronutrient contents (N, P, K, Ca, Mg) of aboveground biomass, forest floor (LFH) and mineral soil in mature fire-origin jack pine forests in north-eastern Ontario, Canada. The nine study sites, representing a gradient in site productivity, had well developed mor humus layers and coarse textured mineral soils developed in glaciofluvial deposits. As part of the Jack Pine Long-Term Soil Productivity (LTSP) study, portions of each site were operationally stem-only and full-tree harvested. In addition, an experimental full-tree harvest with LFH removal was implemented at each site. Estimates of the amount of biomass removed during the stem-only and full-tree harvest were determined by post-harvest slash assessments using the line-intercept method.

Table 1. Nitrogen content (kg ha^{-1}) of logging slash on full-tree harvested plots, forest floor, and mineral soil to 30 cm depth in jack pine stands across a site productivity gradient in north-eastern Ontario, Canada.

	Site Class 1			Site Class 2			Site Class 3		
Site index 50 yrs	19.3	18.3	17.9	16.5	16.5	15.9	15.2	14.3	12.3
Logging slash	43	140	113	104	78	42	47	33	44
Forest floor	672	645	769	721	572	926	560	573	585
Mineral soil	2531	4298	2390	1471	1933	2431	1828	1945	2654

Our study addresses two questions:

1. What quantities of macronutrients are removed during stem-only harvest, full-tree harvest and full-tree harvest with LFH removal?
2. What is the significance of these nutrient removals in comparison with the total nutrient content of each site?

We hypothesized that a) total site nutrient content will decrease with declining site productivity, b) harvest-related nutrient removals will be greater in absolute terms, on more productive sites, but represent proportionately less of the site nutrient content than on less productive sites, and c) decreased total site nutrient content with declining site productivity will reflect both decreases in total biomass and in nutrient concentration in woody plant components, and decreased nutrient concentrations and soil mass in organic and mineral soil horizons. Results from this study, in combination with subsequent growth assessments following the different harvest treatments, will assist in developing site and nutrient-specific guidelines outlining maximum amounts of biomass that can be removed without compromising long-term site productivity.

Bioenergy production, site productivity and forest sustainability

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If forest biomass is to fulfill its potential as a truly renewable energy source, current production can not compromise future productivity. Conservation groups and the public at large continue to demand greater environmental accountability from governments and industry in the management of the forested landbase. Current predictions of the increased utilization of woody biomass for energy reiterate many forecasts that were expressed three decades ago, yet the implementation of bioenergy systems has advanced to a great extent in some countries, while in others development has been slow. Greater utilization of forest biomass for energy production has been politically promoted in more recent years as a target within national energy policies.

While sustainability is an appealing and unarguable concept, determining what levels of biomass removal specific forest ecosystems can sustain with no decrease in site carrying capacity is a difficult objective. Criteria and indicators have been identified and incorporated into certification processes and forest management planning but in many cases threshold levels are a first approximation based on theoretical considerations and simulation modeling. Research efforts have also addressed the impact of biomass harvesting at increasing intensities on organic matter and nutrient removal across a broad range of forest and site types, however, there are few empirical studies that have examined long-term site productivity. In some studies increased biomass removal beyond traditional forest harvesting has been implicated in decreased forest growth and soil fertility. This presentation will examine the potential impact of intensive harvesting on site productivity, existing guidelines where bioenergy production is well developed and current research that will lead to further development and refinement of site specific recommendations and guidelines.

Assessing the environmental effects of biomass scenarios in Sweden applying nutrient mass balances at a national scale

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Increased biomass removal from Swedish forests has become important as the demand for renewable energy has increased. The removal of more biomass (stumps) will result in more nitrogen removal from the nitrogen saturated forest soils in the south of Sweden, which is considered to be a positive effect. However, nitrogen removal in the north of Sweden can be a problem because the soils are nitrogen poor. Although the forest soil in the south of Sweden is rich in nitrogen, other nutrients, such as phosphorous, may be limiting growth. Furthermore, the removal of base cations is also important to consider, as it can result in acidification. In this context, stump removal is not negligible, but the full effect has not yet been thoroughly investigated.

Few studies on nutrients in stumps are available, however in this study, stumps in Sweden, Finland and Denmark have been assessed regarding their nutrient concentrations and correlations with soil properties, climate conditions and deposition level.

A high resolution database, providing nutrient mass balances at a national scale, was applied in Sweden to assess the environmental effect of different biomass scenarios, including stump removal, on nutrient balances in forest soil. Mass balances for nitrogen, phosphorous and base cations were calculated for 20 000 forest sites in Sweden.

Biomass removal will significantly decrease soil base saturation in acidified ecosystems

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Removal and burning of biomass after tree harvesting has been proposed as an action supporting reductions in fossil fuel consumption and increasing the use of renewable resources of energy. However, this harvested biomass (branches, needles, bark and stumps) contains many base cations (between 40–60% of the total pool in trees) and its removal could significantly reduce the pools of soil base cations.

The MAGIC model was used to estimate the influence of biomass removal at 4 catchments with differing natural buffering capacity and acidic deposition. All catchments are covered by regularly harvested Norway spruce (Picea abies) monocultures. The most sensitive and acidified Lysina catchment is underlain by granite, the intermediately sensitive catchments Liz (mountains) and Anenske (highland) by gneiss and the well buffered Pluhuv Bor is underlain by Mg rich ultramafic serpentine.

At all catchments three scenarios were calculated: (i) No harvesting – representing the “virgin forest” hypothetical situation where the net uptake of base cations to the biomass = 0 and only acidic deposition reduces soil base saturation, (ii) Harvest of trunks – representing the current management practice where trunks are removed from the ecosystem and (iii) Harvest of the entire biomass representing a scenario where all future biomass is removed from the ecosystem. At the sensitive Lysina catchment (Fig. 1) removal of all biomass will result in a significant decrease of soil base saturation (to 2.9% in 2050) compared to the current practice of harvesting just trunks (4.8% in 2050). Both practices, together with acidic deposition, will result in a further decrease of base saturation between 2007 and 2050.

In the intermediately buffered mountainous Liz catchments, biomass removal will also result in a significant reduction of base saturation. Biomass removal will not have a significant effect at the well-buffered Pluhuv Bor, where base saturation is very high (89%) and high mineral weathering mitigates the effects of acidic deposition as well as biomass removal.

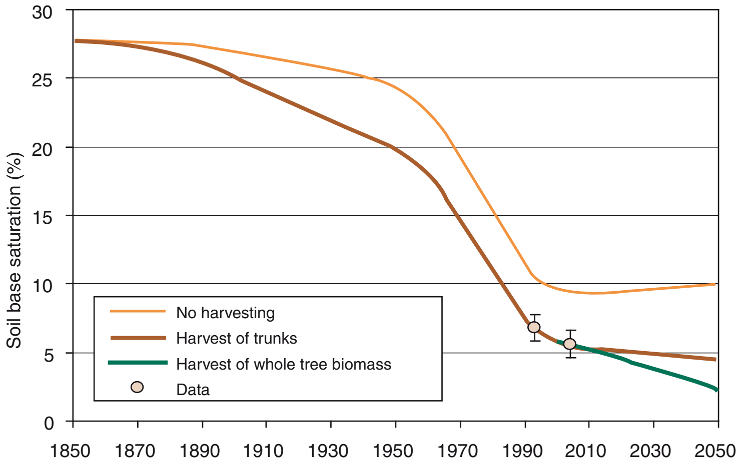

Fig. 1. Measured and simulated changes in soil base cation saturation at the Lysina catchment

Nutrient cycling after harvester thinning in Norway spruce stands as influenced by harvesting intensity and nitrogen status

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Due to rationalisation and intensification of tree harvesting with harvesters and forwarders new skid trails have been located all over Bavaria (Germany). On the one hand a brushwood mat is recommended on the skid trails to protect the soil from compaction, on the other hand often most of the logging residues have been removed due to the increasing demands for production of bioenergy. As logging residues contain significant amounts of nutrients the removal of the material from the stands or the accumulation on the skid trails may have a significant impact on nutrient cycling.

New skid trails were established during thinning operations at (1) the nutrient poor Norway spruce stand in “Eslarn” and (2) the N saturated spruce stand “Höglwald”. At each site five skid trails with and without a brushwood mat were investigated. Each replication consisted of 4 subplots: (a) stand interior, (b) stand edge, (c) wheel track, and (d) median strip. Seepage water was sampled with suction cups in 40 cm depth, volumetric water content was measured online with ECHO soil moisture sensors (0 to 20 cm depth), divers physical soil parameters were estimated, and translocation and export of nutrients after thinning was calculated. First results of soil physical parameters and the time course of the water content at Eslarn indicate impaired, but still tolerable conditions for root development in contrast to skid trails without brushwood mat. According to these results it can be assumed that nutrients transferred to the skid trails can be relocated from the adjacent trees and incorporated again in the elemental cycle of the remaining stand. Until now, elevated NO_3- concentrations (up to 45 mg l^{-1} NO_3-) were only exhibited in the median strip of one skid trails with brushwood mat, where a small gap was formed, while at all other subplots very low NO_3 concentrations (mostly below 2 mg l^{-1}) were detected. This indicates that seepage water losses are less relevant at this site. At the Höglwald the time course of the water content shows impairment for the roots on the skid trails whether with or without brushwood mat, indicating that the slash left on the skid trails could not prevent the soil from severe compaction damages. At the Höglwald site NO_3 concentration under the skid trails were nearly not affected within the first year of observation, but were as high as in the intact stand (mostly above 50 mg NO_3 l^{-1}). The results are discussed in relation to nutrient sustainability and recommendations are given regarding forest practice.

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Nutrient removal in logging residues in thinnings in boreal forests: long-term impact on tree growth

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On mineral soils in boreal forests the amount of available N is the most important factor limiting the growth of trees. Thus, as logging residues are increasingly being used as a source of bioenergy it is important to know how the removal of logging residues affects the N status and the N cycle of the stand. Residues are removed both in clearfelling but increasingly also in thinnings to serve the double purpose of increasing the yield and making thinning operations more profitable (Rolff & Ågren 1999). However, whole tree harvesting (WTH) in thinnings may have a more detectable impact on site productivity than WTH in clearfelling. According to Jacobson et al. (2000), WTH in thinning reduced the volume growth in both Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karst.) stands. The aim of this study was to compare how nutrient removals in conventional stem harvesting (CH) and whole tree harvesting (WTH) in the first, and some cases also in the second thinning, affect the tree growth of Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karst.) stands in Finland.

A series of 12 long-term field experiments was studied; five experimental sites dominated by Norway spruce and seven by Scots pine. The experiments randomized by block design were established during 1978–1986. The first thinning took place at the time of the establishment of the experiments. All the spruce stands and two of the pine stands were thinned twice. The amounts of nitrogen removed in the first thinning varied in the spruce stands from 59 to 129 kg ha^{-1} and in the pine stands from 24 to 57 kg ha^{-1}. The experiments were located in different climatic conditions and on different site types. The treatments were 1) WTH, in which all logging residues were removed from the site, 2) CH, with all logging residues left at the site, 3) CH+R, conventional harvesting with addition of extra residues from a neighboring WTH plot., and 4) WTH / CF with fertilization. The tree stand measurements were done at the time the experiments were established and after that every 5 years. Dry mass and nutrient concentrations of logging residue components were determined.

The volume growth was reduced 5–6% in Scots pine and Norway spruce stands on WTH plots compared to CH during the first 10–year period (Jacobson et al. 2000). The growth reduction started three to five years after thinning at the time when N release starts from decomposing foliage residues. The tree growth changes continued during the second 10–year period but varied between tree species and sites. The tree growth was reduced after WTH in most of the studied Norway spruce stands, and approximately half of the Scots pine stands. Norway spruce growth reduction was greatest in less fertile stands. Scots pine growth was less affected, even if pines grow on nutrient-poor sites. Some indication that WTH affects the needle nitrogen status of the remaining stand was detected. These results are discussed in relation to site fertility and nutrient cycling differences of Norway spruce and Scots pine stands.

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Belowground biomass carbon in mature reed canary grass stands in northern Sweden

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Reed canary grass is a promising bioenergy crop in boreal climate. The climate impact of the crop is however larger than just from substitution of fossil fuels. A large part of the products of photosynthesis in perennial grasses are allocated to belowground structures (Kätterer and Andren 1999), to provide for nutrient uptake and survival and growth in coming years. In this study we have quantified the carbon in live belowground biomass in leys of reed canary grass (*Phalaris arundinacea* L.). Data come from a fertilization experiment in a 5 year old ley and from a field survey on two fields with 7 year old leys at the same site as the experiment.

There was more carbon in belowground biomass after fertilization with 100 kg N ha^{-1} than after fertilization with 50 kg N ha^{-1} (Fig. 1). The difference was significant for total belowground biomass, but not for the different belowground fractions. The belowground carbon increased significantly between October 3 and May 27, indicating that carbon was allocated belowground also during late autumn.

In the 7 year old leys, there was a maximum of 3390 kg carbon ha^{-1} in rhizomes at October 13. Rhizome biomass was stable during winter and decreased between April 27 and June 9 linked, to a corresponding increase in root biomass carbon. We conclude that considerable amounts of carbon are allocated to belowground structures every year. Compared to annual bioenergy crops this will lead to increased carbon sequestration as an ecosystem service of the perennial cropping system (Sanderson and Adler 2008).

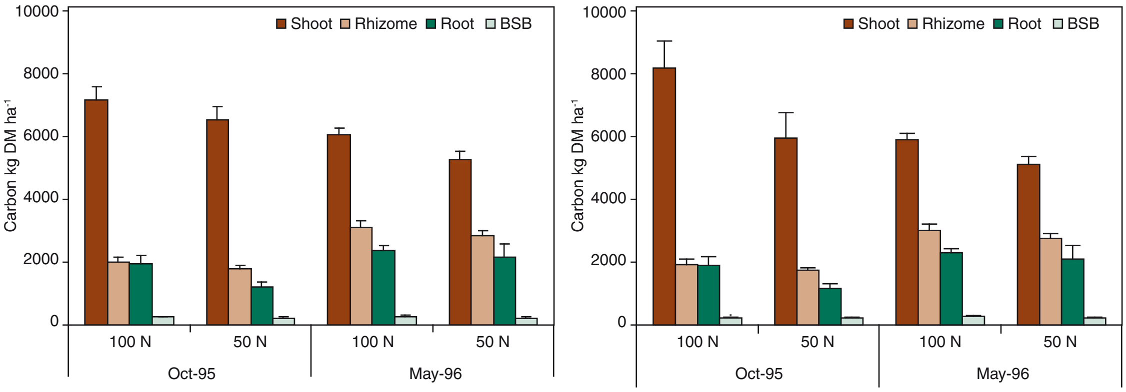

Figure 1. Carbon in above- and belowground biomass of RCG in mineral soil at different harvest times. The data were from a field experiment 1995 with crop of the 5th ley year and expressed by mean ± SE. BSB: belowground stem base.

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Biofuels and sustainable forest ecosystems: evaluating biomass removal under climate change and atmospheric deposition

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In recent decades, the environmental impacts of sulphur and nitrogen deposition have been greatly reduced due to international agreements and national legislation; however, climate change and associated land management now threaten the sustainability of ecosystems. To mitigate the impacts of climate change, many countries have started ambitious programmes to (partially) replace fossil fuels with biofuels. However biofuels compete with food production (in the case of agriculture) and can impact heavily on forest ecosystems, specifically through the removal of large quantities of nutrients, especially base cations. In the current study, we use national-scale Finnish survey data in combination with a dynamic hydro-geochemical model to evaluate which combination of deposition scenarios and harvesting practices provide the optimal use of biofuels while guaranteeing sustainable forest ecosystems under climate change.

Lakes are integrators of geochemical processes in their terrestrial catchment. Accordingly, a random survey of 1000+ lakes was carried out in the late 1980s in Finland to analyse the impacts of atmospheric deposition (Kämäri et al., 1991). The response of these lake catchments to sulphur and nitrogen deposition scenarios and potential tree harvesting practices (in view of biofuel production) was investigated using the dynamic hydro-geochemical Model of Acidification of Groundwater in Catchments (MAGIC). This study is an advance on previous smaller scale (163 lakes) assessments (i.e., Posch et al., 2008; Aherne et al., 2008) that excluded the impacts of climate change on the weathering of base cations and biomass growth. Future depositions were varied between current emission policies and maximum (technically) feasible reductions, biomass removal scenarios were based on stem-only harvesting (SOH) and whole-tree harvesting (WTH), and future climate (temperature and precipitation) was derived from the HadAM3 and ECHAM4/OPYC3 general circulation models under two global scenarios of the Intergovernmental Panel on Climate Change (IPCC: A2 and B2). Results indicate that the current practice of SOH is close to the sustainable maximum harvesting under current (legislated) atmospheric deposition in Finland. Under the WTH scenario long-term re-acidification is predicted for soil and surface water chemistry, the speed and degree depending on the deposition scenario. Increased weathering owing to climate will supply additional base cations but higher biomass growth and harvesting will remove more base cations from catchment soils. Thus the increased utilisation of biofuels may necessitate ‘trading emissions for timber’, or soil amendment, to maintain ecosystem quality and sustainable forest growth.

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Eddy covariance CO_2 balance of a perennial bioenergy crop on a cutover peatland under contrasting climatic conditions

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According to IPCC (2007), the present increase in atmospheric CO_2 levels is anthropogenic and is brought about primarily by the combustion of fossil fuels and deforestation. One of the strategies to reduce the increasing atmospheric CO_2 levels is to increase the use of renewable energy. Bioenergy production from biomass has been proposed to be one of the ways to increase the share of renewable energy in the total energy consumption. Bioenergy is considered to produce “carbon neutral” energy, as the biomass releases the same amount of carbon upon combustion as the amount of atmospheric CO_2 captured during the photosynthetic process. Furthermore, bioenergy use contributes to the security of energy supply and enhances the goals of local employment.

In the boreal region, the area under the cultivation of reed canary grass (*Phalaris arundinacea* L.) as a bioenergy crop is fast increasing. This crop is well suited for cultivation in northern conditions as it is known to produce the highest amount of biomass under low temperatures and high soil moisture. Many previous studies have reported its yield potential in terms of biomass production, its genetic characteristics and fuel quality aspects as a bioenergy crop. There is hardly any information, however, on the carbon balance of RCG cultivation systems. To assess whether the bioenergy production from RCG is beneficial, it is important to know not only the biomass yield but also the overall greenhouse gas balance of the production system.

We are measuring the CO_2 and energy exchange from RCG cultivation on an organic soil, a cutover peatland in eastern Finland since March 2004. The study site is 15 ha in area. A detailed description of the study area can be found in Shurpali et al. (2008). The eddy covariance system consists of an open path infrared gas analyser (Model LI-7500: Li-Cor Inc., Lincoln, NE, USA) for CO_2 and water vapor density and a 3-D sonic anemometer (Model CSAT3: Campbell Scientific Inc., Logan, UT, USA) for conjunct wind velocity measurements. Other supporting measurements included air and soil temperatures, incoming solar and photosynthetically active radiation, humidity, wind speed and direction, precipitation, water table level and snow cover. In addition, soil physico-chemical properties and above- and below-ground plant biomass were measured.

In this paper, we are presenting RCG CO_2 exchange patterns during two measurement years with contrasting weather patterns – 2004 was a wet year with 64% higher and 2005 was a dry year with 25% less than the 30–year (1971–2000) mean precipitation. During the wet year, the ecosystem was a strong sink with a net CO_2 uptake of 211 g C m^{-2}, while it was a weaker sink during the dry year accumulating 9 g C m^{-2}. Gross primary productivity (GPP), not the total ecosystem respiration (TER), was the main process driving the NEE interannual variability in this ecosystem.

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Logging residue removal in Norway spruce thinning stands: Long-term effects on C and N transformations and phenolic compounds and terpenes in the organic layer

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Increasing demand for production of bioenergy has led to an interest of forest management which uses logging residue from both clear-cuttings and thinning stands. In a previous study, changes due to logging residue removal in microbial processes related to C and N cycling were observed in one Norway spruce thinning stand (Smolander et al. 2008). To get a more general picture, we investigated long-term effects of logging residue removal in four Norway spruce thinning stands on soil microbial processes in C and N cycling and on soil concentrations of two important groups of plant secondary compounds, phenolic compounds and terpenes. These two groups of compounds were of interest since logging residue contains the highest portion of most of these compounds. In addition, certain phenolic compounds and terpenes have been shown to regulate N transformations in forest soils.

The study sites were four, 47–70-year-old, Norway spruce (*Picea abies* (L.) Karst) stands growing on relatively fertile sites in Southern and Central Finland. The stands had been thinned twice; the first thinning was performed 22–29 years ago and the second thinning was performed 10 years after the first one, 12–19 years ago. After the thinnings, logging residue from the thinning was either removed (whole-tree harvest) or left on the site (stem-only harvest). For both treatments there were 3 study plots. In one experiment (with only 2 study plots per treatment), there was also a treatment where double amount of logging residue was distributed on the plot.

Samples were taken from the organic layer (F+H). Amounts of C and N in the microbial biomass, and the rates of C mineralization (as CO_2 production), net N mineralization and net nitrification were determined. Soil pH, C-to-N ratio and the concentrations of total water-soluble phenolics, an important group of phenolic compounds, condensed tannins and different terpenes were measured from the organic layer samples.

There were no clear consistent long-term effects of logging residue removal. The rate of net N mineralization in the organic layer was either similar or lower in whole-tree harvest than in stem-only harvest depending on the site. In one of the sites, amount of N in the microbial biomass and rate of C mineralization also tended to be lower in whole-tree harvest. The different harvest treatments did not much affect pH, C-to-N ratio or the concentrations of water-soluble phenolic compounds in the organic layer. The concentrations of diterpenes, including e.g. resin acids, were lower in whole-tree harvest than in stem-only harvest in part of the sites. Altogether, still after more than 12 years soil microbial activities and certain characteristics of organic layer differed in whole-tree harvest from those in stem-only harvest but the effects appeared to depend on the site.

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An assessment of the potential for cropland expansion in Brazil considering land suitability and environmental constraints

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The increased use of biofuels for transport is questioned based on concerns related to both socio-economic issues, including food security, and environmental impacts arising from intensified land use and agricultural expansion into natural ecosystems. One common objection is that global food demand is expected to increase substantially the coming decades while at the same time there are limited prospects for expanding agriculture due to various climate, soil, and topography constraints – or risks of considerable environmental impacts (e.g. biodiversity losses).

Some regions still have an assessed substantial potential for increasing the agricultural output – for food and for bioenergy – based on cropland expansion as well as intensification of current agriculture. Brazil is one of the countries having good prospects for agricultural expansion, with 135 million hectare of land claimed to be available for cropland expansion without illegal deforestation or other major environmental impacts.

This study evaluated the expansion potential of Brazilian agriculture based on a comprehensive and sophisticated GIS based database, including current land use, environmental legislation and land suitability (climate, soil, slope). The results indicate that the expansion potential is lower than 135 million hectare and will mainly be determined by two factors: (i) the revision of current environmental law related to deforestation and (ii) prospects for intensification of beef cattle production.

Stem only vs. whole-tree harvesting – the effects of harvesting in forested peatlands on the leaching of nutrients and heavy metals

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According to current Finnish energy policy, logging residues (tree tops, branches and stumps) will have to be used in addition to stemwood in order to meet targets for bioenergy production. In Finland 4.5 million ha of peatlands have been drained for forestry purposes, and much of it will be at the final stage of commercial growth and set to be harvested within 10 to 30 years. This biomass would provide a major source of bioenergy, especially if whole-tree harvesting were practised. However, the impacts of whole-tree harvesting on biogeochemical cycles and leaching to surface waters are largely unknown, especially in the case of drained peatland forests. It is therefore important to evaluate not only the potential of drained peatland forests as a source of bioenergy, but also the potential consequences of harvesting on the biogeochemistry of these sites.

Disturbance of forest ecosystems, such as through harvesting, is known to increase leaching, at least in the short-term. The disturbance associated with whole-harvesting may be expected to be greater than with conventional stem-only harvesting. Anoxic conditions can develop in pools of standing water formed as a result of harvesting, especially after stump removing, and result in the mobilization of nutrients and trace metals from the peat. Subsequent transport to surface waters (streams and lakes) could result in eco-toxicological damage. We are thus carrying out a study to investigate the potential risk of harvesting of drained peatland forests, both stem-only and whole tree, on the mobilization and leaching of nutrients and trace metals to surface waters.

The study will be carried out in 9 small peatland catchments located in eastern Finland. The peatland in all the catchments have been drained for forestry purposes and the forests are considered ready for harvesting. Five of the catchments are underlain by granitic bedrock and four underlain by black shale. These shales have strongly elevated concentrations of trace metals, including mercury (Hg). We chose to carry out the study on the black shale areas in order to maximise the potential biogeochemical signal due to the harvesting disturbance. In 2007, a study plot was established in each catchment and a runoff gauge installed in the outlet ditch. Ditch water, peat cores and needle samples have been taken to calibrate the catchments. In 2009, two of the catchments will be subject to stem-only harvesting, four subject to whole-tree harvesting and the remaining three left unharvested to serve as controls. The catchments for treatment have been chosen such that we will be able to assess the geogenic effect of the underlying bedrock on drainage water quality. Preliminary results indicate that there are large differences in drainage water quality between the two bedrock types. Concentrations of SO_4, Ca, Cr and Fe were notably higher in drainage waters from the black shale catchments. Surprisingly, however, Hg and methyl mercury concentrations, which were measured four times during 2008, did not differ between different bedrock types.

Nitrogen budget of short-rotation grey alder (Alnus incana) stand on abandoned agricultural land

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Afforestation of agricultural lands for producing bioenergy brings about various changes at different levels of the ecosystem, including nitrogen (N) cycling. For alders, the effect on site N budget and soil N status is particularly significant owing to their symbiotic nitrogen fixation ability. Our aim was to assess, on the basis of N budgeting, the flux of annual symbiotic nitrogen fixation for a young, 10-year-old, grey alder (*Alnus incana*) stand growing on abandoned agricultural land. Also we evaluated the effect of grey alder stand on soil N status and on potential environmental hazards (gaseous N emissions, leaching).

The annual N demand of alders was estimated on the basis of model trees. Nitrogen demand for fine root (d < 2mm) production of alders was estimated, using ingrowth core technique, and it was 6.6 kg ha^{-1}yr^{-1}. Annual net N mineralization in the upper 0-20cm soil layer was established *in situ* using the method of buried polyethylene bags. Nitrogen retranslocation from the senescent leaves of the 10–year-old grey alder was estimated at 6.3 kg ha^{-1}yr^{-1} and annual N input via leaf litter into soil was 95.4 kg N ha^{-1}yr^{-1}. Leaching was assessed using plate lysimeters placed in soil at a depth of 40 cm. Nitrogen leached mainly in the nitrate and organic forms, the share of ammonium and nitrite nitrogen being negligible (0.1% for both). The maximum of N leaching occurred in autumn (September). For measurement of N_2O and N2 emissions, two methods – the "closed chamber" method and the helium-oxygen (He-O) method were used and the annual flux of N_2O-N and N_2-N was estimated as 0.50±0.45 and 73.8±44.5 kg N ha^{-1} yr^{-1}, respectively.

Table 1. Nitrogen budget of 10-year-old grey alder stand growing on abandoned agricultural land (kg N ha^{-1} yr^{-1}).

Fluxes	
Demand of plants (above-ground+below-ground part)	
Alders	164.5 [a]
Herbaceous plants (understorey)	40.7 [a]
Inputs	
Deposition	6.4 [c]
Symbiotic fixation	151.5 [b]
Transformations	
Net nitrogen mineralization	124.0 [a]
Retranslocation from senescent leaves	6.3 [a]
Initial pool of herbaceous plants	6.2 [a]
Outputs	
Leaching	14.9 [a]
Gaseous losses	74.3 [a]

[a] – determined, [b] – calculated by balancing other values,
[c] – estimated on the basis of literature

The grey alder stand on abandoned agricultural land increased significantly soil N content during a short period. The increase in soil Kjeldahl N during 12 years after afforestation was statistically significant (R=0.88 P<0.01) in the upper 0–10 cm and the deeper 40–50 cm (R=0.67 P<0.05) soil layers. The effect of alders on soil pH was very pronounced; soil acidity increased 1.3 units in the upper 0–10 cm topsoil layer (R=0.90 P<0.05). Despite high N input in the new forest ecosystem (symbiotic N fixation 151.5 kg ha^{-1}yr^{-1}), the possible risk for the environment was low; N leaching (15 kg ha^{-1}yr^{-1}) represented a small flux in total N budget (294.4 kg ha^{-1} yr^{-1}). A part of leached N accumulated in the deeper soil layer (40–50cm). Although gaseous emissions were considerable in the whole N budget, the N emitted mainly in its N_2-N form and the share of N_2O was negligible. Thus, short-rotation grey alder stand on former agricultural land, as a perspective source of bioenergy is an ecologically sound alternative land use.

Long term effects of whole tree harvesting on soil nutrient sustainability in the UK

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Nutrient and base cation removal during thinning and harvesting operations represents a significant loss of nutrients and base cations and in acid sensitive areas may enhance the acidification of forest soils and watercourses. The extraction of woody biomass from forests and its use in fossil fuel substitution is increasingly seen as having a significant contribution to make to climate change mitigation. Pressure is already growing to extend whole-tree harvesting (WTH) as opposed to conventional harvesting (CH) to upland conifer plantations as a way of maximising woody biomass yields in the UK. This is likely to lead to WTH being extended onto more acid sensitive soil types, posing a threat to soil sustainability in terms of soil acidification and nutrient loss and changes in soil carbon sequestration potential.

Reducing chemical inputs into forests is another fundamental feature of sustainable forest management in the UK and a requirement for UKWAS certification. The application of N, P and K fertilisers has been the traditional major chemical input to forests located upon poor soils and lithology. Through this study it is possible to evaluate the long term impacts of fertilisation (F) on soil capability to sustain future forest generations and soil status in comparison to CH and WTH practices.

Published research on the long-term effects of WTH, CH and F on soil acidity, nutrient status, base cations, soil water and carbon, is limited. The biggest changes can be expected on soils with high C stocks, which is the major type in the Kielder catchment under study. Long term effects on soil sustainability from this randomised block experiment in northern UK has been assessed after 28 years of second rotation growth of Sitka Spruce on a peaty gley soil. The experiment is one of the oldest whole tree harvesting experiments in Europe.

No evidence was found to indicate that the removal of residues in WTH has reduced soil organic carbon and nitrogen content or soil moisture content after 28 years after the WTH has taken place. Instead, there is significant decreased organic carbon content and total nitrogen in CH and F in comparison to WTH plots. CH has reduced soil C and water content (especially in the H and A horizons) to significantly lower levels that did the WTH. These results suggest that retention of forest residues on site may increase the rate of mineralisation of existing soil organic carbon and nitrogen stocks and thus reduce the rate carbon is sequestered in forest soils. This is also confirmed by the significantly higher available nitrogen in the CH and F plots as compared with the WTH plots. The tendency of soil moisture content to be significantly greater at WTH particularly in H (peat layer) and A horizons (heavy clay horizon), can be attributed to the greater aboveground biomass (and thus potential evapotranspiration) demand in the CH and the F plots, in addition to the lower canopy water interception in the WTH due to poorer tree growth. WTH was found to exacerbate significantly the acidification in the soils when compared to soil acidity status in the CH and F plots. In contrast, CH and F depleted the soils in the nutrients P, N and K as well as in base cations due to the higher uptake by the increased aboveground biomass in contrast to WTH where more of the soil base cations and nutrients were retained in the soils. These results suggest that whilst CH and F in particular may support higher tree biomass aboveground, these practices will compromise the soil sustainability in the long term to support future forest rotations. The overall findings of this study imply that cost benefit analysis should be carried out before decisions are made on the appropriate type of forest operations to the appropriate sites in terms of soils and geology, in order to serve both environmental benefits, long term sustainability and increased biomass production for biofuel.

The impact of site characteristics on the nutritional sustainability of wood production and harvesting

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A renewed interest in forest biomass as an energy source together with the possibilities of modern harvesting technologies and precautions against insect calamities initiated a lively discussion about intensifying forest harvesting and the utilisation of crown material as energy wood. However, a responsible, nutritionally sustainable forest management demands to consider the economic gains of an intensified production as well as the associated nutrient exports and thus the future development of the productivity at the site. Thus, the site specific nutrient availability (deposition, weathering, overall and exchangeable nutrient pools) has to be compared to the nutrient losses via biomass export (harvesting) and seepage output.

As an example, the approach currently realised for the state forests in Bavaria, Southern Germany, financed by the BAYSF (Bayerische Staatsforsten) is presented. Units of comparable site conditions were identified using national soil maps and geo-scientific maps. Specific chemical and physical information was derived from typical soil profiles. Growing stock, increment, and the biomass of wood, bark, branches, and needles/leaves were calculated with the forest growth simulator SILVA, considering pure stands of Fagus sylvatica, Quercus robur, Picea abies, and Pinus sylvestris. Nutrient exports with harvesting were estimated by multiplying biomasses by the specific nutrient contents. Regional deposition rates were derived from measured deposition at level II plots, critical loads assessments and emission inventories. Weathering rates were calculated with the soil chemical model PROFILE using literature based approximations for the mineral composition. Nutrient losses with seepage were estimated via mass balance approaches.

Negative balances for the nutrients calcium, magnesium or potassium are typically found at sites with very sandy soils, soils rich in gravel or very shallow soils. Harvesting crown material in stands of beech and oak leads to high losses of calcium often surpassing the site available inputs. For spruce negative balances are usually found for magnesium and potassium. Pine only shows negative nutrient balances at the poorest sites. Due to the parent material, the northern and eastern parts of Bavaria suffer from deficiencies in calcium and magnesium, whereas in the southern parts, where limestone and dolomitic limestone dominates, unbalanced potassium supply may occur.

In order to further improve the calculation of nutrient balances, site specific nutrient contents for spruce and beech are currently investigated and compared to soil chemical properties. Preliminary results concerning the relationship between the nutrient contents in wood, bark, branches, twigs, and needles and the site specific nutrient availability will be presented.

Modelling Past Mercury Deposition from Peat Bogs – The Influence of Peat Structure and ^{210}Pb Mobility

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Historical records of mercury (Hg) accumulation in lake sediments and peat bogs are often used to estimate human impacts on the biogeochemical cycle of mercury. Atmospheric Hg loads are estimated to have increased 3–5-fold in modern times compared to background values, an estimate based largely on lake sediments. Recent studies of the Hg record in peat bogs, however, suggest a significantly higher modern increase, by as much as 30–100-fold. To evaluate the apparent difference between these two natural archives we compared literature data of modern and background Hg accumulation rates derived from globally distributed peat bogs and lake sediments and discuss reasons for the observed differences.

Median pre-industrial mercury accumulation rates in peat were about 1 µg m^{-2} yr^{-1}, only varying within the range of 0.6–1.7 µg m^{-2} yr^{-1} at most sites; lake sediments, when corrected for catchment size and sediment focusing, show background Hg accumulation rates that are 3–5-fold higher (3–3.5 µg m^{-2} yr^{-1}) than peat. Modern mercury accumulation rates in bogs vary from 16 to 184 µg m^{-2} yr^{-1} (median 59), which correspond to an average increase in the industrial age of 69-fold (9–410, median 38). In contrast to higher background accumulation rates, modern Hg accumulation rates (mean 12 µg m^{-2} yr^{-1}) in lake sediments increased on average by only 3.5-fold, which is ~10–20 times lower than in peat bogs. Direct measurements of modern wet Hg deposition rates (~10 µg m^{-2} yr^{-1}) gave values 6 (up to 18) times lower than in peat suggesting that recent Hg accumulation rates in peat bogs tend to overestimate deposition. Smearing of ^{210}Pb used for dating and dynamics of mass loss in the uppermost peat layers are suggested to be the predominant reasons for the overestimation of modern Hg accumulation in many peat bogs. Similar strong increases in accumulation rates of other trace elements such as bromine or selenium in the uppermost peat sections which could not be explained by changes in atmospheric fluxes, confirm the general overestimation of trace element accumulation in peat due to ^{210}Pb smearing. Mercury fluxes could be corrected for overestimation using accumulation rates of bromine or selenium assuming that deposition fluxes of these elements have been constant during the past 150 years. This results in corrected modern Hg accumulation rates, which are in line with those derived from lake sediments or direct Hg deposition measurements. The lower background Hg accumulation rates in peat as compared to sediments are assumed to be a result of non-quantitative Hg retention or release of Hg during peat decomposition.

Use of organic sediments of Velke Darko to study climatic changes during 15,000 years (Protected Landscape Zdarske vrchy, Czech Republic)

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During the geological mapping of the Protected Landscape Area Žďárské vrchy (Zdarske vrchy) on a scale of 1:25 000 the research of organic sediments is being carried out. The geological mapping of the Quaternary sediments and the palynological investigation on the selected localities offers data on the Quaternary development of the territory and of a good condition of the contemporary ecosystems. The organic sediments on the map sheets were the subject of palynological investigation. Samples of the locality Velké Dářko (Velke Darko) were radiocarbon–dated too (Radiocarbon Laboratory Silesian Technical University, Gliwice, Poland). The results of the pollen analyses augment knowledge of the territory development and its state from the environmental quality point of view. They also indirectly draw attention to the water management importance of this area.

The Žďárské vrchy Hills are situated at the borders of Bohemia and Moravia, in the highest part of the Českomoravská vysočina Highland. Peat-bogs mainly occur at the edge of the territory on the transition into the flat or undulating terrain of the rest of the Českomoravská vysočina Highland. The climatic conditions belong for their origin to the most favourable ones in our republic, because the annual course of the weather is uniform without bigger extremes both at rainfalls and temperatures. They belong among more humid territories of the state and these conditions create possibilities of formation and functioning of wetlands to peat-bogs. The territory of the Protected Landscape Area interferes in the northern part into the Železné hory Mts., in the western part in the Hornosázavská pahorkatina Upland, in the southern part into the Křižanovská vrchovina Highland. The bigger part of the territory belongs to the Hornosvratecká vrchovina Highland. The geomorfological under-whole the Žďárské vrchy Hills represents the culminating part of the whole territory and therefore the Protected Landscape Area bears particularly this name. The geographical situation of the Žďárské vrchy Hills and their environs demonstrates their important water management situation (Břízová 2006). Disturbance of the forest ecosystems and thus consequently of the peat-bogs function, how it is happening in the area, might have consequences, which appeared during the floods in 1997 and 2002.

The Velké Dářko locality is located in the vicinity of the Žďárské vrchy Hills. The surroundings of Velké Dářko are very important and interesting mainly from a geological, geomorphological and palaeoecological points of view. The results of the pollen analyses augment knowledge of the territory development and its state from the environmental quality point of view. They also indirectly draw attention to the water management importance of this area. The oldest palynological investigations come from the beginning of the pollen analysis introduction into the geology awareness and therefore it was necessary to carry out their revision namely from the Quaternary development point of view, and mainly on account of the Late Glacial, which is not mostly recorded in the old works. Their descriptions indicate that authors identically considered the Preboreal (10,250–9,100 B.P.) for the initial period of the origin, however, they mentioned that the lower ca 2 m in profiles were not analysed. In the research works quite different conditions at the development than it is in the peat-bogs of the border mountains of the Czech Republic are described. The spruce (*Picea*) forests with beech (*Fagus*) and fir (*Abies*) are taken for the final state of the Žďárské forests before human interference. Three radiocarbon data (^{14}C) spring from this locality, too: 1. VD-D3/1/6.75-6.80 m, Gd-16468, **14,980 ± 310 B.P.,** 2. VD-D4/20/8.00–8.05 m, Gd-17454, **12,280 ± 360 B.P.** and 3. VD-D4/19/7.75-7.80 m, Gd-12974, **11,780 ± 150 B.P.** All measurements date the lower parts of the peat-bogs and confirm hypothesis that the origin is substantially earlier the Late Glacial (15,000/13,000–10,250 B.P.) than only the Preboral (10,250–9,100 B.P.).

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Lake-sediment archives of preindustrial mercury pollution in the Andes

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Here we present the first records of preindustrial atmospheric mercury (Hg) pollution from lake-sediment cores in the Peruvian Andes. We targeted two regions, both hypothesized to have been major preindustrial sources of atmospheric Hg emissions: Huancavelica, the largest Hg deposit in the New World; and Cerro de Pasco, once the world's largest silver mine and foundation for the adoption of Hg amalgamation. At Huancavelica, intensive Hg mining first began ~1400 BC, predating the emergence of complex Andean societies. The earliest mining targeted cinnabar (HgS) for the production of vermillion, and generated local-scale cinnabar pollution. Following Inca conquest (~1450 AD), smelting was adopted at the mine, Hg pollution became widely circulated, and the deposition of matrix-bound phases of Hg predominated over cinnabar dust. The mine was seized by Spanish metallurgists in 1564 AD, and for the next ~300 year Hg extracted from Huancavelica was exported to silver mines throughout the Andes for use in Hg amalgamation. The sediment records capturing Hg emissions from Cerro de Pasco confirm widespread Hg pollution beginning with the deployment of amalgamation technology ~1600 AD. Our results provide the first evidence for intensive preindustrial Hg pollution associated with Hg mining and amalgamation, and place recent Hg enrichment in the Andes in a broader historical context.

A 250,000-year record of mercury accumulation in the Arctic

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There is increasing concern regarding the impact of anthropogenic mercury (Hg) deposition to arctic foodwebs and ecosystems. Lake-sediment cores collected from across the Arctic suggest a one- to four-fold increase in Hg deposition since 1850–1900 AD, and testify to the global nature of anthropogenic Hg pollution. Coupled to this recent increase in Hg pollution is the rapid warming of the Arctic. Yet little is known regarding the long-term natural variability of mercury deposition in the Arctic. Moreover, both modelling and lake-sediment studies suggest Hg-climate couplings exist at multiple timescales. Here we present a unique multi-proxy lacustrine-sediment record from Lake CF8 (located on the east coast of Baffin Island, Canada) to investigate natural Hg variability and Hg-climate couplings over millennial timescales. The lake record preserves four organic lake sediment units, which are separated by sands and record portions of the past three interglacial periods and one interstadial. Both Hg concentrations ant total organic matter (TOM) are characterized by a progressively declining trend over the Holocene, the last interglacial (LIG), and previous interglacial (PIG) warm periods. These trends are in contrast to profiles of biogenic silica and Chl *a*, both of which record increases in within-lake primary production over the Holocene and the LIG. When considered alongside C:N ratios of TOM, the Lake CF8 sediment record suggests that temperature-mediated export of catchment-derived organic matter exerts a first-order control over Hg deposition. These results hold important implications for the future of mercury cycling in the Arctic given the recent trajectory of accelerated warming and anthropogenic Hg deposition.

Influence of peat decomposition on distribution of major and trace elements in peat

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Peat bogs are widely used as geochemical archives to study historical changes in atmospheric deposition of trace elements. Recent studies hint at an important influence of climate and hydrology driven changes in peat decomposition and mass loss on the enrichment and release of organically bound elements (Hg, Br, I) in peatlands. However, this relationship has only been demonstrated for a small number of elements. Here, we investigated the historical distribution of Fe, Mn, Cr, Zr, Ti, Hg, Br, and I concentrations in four German peat bogs located in the lowland of northern Germany and the Harz Mountains and its relationship with peat decomposition patterns (C/N-ratios). Results indicate three different patterns of relationship between peat decomposition and element distribution. Concentrations of Hg, Br and I increase with increasing peat decomposition and mass loss due to the formation of stable organometal or organohalogene compounds. Concentrations of the conservative elements Ti and Zr also increase with increasing peat mass loss due to the low solubility of Ti and Zr species in peat. Although concentrations of Fe, Mn and Cr in peat are thought to be determined by changes in redox-conditions or varying input of mineral dust particles, enrichment or depletion of peat in all three elements were found to be mainly controlled by organic matter decomposition processes. Accordingly, highest concentrations of Fe, Mn and Cr were observed in less decomposed peat sections and decrease with increasing decomposition indicating that these elements are released from the peat during decomposition. In contrast to previous studies our results show that the trace element distribution in peatlands is predominately controlled by peat decomposition processes and to a minor extent by changes in atmospheric fluxes. Based on our observation we hypothesize that changes in climate and/or hydrology, especially bog wetness, will have strong influence on the fate of trace elements in peatland systems.

Historical mercury deposition in the vicinity of Pb smelter as recorded in tree rings

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Tree rings have been used as geochemical archives of historical pollution in several studies on different tree species and for a number of different elements. In most works Pb and Cd concentrations in tree rings were investigated. Studies on past Hg pollution recorded in tree rings are rather rare. In this study tree rings from Norway spruce (*Picea abies* L.) were used to monitor historical Hg deposition in the Příbram area, central Czech Republic, affected by historical ore mining and smelting.

The Příbram smelter has been in operation for over 200 years. Historically it processed Pb-Ag ores mined in the area and at present produces Pb from scrap materials, mainly from car batteries. Mercury contamination in the Příbram region has been documented by number of studies, but precise information on Hg emissions from the smelter are unfortunately unknown. Dendrological cores were collected from three spruce trees (PB1, PB2 and PB3) in the close vicinity of the Pb smelter. The sampling sites were located approximately 0.5 km (PB1 and PB2) and 2.5 km (PB3) from the smelter stack.

Mercury concentrations in tree rings are depicted in Fig. 1. All three tree cores showed similar trend in distribution of Hg concentrations. The concentrations increased since the 1960s with maxima (up to 8.4 ng.g^{-1}) in the 1970s. Concentration maxima corresponded with reported peak of metallurgical production in the mid1970s. Maximum net Hg accumulations between the 1960s and 1980s were observed also by Ettler et al. (2008) in peat cores from the vicinity of the Příbram smelter.

Significant decrease in Hg concentrations since the 1980s was recorded in the tree cores PB1 and PB3. The decrease was probably related to the improvement of flue-gas cleaning technologies launched in 1982. Local maximum in Hg concentration in the tree core PB2 in 1990 could be a result of radial movement of this element in the sapwood.

The present study showed that tree rings may provide a good document of the course in Hg deposition in the area affected by ore mining and Pb smelting. Nevertheless further investigation on Hg cycling in trees will be necessary to interpret satisfactorily the historical record of Hg in this archive.

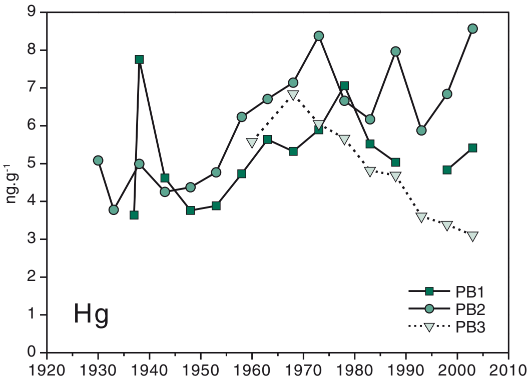

Figure 1. Mercury concentrations in tree rings of three spruce trees (PB1, PB2, PB3) in the vicinity of Pb smelter.

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The biomarker method: can a novel combination of organic chemical analysis and inverse modeling help reconstruct the past upper forest line in the Ecuadorian Andes?

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The higher parts of the Ecuadorian Andes consist of fragile ecosystems characterized by páramo grasslands and montane cloud forests. Natural climatic change and human interference (i.e. burning and clear-cutting) are believed to have dramatically lowered the UFL (upper forest line) in the area to the point that its natural position in the absence of disturbance is now uncertain. This is impeding our understanding of the response of the UFL to global climate change and hindering a correct strategy to reforest areas in the frame of Kyoto Protocol driven activities to fix carbon dioxide. An important cause of the uncertainty is that the traditional method of pollen analysis from peat or sediment deposits alone does not suffice to reconstruct shifts in the UFL Reasons are the spatial uncertainty caused by wind-blown dispersal of pollen and the limited availability of peat or sediment deposits at all altitudes of interest. The RUFLE[1] program tackles this problem by combining traditional pollen and vegetation analyses with a novel biomarker approach. In the latter, plant species typical for specific vegetation zones are examined for the presence of biomarkers, defined as plant-specific (combinations of) organic chemical components. Our results show that the leaves and roots of the higher plants are responsible for the dominant biomass input in our study area in the Eastern Cordillera, Northern Ecuadorian Andes contain unique combinations of *n*-alkanes and *n*-alcohols in the carbon number range of C_{20}-C_{36}. Furthermore, we found these compounds to be well preserved in peat deposits and soils in chronological order for extended time periods (>6000 ^{14}C years B.P.). As such they offer great potential to serve as biomarkers for past vegetation dynamics, including UFL shifts. However, since there are unique combinations of otherwise ubiquitous *n*-alkanes, *n*-alcohols of various carbon chain-lengths that constitute our biomarkers, unraveling the mixed signal of various plants accumulated in soils and peat sediment over time poses a major challenge. To tackle this problem, we developed the VERHIB model that describes the accumulation of biomarkers in soils and peat sediments. By inversion the most likely vegetation composition leading to the mixed biomarker signal in the soil or peat sediment in question can be derived. Here we describe the results of the first application of the model in a peat core and several soil monoliths at various altitudes from our study area. Our results show that biomarker analysis using the VERHIB model can indeed serve as a new proxy to reconstruct historic vegetation compositions including the UFL in the Ecuadorian Andes, yielding information that is highly complementary to that which can be obtained through traditional pollen analysis. This is a significant breakthrough from a paleo-ecological point of view as it means an additional proxy is available to be used in combination with traditional pollen- and vegetation analysis. In addition, it is a very promising result from an applied point of view as the information gained will aid the Ecuadorian government in its strategic decisions concerning reforestation of possibly degraded natural areas.

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[1] RUFLE stands for Reconstruction of the Upper Forest Line in Ecuador.

Spatial variability in Hg and Pb accumulation in the Chao de Lamoso bog (Xistral Mountains, NW Spain)

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Mercury and lead are heavy metals intensively investigated in peat cores, with the purpose of reconstructing past atmospheric pollution (i.e since prehistoric times, using long peat cores) and also of determining the timing of pollution since the start of the Industrial Revolution (using short peat cores). But most of the reconstructions rely on single peat cores and do not evaluate the whitin-bog spatial variability in metal accumulation. Recently, Bindler et al. (2004) analyzed Hg and Pb in multiple short cores from the same bog (Store Mosse, Sweden) and reached the conclusion that although general temporal trends were similar for all cores, single reconstructions didn't provide a representative flux for the bog as a whole. We have applied a similar approach to investigate the spatial variability in a blanket bog from NW Spain, Chao de Lamoso (CHL), where we collected 13 cores in a surface of 2 ha. Mercury was analyzed using a LECO-Altec AMA-254 analyzer and Pb using an EMMA-XRF analyzer (1996). The main results are synthesized in Table 1.

Maximum concentrations and total inventories of Hg and Pb in the CHL cores tend to be higher than those observed for Store Mosse (100–400 ng g^{-1}, 85–340 ng cm^{-2} for Hg; 70–200 µg g^{-1}, 75–140 µg cm^{-2} for Pb; Bindler et al., 2004). In the CHL cores concentrations and total inventories show similar ratios between maximum and minimum observed values: 2.4–2.4 fold for Hg and 1.6–1.7 fold for Pb. This variation is lower than that found in the Swedish bog (2 fold for Pb and 4 fold for Hg). The slopes of the relationship between Hg and Pb cumulative inventories also suggest differences in relative accumulation of both elements, and show a variation which is quite similar to that in Store Mosse (2.5x and 2.1x respectively).

Thus, although the Chao de Lamoso bog is located in a quite different climatic area (humid and temperate mid latitude), and closer to pollution sources than Store Mosse, the results still indicate a substantial spatial variability in Hg and Pb accumulation. Thus, in agreement with Bindler et al. (2004), these results also support the conclusion that multiple cores are necessary to provide representative data for a single bog.

Table 1. Mercury and Pb maximum concentracions (Hg_{max} ng g^{-1}, Pb_{max} µg g^{-1}), inventories (Hginv ng cm^{-2}, Pb_{inv} in µg cm^{-2}, for a reference accumulated mass of 4 g cm^{-2}) and slope of the Hg and Pb cumualtive inventories relationship (Pb/Hg*).

Core	Hg_{max}	Pb_{max}	Hginv	Pb_{inv}	Pb/Hg*
CHL-01	142	74	370	167	0.455
CHL-02	224	106	639	244	0.406
CHL-03	144	95	443	288	0.661
CHL-04	338	122	540	190	0.359
CHL-05	148	85	386	171	0.462
CHL-06	300	85	807	202	0.260
CHL-07	295	75	860	219	0.260
CHL-08	181	96	536	194	0.371
CHL-09	146	96	420	217	0.547
CHL-10	214	84	561	262	0.466
CHL-11	181	77	593	235	0.403
CHL-12	170	111	448	237	0.543
CHL-13	242	79	622	207	0.330
Mx/Mn	2.4	1.6	2.3	1.7	2.5

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Accumulation of trace metals in lakes with different catchment area and input of organic matter

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Many trace metals are shown to be enriched in the upper part of the sediments in several Norwegian lakes, due to long range atmospheric transport of pollutants (Rognerud and Fjeld, 2001). For the last decades, however, the aerial depositions of several trace metals and sulphate are shown to be reduced, indicating that the anthropogenic deposition of metals has decreased. At the same time, the colour and concentration of dissolved organic carbon (DOC) in surface waters of the boreal zone of Europe and North America have increased, possibly imposing a contrary effect with respect to metal accumulation, as DOC is an important transporting agent of metals.

In order to track long term development and recent changes in metal deposition of forest lakes located in a recreation area close to the city of Oslo, a paleolimnological study was conducted. Sediment cores from 5 lakes, differing in catchment area, retention time and DOC concentration (Table 1), were sectioned and subject to analyses of organic carbon, total S, total N, dry matter, radio-cesium and several trace metals (e.g. Hg, Cd, Cu, Zn, Pb).

Table 1. Lake water characteristics of 5 lakes in Oslo Østmark, Norway, subject to sediment sampling in March 2008,. Total organic carbon (TOC), pH and conductivity were measured during the autumn circulation period in Nov. 2008.

Lake	TOC (mg L^{-1})	Conductivity (mS cm^{-2})	pH	Lake surface area (km^2)	Catchment area (km^2)
Lutvann	1.9	5.8	6.7	0.43	1.73
Krokvann S	3.4	3.1	6.7	0.23	1.36
Forfoten	8.5	2.6	6.3	0.098	3.47
Solbergvann	16.5	3.3	6.1	0.013	0.12
Bonntjern	16.6	2.8	5.8	0.005	3.44

Generally, the upper layers of the sediments had elevated concentration of trace metals compared to deeper layers. For some elements a small reduction in the uppermost layer was observed. Factors influencing both long term and recent accumulation of trace metals will be further discussed, with a particular focus on the impact of organic carbon and sulphur.

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Chironomid-inferred Holocene summer temperature at Plešné lake, the Bohemian Forest, Czech Republic

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A number of regional chironomid-based inference models of mean July air temperature has been development and successfully used for reconstruction of Late-glacial climate fluctuations (Brooks, 2006). Even though the Holocene time period records relatively small temperature variability that is often within the prediction errors of inference models (Broecker, 2001), the Holocene paleotemperature reconstruction in the Swiss Alps (Heiri et al., 2003) suggested that the chironomid-inferred models is able to reflect also smaller climatic signals.

In co-operation with dr. Heiri from the Utrecht University in Netherlands, we used the transfer function developed for the Swiss Alps (Heiri et al., 2003). The inferred July air temperature varied from 10.6 to 14.0°C. The oldest samples coinciding with the period of Preborel (10.3–9 cal ka BP), produced a temperature range of 10.6–12.2°C and showed decreasing trend. The temperature inferred for Boreal interval (9–8 cal ka BP) varied between 11.4–12.4°C with an increasing tendency reversing around 8 cal ka BP. The reconstructed temperature for the followed period of the Late Holocene demonstrates increasing trend with a reverse in period of 3–2 cal ka BP and exhibits large fluctuations overall (Fig.1).

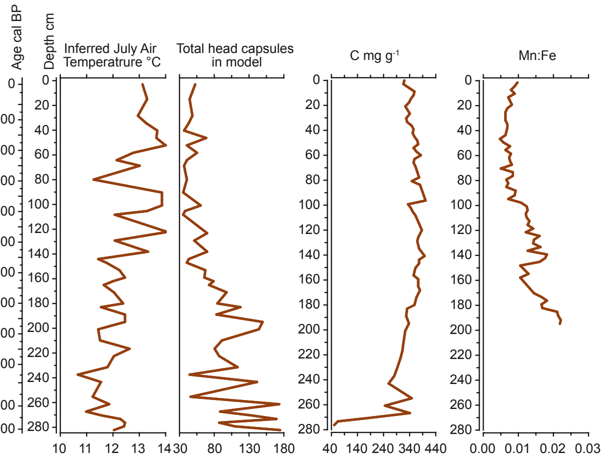

Fig.1. Chironomid-July air inferred temperature, organic Carbon (C) and Mn:Fe molar ration in the sediment of the Plešné lake.

The quantitative temperature reconstruction from Plešné lake does not follow the common trend of the maximum temperature recorded in the early Holocene and subsequent cooling, as was documented by chironomid records from other sites throughout much of the northern hemisphere (Larocque & Hall, 2004).

Over the period ca. 6–5 cal ka BP, the greatest afforestation took place in the catchment of Plešné lake, and the climax forest has become a source of organic matter for the lake. Since ca. 2 cal ka BP, the pollen analysis (Jankovská, 2006) showed a first distinct human impact on the original vegetation. The high organic matter input and human activities near the lake probably has led to the oxygen deficiency or anoxia in the lake. Decreasing trends of Mn:Fe molar ration (Koining et al., 2003) in the sediment from Plešné lake suggest the oxygen depletion could be the explanatory factor that has overridden the effects of temperature on chironomid community.

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Investigating the role of humic acids from ombrotrophic peat in the accumulation of Pb and Hg along a Swiss bog profile

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Peat bogs are often used as archives of atmospheric deposition of Hg and Pb, but the possible mechanisms by which bogs are able to preserve a historical record of either elements have undergone limited investigation. Here we compare the abundance of Hg and Pb in peat and its corresponding humic acids (HA) fraction, in an effort to understand the extent to which humification may contribute to the accumulation of these two environmentally significant metals. For this study, a new peat core was collected from a Swiss bog (Etang de la Gruère) which has been the subject of studies of Hg and Pb in the past. Both bulk peat and HA samples were characterized using several molecular spectroscopic methods (Ft-IR, UV-Vis, Fluorescence) and elemental analysis (CHNS). In addition to Hg and Pb, a variety of other trace metals (including Ti and Zr) and non-metals (e.g., Br) were measured also, for comparison.

Lead and Hg are two “soft” cations that show a strong affinity for the organic ligands, and tend to form inner-sphere complexes. Although both are considered quite immobile along peat profiles, our data underlined completely different behaviours: Hg showed a similar trend both in peat and corresponding HA ($R^2 = 0.84$, $p<0.001$), and highest concentrations in the latter fraction, while Pb, although abundant in bulk peat, was almost undetectable in the HA molecules. In detail, ca. 66% of the total Hg present in peat was strongly bound by the HA fraction, while this percentage averaged around 3% for Pb, thus suggesting that the latter element could be preferentially bound to the humin, non-humic substances and/or associated to mineral particles. In fact, while Hg is present in the atmosphere mainly in the form of a gas (Hg^0), but can be readily washed out once it has been oxidized to the ionic form (Hg^{2+}), Pb, in the studied bog, seems to behave similarly to Ti and Zr. Since the latter ones are known to be associated almost exclusively with dense accessory minerals (such as rutile and zircon) which are resistant to chemical reaction, even at the low pH (4) which is typical of ombrotrophic bogs, the absence of these elements in HA suggests that, during humification, the mineral phases bearing these elements are unaffected, and therefore that these metals are not available for chemical reaction. Thus, basing on the observed similarity among Pb, Ti and Zr, we assume that Pb which is deposited on the surface of the bog, whether derived from natural or anthropogenic processes, could be present in minerals or aerosols which become preserved in the peat, possibly via the formation of protective organic coatings. As a consequence, very little Pb is labile, and available for incorporation into HA molecules.

Even though Br has different chemical features, it seemed to behave similarly to Hg showing higher concentrations in HA rather than in corresponding bulk peat samples (ca. 40% of total Br in peat was found in the HA fraction). In addition, Br and Hg trends in HA were significantly correlated ($R^2 = 0.78$, $p<0.001$). Further, data clearly showed that the magnitude of changes in Br and Hg concentrations along the studied profile cannot be attributed to the different degree of peat humification, as resulted from both the HA extraction yield and the C/N ratio. In fact, higher Br and Hg concentrations were found in the upper layers, where a lower humification degree and higher C/N ratios occur. Consequently, because the zone of elevated Br and Hg concentrations seen in the surface layers of the Swiss peat core corresponds to the decades of greatest industrialization, the accumulation of these elements is probably the result of both natural processes as well as anthropogenic inputs, with the latter clearly dominant during the past few centuries.

Experimental manipulation of urban soils: stability and mobility of heavy metals and arsenic in relation to soil carbon

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Organic amendments can be used to improve the amount of carbon stored in degraded urban and brownfield soils that are currently well below saturation levels. However, organic matter also has a significant impact on the mobility and fate of residual pollutants in the soil (Clemente et al, 2008). Experimental manipulation of urban soils through application of composted greenwaste and biochar is described, in both field and laboratory experiments, in the context of residual metals and arsenic. A model of carbon storage in urban soils has been developed, based on detailed analysis of soil profiles, lysimetry, leachate analysis using rhizon samplers, Dissolved Organic Carbon (DOC) mobility and respirometry (using an open chamber respirometer). Soil profiles were excavated and rhizon porewater samplers were placed within the soil profile and amendments.

Significant differences in the solubility of individual dissolved elements within the porewater from the compost mulch layer were observed (Fig. 1). Mobility of Cu, Zn and Pb were correlated with DOC whilst As was not, indicating the possible rapid leaching of dissolved As through the soil profile. Large seasonal fluctuations in DOC concentrations in porewater from compost and control soils showed a large contributory effect of soil hydrology. Soil organic matter affects the dispersal of pollutants through its binding and buffering capacity and through decomposition. The decomposition of organic matter releases essential plant nutrients, whilst forming complexes (chelates) with heavy metals and binding organic pollutant residues, but the sorption and fixation capacity for heavy metals by humified organic matter in the long term is not well understood. Biochar, unlike compost, has a low soluble carbon content and may be able to effectively store carbon in soils without enhancing metal mobility. In this paper the results are interpreted in the context of (i) the realistic steady state or carrying capacity of C in urban and remediated brownfield soils. And (ii) whether there is a risk to groundwater quality from metals and As if organic materials are applied to contaminated soils.

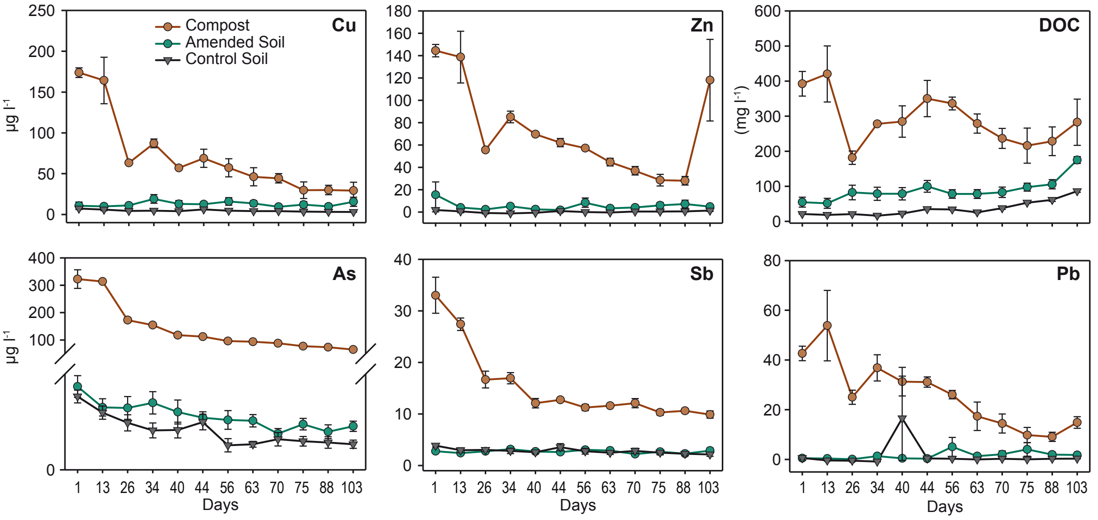

Fig.1 Concentrations of arsenic, metals and DOC in porewater from a compost-amended urban soil following 100 days of leaching under natural conditions.

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Ecological and biological research on soil quality, ecological rehabilitation and sustainable management in North-East Romania

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Soil quality evaluation is a tool to assess management-induced changes in the soil and to link existing resource concerns to environmentally sound land management practices. Ecological and biological research on soil quality was carried out in pasture ecosystems on Gleyc chernozem in humid areas of the forest steppe in Oroftiana and Liveni counties. From an ecological point of view, we analyzed a "constellation" of 20 main ecological factors and determinants, climatic and pedologic, through 8 quantitative classes of ecological size and 6 qualitative classes of ecological favorability. The main ecological determinants were by lack or excess: the low level of summer precipitations, the dry winds, the fine texture and the hard soil consistency in the summer season, the low aero-hydric regime of the soil, the soil treading, the excess of subsoil water. Using a matrix of ecological impacts (Leopold method, 1971 improved by Bireescu, 2007) we identified the main negative ecological effects which have induced the degradation of soil resources and structure of biocenosis. From a pedo-biological point of view we pointed out a moderate enzymatic activity (catalase, invertase, urease, total phosphatase and the Indicator of Enzymatic Activity Potential) because overgrazing and soil compaction affected soil enzymes. These ecological and biological studies pointed out the need of rehabilitation of these degraded lands through protective forest belts, drainage and rational grazing.

Table 1. The graphical matrix of ecological impact

Ecological factors and determinants of negative impact	Ecological negative effects						
	Low soil aeration	Soil treading	Decreased biological activity	Decreased trophic potential	Ruderalization and detrimental species	Soil compaction	Decreased ecosystem productivity
Excess of subsoil water	●	○	●	●	○	□	●
Lack of drainage	●	○	○	●	○	○	●
Hard summer soil consistency	●	●	●	●	●	●	●
Low level of summer precipitations	○	○	○	●	●	●	●
Fine soil texture	●	●	●	●	●	●	●
Dry wind	□	□	●	●	○	●	●
Overgrazing	●	●	●	●	●	●	●

Legend: □ minor impact ○ moderate impact ● major impact

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Groundwater radioactivity at the former uranium and radium mining region of Sabugal, Portugal, and environmental remediation

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In Sabugal county in the central region of Portugal, several radium and uranium mines were in operation during the first half of the 20th century. One mine, Bica Mine, the largest in this region was in operation until the late 80s. After the closure of mines there has been no environmental remediation works to cover the mining and milling waste heaps left on site. Recent concerns have been raised of potential radiological hazards by radioactivity measurements in underground waters of this region. Water samples collected at the former uranium mines, in irrigation wells nearby, and in drinking water supplies to villages in the region were analyzed for uranium series radionuclides by radiochemistry and alpha spectrometry. Water from the Bica Mine contained 4.4 Bq L^{-1}, 1.5 Bq L^{-1}, and 0.48 Bq L^{-1} of dissolved ^{238}U, ^{226}Ra and ^{210}Po, respectively, and these were the highest concentrations measured in waters from this region. Water samples from other mines were under 150 mBq L^{-1} of ^{238}U and ^{226}Ra and even less for other radionuclides. Water from irrigation wells in the region generally displayed concentrations under 50 mBq L^{-1} both for ^{238}U and for ^{226}Ra, although water from several wells in the surroundings of the Bica Mine displayed enhanced concentrations of dissolved uranium, reaching 820 mBq L^{-1} of ^{238}U, although not accompanied by high concentrations of other radionuclides, such as ^{226}Ra, ^{210}Po and ^{230}Th. Enhanced uranium concentrations are likely due to migration of mine water from Bica Mine into the aquifer. Water from a local spring used to supply a village exceeded the recommended limit for alpha radioactivity in drinking water with 1.12 Bq L^{-1}. The overall assessment of radioactivity in water at this uranium mining region indicates that water resources were not significantly contaminated by the historic uranium mining activity. Nevertheless, mine water from Bica Mine require acid treatment to prevent dispersal of the acid and radionuclides into the aquifer and, thus, requires remediation. This is currently performed through active pumping of acid water from the underground mine for neutralization at the surface, a process that is costly in energy and chemicals. Other options, such as reduction of dissolved uranium U^{6+} to U^{4+} which may precipitate this radioelement in the underground mine, could be implemented to prevent dissemination of radioactive water into the aquifer. Waste materials deposited on the surface at Bica Mine and at other mine sites contain high concentrations of radionuclides of the uranium family. Through erosion and leaching by rain water these waste piles may enhance natural radioactivity levels in the watershed of streams as observed elsewhere (Carvalho et al., 2007 a, b) and thus require adequate confinement. These aspects of legacy uranium mine sites and the need for environmental remediation are discussed.

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Radionuclides in plants growing on sludge from uranium mine water treatment

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After closure, uranium mines may generate acidic and radioactive waters for many years. This acid drainage originates in the dissolution of sulphur from the rock but, in many cases, also from sulphuric acid used for the *in situ* extraction of low grade uranium ores. Neutralization of the acid with lime and co precipitation of radionuclides with barium sulphate in water treatment tanks, produces sludge (mud) that is disposed of in surface ponds. Most of radioactivity, especially uranium, originally in mine water is transferred to the sludge (Carvalho et al., 2006). Sludge remains in these ponds generally as a swamp where spontaneous vegetation develops. Accumulation of radionuclides by this vegetation was assessed to check the potential transfer of radioactivity into the terrestrial food chain.

Samples of vegetation growing in sludge ponds of the acid mine water treatment station of Urgeiriça uranium mine (North of Portugal) were collected in June 2007. Grass (*Polygonum sp.*), reeds (*Phragmites sp.*), and rush (*Typha sp.*) were washed with tap water and dried. Homogenates of samples were analyzed for the main radionuclides of the uranium family by radiochemistry and alpha spectrometry. Radionuclide concentrations in vegetation growing in the sludge ponds vary with the type of vegetation. Grass displayed the highest concentrations, attaining 62 Bq kg^{-1} (dry weight) for ^{238}U and 25 Bq kg^{-1} (dry weight) for ^{226}Ra. Comparing these concentrations with pasture from the same region, grass from the sludge ponds contained 30 times more uranium than pasture, but about the same ^{226}Ra concentration. Uranium concentrations in the sludge were about 180 times higher than in soils of the region. In spite of high concentrations in sludge, plants grown on the sludge did not accumulate radionuclides up to the same extent as soils, indicating that radionuclides probably were not fully available for bioaccumulation by plants. Nevertheless, vegetation growing on the sludge from uranium mine water treatment contained enhanced concentrations of uranium and uranium daughters. This vegetation may transfer radionuclides to grazing animals and is not suitable as livestock feed.

Table 1. Radionuclide concentrations in Bq kg^{-1} (dry weight) or Bq L^{-1} for water samples. Relative uncertainties are around 5% at 1 SD level.

Sample	238U	234U	230Th	226Ra	210Pb	210Po
Sludge	41600	40200	13400	1690	--	1180
Grass leaves Polygonum sp.	62	60	10	17	25.4	10.6
Reed leaves Phragmites sp.	2.8	2.6	2.3	58	16.0	8.9
Rush leaves Typha sp.	7.6	7.8	1.6	3.6	10.2	4.5
Pasture	1.79	1.74	2.4	25.2	6.3	0.67
Soil from the region	230	235	300	615	290	290

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Recovery of post-agricultural forest:Tree species determines soil properties and possibilities for ecosystem restoration

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Reforestation of agricultural land in many European countries has progressed more slowly than anticipated. Many years' fertilization has caused an accumulation of nutrients in the top soil layer. Phosphorus (P) has proven to be particularly persistent and elevated concentrations in soil and vegetation are found up to thousands of years after agricultural abandonment. This persistently elevated bioavailable P is a paradox for ecosystem recovery in post-agricultural forests: on one hand, higher P bioavailability stimulates stand productivity and tree growth but, on the other hand, it limits the development of typical forest plant communities (Baeten et al. in press) and associated organisms. Limitation of bioavailable P seems to be a necessity for the recovery of species-rich target communities and for the conservation of endangered species (Wassen et al. 2005).

Reforestation of agricultural land results in a decrease in soil pH with increasing forest age, but the extent and rate of soil acidification differs highly between tree species. Gymnosperm tree species are often contrasted to angiosperms because of their acidifying impact on soils. We will present data showing that rapid (within 2 decades) changes in soil properties can also occur beneath different broadleaved tree species. Ca concentrations in leaf litter seem to be the driving factor for differences between species: tree species with higher litter Ca concentrations such as *Populus* and *Fraxinus* support a significantly higher soil pH, base saturation degree and lower quantities of bioavailable aluminum compared to the Ca-poor *Fagus* and *Quercus* species. *Tilia* and *Prunus* trees are intermediate between these 'soil preservers' and 'soil acidifiers'. Furthermore, tree species have a major influence on the short-term and long-term bioavailability of P. Below 'soil acidifiers' we found significantly higher bioavailable and slowly cycling P fractions compared to 'soil preservers' which mainly retained P in less soluble pools.

To date, there are no integrated studies on the long-term effect of different broadleaved tree species on soil properties in general and the bioavailability of P through soil acidification in particular. Most studies evaluating the bioavailability of P use extraction methods that only provide short-term dose-response insights into the readily available P pool for plants and soil microbes. However, for studying the role of P in recovering (semi) natural ecosystems, it is much more relevant to gain insight into time-scales extending a single growing season (Richter et al. 2006) and to include more slowly cycling P fractions. We discuss six common garden experiments in which broadleaved tree species have been planted on loamy agricultural soil for between 5 and 35 years. We argue that vegetation choice can be an important driver of regional biogeochemistry and biodiversity.

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Biogeochemical aspects of rehabilitation of contaminated soil and sediment: an urban case study

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Brownfield land consisting of a closed old-style sanitary landfill, derelict former industrial land and an adjacent abandoned canal with 1.5m depth of contaminated sediment is being converted into an urban nature park. This paper describes the site investigation, risk assessment of the site and the practicalities associated with conversion of the site to manage risk, improve the nature conservation status and to demonstrate the use of sustainable soft end-use remediation techniques. No materials have been exported from the site, but recyclable wastes have been imported to stabilize pollutants and for habitat improvement. The challenge for the research component of the project was to understand the mobility and sustainable management of metals, arsenic and PAHs, both from disturbed canal sediment and from hotspots on land, in the context of human, groundwater and ecological receptors. Biogeochemical aspects of the rehabilitation are the focus of this paper.

Engineering work began in 2008, transferring sediment from the centre to the sides within the 15 m wide canal, leaving open water in approximately 50% of the width of the canal. The transferred sediment was retained using gabions and covered with a geotextile membrane and a variety of growth substrates that used recycled materials including green waste compost. Contamination hotspots aside from the canal were monitored whilst being amended with imported compost and other materials to create a diversity of habitats ranging from calcareous to acidic wildflower meadow communities. Complex mixtures of metals, arsenic (Table 1) and hydrocarbons (benzo [b] and [k] fluoranthenes, Benzo [a] pyrene and Dibenz [a,h] anthracene) at highly elevated concentrations exist in the canal sediment. This residual contamination has little pollution linkage when permanently covered by non-flowing water largely due to the associated reduced, anoxic conditions that are maintained in the undisturbed sediment. When the sediment is disturbed or exposed, drying and oxidation brings about profound physical and chemical changes (Table 2). Associated changes in pH, Fe and S status rapidly cause some elements (including heavy metals) to become highly mobile.

Table 1. Total metal concentrations (mg kg^{-1}; means ± s.d.), pH and LOI of sediment [n = 166].

As	Fe	Cd	Cr	Cu	Pb	Zn
397	46298	12	918	642	1370	2584
12	9333	6.6	177	135	425	1374
pH (wet sediment)			pH (dry sediment)			LOI (%)
6.2			3.7			26

Table 2. Changing pH of canal sediment following exposure to the atmosphere for up to 41 days

No. of days	0	4	6	16	20	24	36	41
pH	5.85	4.57	4.03	4.67	4.28	3.96	4.42	3.67

Concerns in the hotspots aside from the canal related to five key contaminants present in surface soils at potentially significant concentrations: benzo(a)pyrene, bis(ethylhexyl)phthalate, hexachlorobutadiene, vinyl chloride and arsenic. However, the canal sediment presented a much more complex system within which to confidently manage contaminants in the medium- to long-term. Precautionary exposure scenarios have been modeled and are evaluated from a biogeochemistry perspective.

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Arsenic stability at a grassland site overlying chemical waste

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A 6.6 ha grassland landscape, established on a former chemical waste site adjacent to a residential area, contains arsenic (As) in surface soil at concentrations 200 times higher than UK soil guideline values, following rehabilitation in the 1980s and to the restoration standards of that era (Hartley et al., 2009). The site is not recognized as statutory contaminated land, partly on the assumption that mobility of the metalloid presents a negligible threat to human health, groundwater and ecological receptors. Evidence based on several studies including data on the effect of organic (green waste compost) and inorganic (iron oxides, lime and phosphate) amendments on As fractionation, mobility, plant uptake and earthworm communities are evaluated in this paper.

Arsenic mobility was significant, largely related to dissolved organic carbon (Fig. 1) and phosphate; iron oxides immobilized As (Fig. 2). Plant uptake was low and there was no apparent impact on earthworms. The existing vegetation cover may minimize re-entrainment of dust-blown particulates that would otherwise present human health risk. Risks to other receptors are low, but results suggest avoiding disturbance and soil exposure, and compost and phosphate application that may mobilize As.

A realistic interpretation of the evidence is that surface soil at Merton Bank is contaminated with As, but currently appears to be relatively stable in terms of environmental mobility of this element. The metalloid generally is not mobile and strongly adsorbed in the soil. The reclamation carried out at Merton Bank in 1980 falls below acceptable modern standards, but appears to have remained relatively stable for the past 28 years. In common with many brownfield sites in this region and elsewhere in the UK, the approach to management is through Monitored Natural Attenuation (Environment Agency, 2004). Natural processes are unlikely to adequately resolve the pollution issues, but there is no evidence that suggests any exacerbation of risk. This site is not currently monitored in any form.

Surface soils will naturally accumulate organic matter from vegetation over time and potentially this could increase As mobility. Amending the site with recycled GWC or fertilizing with phosphate would not appear to be sensible options for sustainable site management. In terms of future management, clearly, iron oxides are worth considering as an amendment to reduce As mobility if remediation is required to prevent mobilization of the metalloid to the wider environment. To date, As mobility into deeper layers of the waste has not been investigated, which is a major shortcoming of the existing site characterization. More detailed studies of downward As migration, particulate re-entrainment and ecological monitoring at Merton Bank are required.

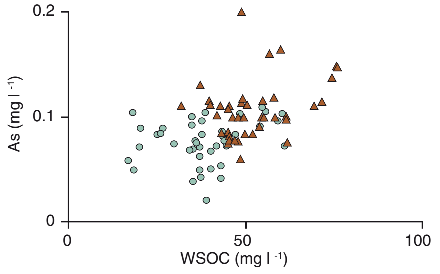

Figure 1. Relationship between concentrations of pore water As and water soluble organic carbon in untreated (●) and GWC (30% v/v) treated (▲) Merton Bank soil.

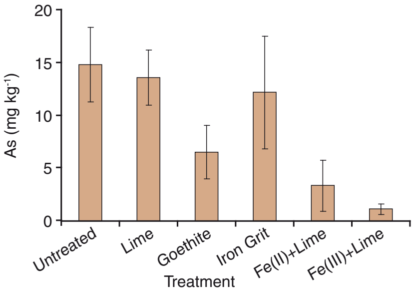

Figure 2. Changes in labile As in Merton Bank soil as a function of amendments (1% w/w), assessed using the modified Dutch Leaching test (means ± s.d., n=3).

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Carbon accumulation in young Scots pine (*Pinus sylvestris*) stands in reclaimed oil shale opencast mine

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An understanding of carbon dynamics in reclaimed mine spoils may enhance their potential future use to sequester carbon through better management. In Estonia, mining of oil shale in opencasts has degraded about 130 km^2 of land. *Pinus sylvestris* has been the main species planted on the levelled spoil, nowadays covering over 80% of the reclaimed area. The aim of this study was to estimate total carbon stock and its distribution along forest ecosystem partitions in three Scots pine stands growing in the Narva oil shale opencast, north-east Estonia. Sites were afforested with 2-year-old seedlings in 1990, 1983 and 1968. In 2004, a circular plot of 100 m^2 was established in each stand for the vegetation survey, soil profiles were sampled in 2005. Dry mass of different tree fractions was calculated using allometric equations derived from model tree data, understory biomass was measured in randomly placed sample quadrats.

Estimation of soil organic carbon (SOC) accumulation was made difficult by the presence of carbon-containing oil shale fragments in the soil; currently there is no definitive methodology to differentiate plant-derived recent carbon from fossil carbon. We determined the contribution of recent carbon to total SOC by combining measured radiocarbon activities of different soil horizons with a simple model of litter production and the record of atmospheric ^{14}C. The share of recent carbon was 99–100% for the forest floor horizons and decreased with depth. SOC in the C-horizon originated mostly from oil shale, but contained also considerable amounts of recent carbon (16–39% of total organic carbon). This was presumed to be largely a legacy from pre-mining ecosystems.

Plantations of Scots pine showed remarkably good growth on calcareous and stony oil shale mining spoil, accumulating over 130 t C ha^{-1} less than 40 years after establishment (Table 1). Most of the added carbon was allocated to tree biomass (76–87%), but the share of SOC was increasing with stand age. Recent carbon stock in topsoil (O and A-horizons) formed 5% of the ecosystem total in the youngest, 15% in the second and 24% in the oldest stand.

Table 1. Carbon stocks (t ha^{-1}) of Pinus sylvestris stands. The carbon content of all biomass fractions was considered to be 50%.

Fraction	Year of afforestation		
	1990	1983	1968
Stems	2.2	15.7	68.2
Needles	2.0	3.3	4.4
Living branches	1.7	4.0	9.3
Dead branches	0.04	2.7	8.1
Stumps and coarse roots	0.9	3.3	11.6
Shrub layer	0.5	0.6	0.4
Herb layer	0.1	0.01	0.04
Forest floor	0.1	4.6	12.2
A-horizon	0.2	0.4	19.0
Stand total	7.8	34.5	133.4

Technological renovation influence on biogeochemical cycles in wetlands of North-East of Estonia

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Power plants in North East of Estonia using oil shale as a fuel have had significant impact on ecosystem, both locally and in neighbouring countries. It has been reported that growth of trees has been accelerated due to excess nitrogen load, peat growth has stopped on about 100 quadrate kilometres due to excess alkaline deposition and fish biology has changed due to excess load of heavy metals and organic compounds. Recently many renovations have taken place in the power plants: 1) two boilers were renovated from pulverised bed (PB) combustion to fluidised bed (FB) combustion, 2) old boilers and lower stacks at Baltic Power Plant were decommissioned, 3) new electrostatic precipitators for removing particles from exhaust gases built. These renovations should have had an influence on the emissions and therefore on exposed ecosystems.

Studies carried out included: 1) modelling deposition with air distribution models SILAM and AEROPOL separately for gaseous compounds and different sizes of particles, 2) determination of current deposition loads with snow samples from an open area, 3) determination of longer period changes with samples of soils. Study period was 2008 and winter 2009. In samples main cations, anions and heavy metals were determined by ion chromatography and AAS. Determination of spherical fly ash particles by microscopy enable to separate particles from PB boilers from other boilers.

Results of modelling show that deposition of elements, compounds have changed significantly: 1) sulphur depositions should drop by factor of two, 2) fly ash emissions and also deposition should drop by factor of ten, 3) slight diminishing should occur also for nitrogen, 4) some compounds deposition like Cl and VOC should be increased. Samples of snow are in well agreement of modelling: 1) number of spherical particles in deposits have dropped 3-4 times, closer to stacks even a drop of ten times occur, 2) deposition of Ca dropped about 10 times showing diminishing fly ash particles, 3) similar patterns with fly ash was observable also for heavy metals., 4) deposition of Cl has increased slightly.

The study showed that renovation of power plants could soon result in a re-growth of peat on areas where earlier it has stopped due to too alkaline deposition.

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Early growth, biomass production and root characteristics of silver birch, black alder and Scots pine on a reclaimed oil shale mining area

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Young plantations of silver birch (*Betula pendula*), black alder (*Alnus glutinosa*) and Scots pine (*Pinus sylvestris*). the main deciduous species and coniferous used for mining area reclamation on oil shale mining spoil were investigated by analysing growth, biomass production and fine-root early adaptation strategies.. One- and two-year-old plantations were used because the first years of stand development are most critical for tree survival in this stony alkaline (pH~8) wasteland with low nitrogen content. Survival of trees was measured, biomass allocation was assessed and the proportions of the root system in tree biomass (root ratio – RR) and of fine roots in the root system (FRR) were calculated. The short-root morphological characteristics: diameter (D), length, volume and mass of root tips as well as specific root length (SRL), specific root area (SRA) and root tissue density (RTD) were determined using WinRHIZO^{TM} PRO 2003B (Regent Instruments Inc) in 15-20 samples per species; the number of tips in a sample was counted under microscope. SRL, SRA and RTD were determined for fine ($D < 2$mm) roots.

Survival of tree species after the first year ranged as follows: black alder ≥ Scots pine > silver birch; 93, 83 and 64%, respectively. Relative height increment of species was highest for Scots pine (0.63±0.01) in one-year-old stands, and for silver birch (0.43±0.01) in two-year-old stands. The largest aboveground biomass (B) occured in black alder stand compared with other studied species in both growth seasons. Relative aboveground production ($\Delta B/B$) was significantly higher for Scots pine in one-year-old stands, but in two-year-old stands this value didn't differ between species. The higher fine root/leaf biomass ratio was proportional to the better survival of seedlings when comparing different tree species; black alder had the highest, and silver birch the smallest value. After the first growing season RR was similar in all species; the means ranged from 39% to 47% and FRR was for Scots pine twice as high than for black alder or silver birch, 77±6, 38±5, and 35±4%, respectively. After the second growing season RR vas similar for deciduous species (51% – silver birch; 48% – black alder but significantly smaller for Scots pine (28%). FRR varied between 14 and 20%; impact of tree species was insignificant. The fine root SRA decreased and RTD increased with stand age for all studied tree species. Mean D of short roots decreased in order: $D_{pine} > D_{alder} > D_{birch}$. Comparing tree species, much higher short-root SRA and SRL values and lower RTD values were found for silver birch than Scots pine or black alder; SRL for silver birch, black alder and Scots pine after the first growing season was 365, 172, and 62, mg^{-1}, respectively. In deciduous trees mean SRL and SRA decreased with increasing stands age. The morphological adaptations of fine root system support the effective functioning of developing forest ecosystems on reclaimed oil shale mining area. The study showed that during first years after planting black alder was best adapted to harsh conditions of the mining substrate and hence it is the best choice for a reforestation of oil shale mining areas.

Greenhouse gas emission from UK upland is changed by water level restoration

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Upland ecosystems in the UK are important stores of soil organic carbon, while their significance as sources or sinks of the greenhouse gases such as CO_2 and CH_4 is uncertain, particularly under changing climate and land management. We assessed the importance of a typical upland area for net exchange of greenhouse gases and measured the effects of moorland habitat restoration represented by drain blocking on greenhouse gas fluxes, vegetation structure and plant biodiversity. We have used the Ecotron, a controlled environment facility, to maintain mesocosms of two contrasting sizes at stable environmental conditions and at two water table levels. Intact mesocosms were extracted in March 2008, transported to the Ecotron where gas flux and soil water chemistry observations were carried out at monthly intervals until November 2008.

We successfully established the effect of the water table level on CO_2 (Fig. 1) and CH_4 fluxes, on soil surface heaving and light interception and reflectance. Bringing the water table level close to the surface has a significant positive effect on methane emission. Dark ecosystem respiration, on the other hand, is significantly diminished in high water table conditions. We also found that mesocosm size influences gas flux rates and does interact with water table effects, an effect that could be related to studied plant size and its sensitivity to the cutting of roots during mesocosm collection. In our case, observations from small (0.03m^2) mesocosms did not appear to produce meaningful estimates of gas emission and the size of the mesocosms appeared to affect plant survival, especially that of heather. Large mesocosms (0.24m^2), on the other hand, did show a greater degree of reliability and repeatability of results. For example, dark mesocosm respiration showed a lasting response to changed water table conditions in large mesocosms only. Net ecosystem exchange measured in light and gross photosynthesis were not significantly affected by the water table, but both fluxes, as well as ecosystem respiration, were significantly lower in small mesocosms.

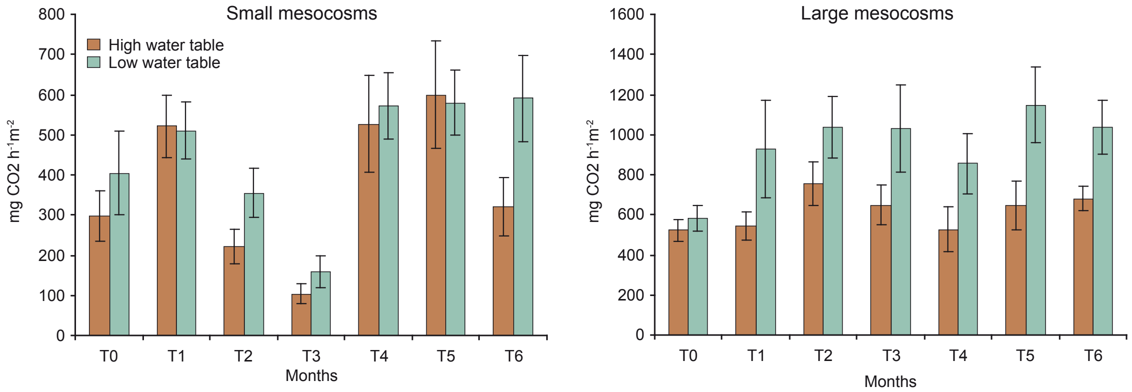

Figure 1. Dark ecosystem respiration from small and large mesocosms (mg CO_2 h^{-1} m^{-2} ±st.dev.; note different scale) .

Environmental impacts of hydrological restoration after peat extraction

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Restoration is highlighted in European land-use exploration. Peatlands used for peat harvesting is one such priority land use type. Considerable changes in site conditions have occurred during extraction of peat and new prerequisites exist as the very old peat bottom layers are exposed to land surface re-colonisation. Peatland restoration is therefore difficult. Management aims to focus initially on rewetting to restore hydrology and improve conditions for biogeochemistry and biodiversity.

In southwest Sweden, rewetting of two such areas started about ten years ago. Porla site inundation represents an ordinary nutrient poor site and Västkärr a richer site. Ecological characteristics of developed wetlands differ considerably and are reflected in remaining peat conditions, established hydrology and water chemistry, evidently being the driving force for established vegetation and limnic life, i.e. bottom fauna. Peat and mineral soil chemistry exert crucial influences on the developed biogeochemistry.

Before and after inundation, management investigations include soil sampling, monitoring of the site hydrology and water quality as well as effects of inundation on downstream watercourses, vegetation, limnic life and initial studies in gas exchange. Vegetation and surface soil conditions, partly with floating rafts, start to come into balance with new spontaneous *Sphagnum* colonisation. Water quality changed also with biological effects.

Changes in hydrochemistry after rewetting at the relatively nutrient poor Porla site were lowered pH, DOC, base cation content, sulphate and organic nitrogen. Sulphate decreased because a lack of oxidation of organic material in reduced bottom conditions initially released phosphorus. Organic nitrogen making up most of the total nitrogen decreased related to sedimentation. Nitrate first decreased because of less decomposition but increased due to nitrification of ammonia and organic nitrogen in free water, probably contributing to denitrification. At the richer West fen site, rewetting was associated with lowered pH, Ca, SO_4 and NO_3 content. DOC and phosphate increased the first years but later decreasing over time. Despite a lowered Ca content, pH increased probably dependent on the lack of sulphate production. This because turning to anaerobic conditions in the sediments and thereby releasing phosphate. After a few years P-release finished and PO_4 concentration dropped.

Peat site properties such as chemical conditions affect the greenhouse gas emissions and this was studied at the Porla site. The CO_2 emissions from the vegetation types varied, with the lowest emissions measured on the pristine mire and the drained bare peat The CH_4-fluxes showed a similar pattern as the CO_2 fluxes. The higher CO_2 emissions on tussocks on drained peat compared to the bare drained peat, can easily be explained by the respiration from living biomass. However, while the bare drained peat did not emit any CH_4, the tussock on drained peat did. This suggests that the plants can (*i*) emit CH_4, (*ii*) promote the transport of CH_4 from the soil to the atmosphere and/or (*iii*) promote the formation of CH_4 in the soil. Plant development partly reflect soil and hydrological conditions.

Use of ameliorants for preventing the contamination of soils with heavy metals

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Introduction. A barrier function is an essential function of soil for protection of natural waters, air, and plants from pollutants. In this context the use of ameliorants could be developed for remediation of polluted soils with, based on mechanisms of strong metal fixation. The aim of this work was to study the influence of various methods of chemical remediation on heavy metal mobility in a Chernozem.

Materials and methods. The effect of different ameliorants on ordinary chernozem (C_{org} 2.55%; clay 58.0%; $CaCO_3$ 0.85%; pH 7.6) contaminated with heavy metals (HM) was studied in a long-term field experiment. Metals were added to the soil as acetates at the following rates (mg kg $^{-1}$): Pb 300 and Zn 96. These doses corresponded with usual level of obtained soil pollution by these metals in the Rostov Region. Chalk and glauconite were applied separately and together with manure after 2 months of artificial soil contamination. HM were extracted by 1 M NH_4Ac, pH 4.8; 1% EDTA in NH_4Ac, and 1M HCl. The sum of HM content in this parallel extracts characterize the weakly bound metal compounds (WB) (Minkina et al., 2008). The relative content of WB shows the metals mobility in soil. Metal contents in all solutions were analyzed by atomic absorption spectrophotometer.

Results and discussion. The application of ameliorants significantly decreased the mobility of metals (Table 1). Their effect depended on the ameliorant and was most significant at the simultaneous application of chalk and manure. This effect was presumably due to the strong binding of metals by carbonates through chemisorption and formation of low-soluble Zn and Pb compounds and to the additional fixation in the form of complexes at the addition of organic material (Minkina et al., 2007). Therefore, the share of weakly bound metal compounds in the contaminated soils decreased to the level typical for the clean soils or even below (in the case of zinc). The transformation of both metals, from less to more strongly bound compounds, was accelerated by ameliorants, but the rates of these processes for Zn were higher than for Pb.

Table 1. The total content and the ratio between the weakly (WB) and strongly (SB) bound Zn and Pb compounds during one year after the application of ameliorants

Experimental treatments	Zn		Pb	
	Total content, mg/kg	WB, % of total content	Total content, mg/kg	WB, % of total content
Without metal addition	68	12	24	15
Metal (Me)	356	32	110	38
Me + glauconite	346	14	106	32
Me + manure	360	17	110	26
Me + glauconite + manure	363	15	109	22
Me + chalk, 2.5 kg/m^2	350	13	111	18
Me + chalk, 5 kg/m^2	347	16	108	17
Me + chalk, 2.5 kg/m^2 + manure	361	11	105	19
Me + chalk, 5 kg/m^2 + manure	359	11	114	13

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Creating and restoring wetlands: Enhancing ecosystem services

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Wetlands provide many ecosystem services such as cleaning water, mitigating floods and coastal damage, supporting biodiversity, and sequestering carbon. Yet we have lost wetlands throughout the world at an alarming rate in the 20th century. There are now significant opportunities to reverse that trend and create and restore wetlands, while conserving the wetlands that remain. Florida Everglades, coastal Louisiana (Costanza et al., 2006), the coastline of the Indian Ocean, and Mesopotamia in Iraq all are now involved in large-scale wetland restoration triggered by ecological or social disasters. At a very large scale, there has been discussion of restoring 20,000 km^2 of wetlands in the Mississippi-Ohio-Missouri River Basin in the USA to minimize the size of a 20,000 km2 hypoxic zone in the Gulf of Mexico (Fig. 1; Mitsch et al., 2005a; Mitsch and Day, 2006). On a smaller scale, we are learning about the pace at which wetlands can be created and their ability to retain pollutants and sequester carbon with studies at the Olentangy River Wetland Research Park over the past 15 years (Mitsch et al. 2005b; Anderson and Mitsch, 2006; Fink and Mitsch, 2007). Self-design remains the guiding principle for these wetland creations and restorations.

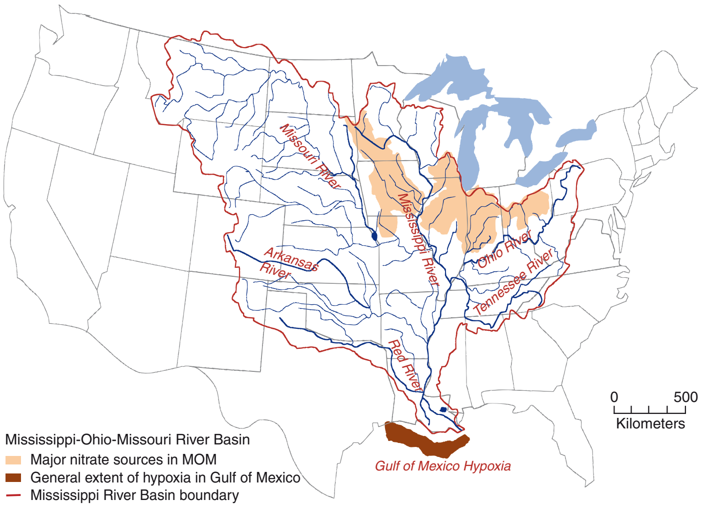

Fig. 1. Mississippi-Ohio-Missouri River Basin in USA showing main source of nitrogen pollution and effect of that pollution in the Gulf of Mexico (Mitsch et al., 2005a)

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Microbial biomass C dynamics and heavy metal mobility in long-term contaminated soils after amendment with chelates

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Heavy metal contamination is an environmental problem in industrial areas. The possibilities of removal of these elements are limited, therefore metal phytoextration strategies by plants are popular. The mobility of lead in soils is limited due to its chemical characteristics, so methods supporting the metal uptake by plants are in development. One of the possibilities is soil amendment with chelates, which could increase metal availability for plants. On the other hand, addition of chelates can inhibit soil microbial characteristics (Ultra et al., 2005).

Soils from vicinity of a smelter of Pribram (about 60 km SW from Prague) for more than 200 years contaminated with lead, cadmium, arsenic and zinc were used for the experiment. Soil samples were sampled from the depth 0–20 cm. Arable and grassland soil of similar heavy metal concentrations were used for the experiment. Soils were after the removal of plant debris sieved at < 2 mm. The possibilities to increase heavy metal availability for phytoextraction were studied in the incubation experiment with addition of EDTA and EDDS into the contaminated soils. Contemporaneously, the microbial biomass C dynamics and respiratory activities were studied.

The microbial biomass C and metal dynamics after addition of chelates is shown in Fig. 1. Negative effects of the biodegradable chelate EDDS on the soil microbial biomass were observed during the first 10 days of the experiment, thereafter microbial biomass C contents increased. Higher metal availability was found only for Cu and Zn, which do not belong to the main contaminating elements in the area. The increase of mobile fractions of main contaminants Cd and Pb was not observed. The addition of EDTA inhibited significantly microbial biomass C. Respiratory activities in studied soils increased probably due to the process of destruction of soil microorganisms after EDTA addition and the release of C from microbial cells. Similarly, the increase of metabolic quotient (qCO_2) was observed after EDTA amendment. Mobile and organically bonded metal concentrations, particularly Pb, increased after EDTA addition.

The application of chelates, particularly EDTA, increased the heavy metal availability, however it is necessary expect lower microbial activities with all possible consequences.

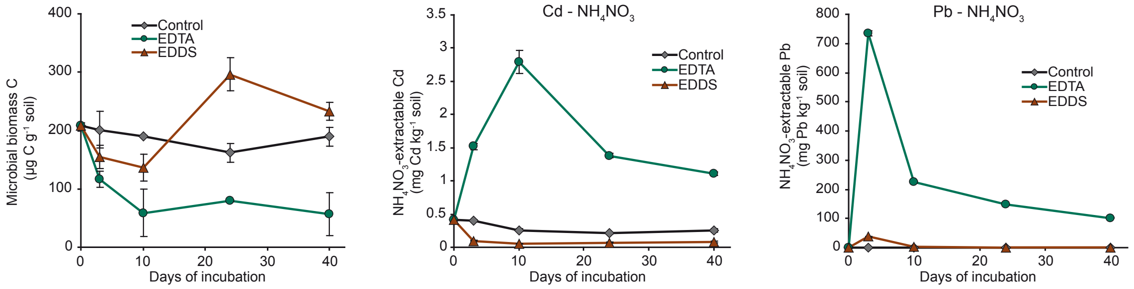

Fig. 1. Dynamics of microbial biomass C and available metal fractions during the incubation experiment with addition of chelates.

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Biogeochemical consequences of grazing for weed control in a polluted and remediated area: risks of trace element ingestion by herbivores

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Polluted areas require an active management in order to reduce the risk derived from pollution for human and ecosystem health. Afforestation stabilises the polluted soil, minimizing wind and water erosion, thus reducing the risk of migration of pollutants. In Mediterranean environments, weed competition can limit the survival and growth of afforested plants, since they compete for water and nutrients, and also constitute a favourable focus for wild fires. Herbage control by grazing is currently been considered in some restoration programs in Mediterranean areas. However, in afforested metal-polluted areas, the accumulation of metals in grasses may pose a risk to grazing livestock. We assessed the risk associated with managing pasture by grazing horses (non-edible livestock) in the Guadiamar Valley (SW Spain), where a large-scale restoration program was implemented after a major pollution incident. We analyzed the trace elements accumulation in grasses over different seasons, and assessed the potential ingestion of these elements by horses. Hair and faecal analyses of horses were also analyzed, as possible indicators of metal ingestion.

During the autumn, concentrations of trace elements in pasture were higher than in spring, due to a dilution effect of the greater biomass in the spring season. Only Cd (mean autumnal concentration ca. 0.5 mg kg^{-1}) and some values of Fe and Zn (less than 10% (Fe) and 2% (Zn) of the total samples analysed, derived from soil contamination of herbages) were comparatively high. The soil-plant transfer coefficients (TC) depended on the element and on the plant group, although, in general were low. The highest transference corresponded to some Cd and Zn in some Asteraceae species, such us *Senecio vulgaris* (TC from soils to leaves of 0.43 and 0.37, respectively). For other plant groups, such us Poaceae sp. and Fabaceae sp., the TC of these two elements was lower than 0.25. Estimated values of daily intake for horses were much lower than the poisoning ingestion values recorded in the bibliography (Table 1). In general, faeces analyses showed that essential element absorption is regulated by homeostatic mechanisms which control their accumulation, while non essential elements tend to be preferentially excreted from horses' body. This pattern was also observed in faeces of other herbivores of the area, such as wild hares (*Lepus granatensis*). We conclude that grazing by horses could be considered in the management of the area, although 1) as caution, grazing should be avoided during periods with a low pasture biomass and 2) chronic exposure to metals should be assessed in the long-term.

Table 1. Autumnal daily food intake of essentials (E) and non essential (NE) trace elements (Mean values ± SD) in the affected (n=90) and control (n=10) soils. Estimated food intake for horses in mg kg^{-1} body weight day^{-1} (data based on a daily food intake of 21 g of plant dry weight per kg of body weight). (* $p < 0.05$).

Elements	Soil	Cu	Fe	Mn	Zn
E	Affected (A)	0.23 ±0.12*	20.9 ±31.3*	2.32 ±2.41*	1.44 ±1.48
	Control (C)	0.18 ±0.02	5.90 ±3.53	1.40 ±0.31	0.86 ±0.45
	A/C	1.28	3.54	1.66	1.67
		As	Cd	Pb	Tl
NE	Affected (A)	0.04 ±0.06*	0.010 ±0.02*	0.10 ±0.14	0.001 ±0.001*
	Control (C)	0.002 ±0.002	0.0006 ±0.0006	0.02 ±0.01	0.0001 ±0.00004
	A/C	20.0	16.6	5.0	10.0

Biowaste and native woody plants in remediation of Cu-Ni polluted forest soil

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Our main aim was to evaluate the long-term recovery of a heavy-metal polluted forest ecosystem located close to a Cu-Ni smelter complex through the establishment of a functioning organic layer, and through revegetation using seedlings of native tree species and cuttings of native dwarf shrub species. We studied how the application of a mulch cover (mixture of household biocompost and woodchips) onto polluted forest soil affects 1) survival and growth of planted dwarf shrubs and tree seedlings, 2) spontaneous revegetation, 3) fate and mobility of soil Cu and Ni and 4) distribution of fine roots.

Native woody plants (*Pinus sylvestris*, *Betula pubescens*, *Empetrum nigrum*, *Arctostaphylos uva-ursi*) were planted on summer 1996 in mulch pockets on mulch-covered and uncovered plots. The mortality of the tree seedlings and dwarf shrub cuttings were recorded every spring and autumn during the ten year monitoring period (1996–2005). The spontaneously spread non-woody plant species were recorded in June 2002 and in August 2005. Soil samples for chemical analysis were taken in August 2005. Exchangeable Cu and Ni concentrations were determined by extraction with $BaCl_2$ + EDTA followed by analysis by ICP-AES. Three seedlings or cuttings per plot were harvested after 10-years growth for biomass determination and element analysis. In addition, three volumetric soil core samples (core diameter 58 mm) for fine root biomass determination were taken in August 2005. Roots were washed out of the soil, and sorted under a microscope for living and dead, for tree species and understorey, and for root diameter (< 1 mm, 1–2 mm, >2 mm). Numbers of ectomycorrhizal root tips per root weight unit were counted under a microscope from 10% of the finest root (diameter < 1 mm) biomass of Scots pine.

Despite initial mortality, establishment was successful during the following ten years. Only 3.5% of *Empetrum* cuttings died on the mulch-covered plots, and 48 % on the uncovered plots. Over half of the *Arctostaphylos* cuttings died in both treatments, but the survived plants have spread over a wide area. The mortality rate of *Pinus* was low, < 12% in both treatments. The mortality of *Betula* on the mulch-covered plots (48%) was higher than on the uncovered plots (17%). Natural recolonization of pioneer species (e.g. *Epilobium angustifolium, Taraxacum* sp. and grasses) and tree seedlings (*Pinus sylvestris, Betula* sp. and *Salix s*p.) was strongly enhanced on the mulched plots, whereas there was no natural vegetation on the untreated plots.

In the organic soil, exchangeable Cu and Ni tended to be lower in the mulch of pockets containing transplants than in those without**.** In the mineral soil, exchangeable Cu and Ni were relatively low and there was a considerable spatial variation between plots. The biomass of the living fine roots (mainly Scots pine) was significantly higher in the organic mulch layer spread on the experimental plots than in the polluted organic layer of the non-covered soil. Furthermore, the number of mycorrhizal root tips of Scots pine was much higher in the organic mulch than in the organic layer of the non-covered soil. The biomass of the living fine roots, as well as the number of mycorrhizal root tips, was also high in the uppermost part of the mineral soil (0–5 cm) on the mulch-covered plots.

We conclude that mulching of the metal-polluted site created a functioning organic layer by reducing exchangeable Cu and Ni and improving the water holding capacity, and subsequently increasing the amount of living fine roots and mycorrhizal root tips in the surface soil. Soil remediation was reflected as successful revegetation of the barren forest floor.

The effects of harvesting residues on natural regeneration, nutrient availability and uptake at a broadleaf restoration site in southern UK

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Conservation and biodiversity have been of increasing importance in British forestry in the last 10 years, culminating in the commitment to reduce or remove conifer trees on sites known to have been previously native broadleaf forest (Thompson et al.,2003). The desired procedure is to change canopy dominants from conifer to broadleaf with ‘minimum intervention regeneration’. Conifer stands reaching maturity, or of low current economic value, such as Western Hemlock and Corsican pine have been targets for clear felling. In most cases forest practice has resulted in woody brash which has both chemical and physical effects on potential natural re-colonisation by trees, herbs and shrubs. The decay rate of Western hemlock (*T. heterophylla*) residue, previously determined from field situations, has been shown to be very slow. Investigtions of residues from other species show that nutrient rich needles and twigs are the most important source for immediate forest regeneration but these researchers note that the quantitative role of developing ground flora as a sink for these nutrients remains unclear. A nursery study by Weatherall et al. (2006) with Sitka seedlings (*P. sitchensis*.) growing on decaying brash demonstrated uptake of nutrients within one year.

The objective of this study was to examine the effects of the manipulated brash on soil nutrients, particularly N, and their availability to support colonising ground flora and broadleaf tree seedlings. The physical and chemical effects of four treatments (light and heavy (x2) Brash, a coarse Mulch, and a Grass treatment) with a Bare control on the plants, soils and status of the residue have been compared over five years.

Initial site colonisation by *Calluna* and C*arex* sp after clearfell came from the seed bank and with *Betula*, (from mature trees) and Agrotis grass (experimentally seeded), the 4 dominants have spread across all treatments except Mulch. This has been a good plant suppressant, and remains 50% un-colonised. Birch growth is lowest in Grass and Mulch treatments and significantly greatest in the LtBrash treatment where it has locked up ~50 kgN.ha^{-1} > the 5 years .Grasses and heathers competing for dominance in Grass and Bare plots, have taken up 10–15 kgN.ha^{-1}.The persistence of a dominantly heathland ground flora was unexpected and oak colonisation by acorn dispersal has been sporadic, despite good mast years. The release of N from different fractions of the residue has been followed by litterbag decay, and ground sampling of brash and mulch material. Separate decay constants (k) have been identified for the needle, small twig and branch fractions, each with a different lag time to initial N release. Biomass loss of brash branch material has been matched by similar increases in fragmentation. Within the mulch too there has been increasing proportion of ‘fines’, but also a total rise in biomass, which must result from fungal and bacterial in-growth during decomposition. C:N ratio of the mulch chip has declined, but N concentrations are still increasing, indicating continuing N lock-up. Soil solution DON measured in the underlying clay has remained at 15 kg Nha^{-1} under Bare and Grassed treatments, but initial rise under Heavybrash and Mulch (to ~24 kgN ha $^{-1}$) has now significantly declined (~18kgN.ha^{-1}). With limited plant colonisation of the Mulch, which favours bracken, heather and conifer seedlings, this can only be attributable to fungal action. As DON is degraded preferentially by micro-organisms like pine and ericoid mycorrhizae, the success of heathers and conifers is to be expected - but the status of birch needs further investigation. Other broad leaf trees may be inhibited by the application of conifer brash yielding inaccessible forms of N through decay, and retention of conifer brash on restoration sites should be reconsidered, particularly as removal expense might now be offset by biomass income.

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Recreating a functioning forest soil in reclaimed oil sands in northern Alberta, Canada

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During oil-sands mining all vegetation, soil, overburden and oil sand is removed, leaving pits several kilometres wide and up to 100 metres deep. These pits are reclaimed through a variety of treatments using sub-soil or a mixed peat-mineral soil cap. Using non-metric multidimensional scaling and cluster analysis of measurements of ecosystem function, reclamation treatments of several age classes were compared with a range of natural forest ecotypes to discover which treatments had created ecosystems similar to natural forest ecotypes and at what age this occurred. Ecosystem function was estimated from bio-available nutrients, plant community composition, litter decomposition rate and development of a surface organic layer.

On the reclamation treatments, availability of nitrate, calcium, magnesium and sulphur were generally higher than in the natural forest ecotypes, while ammonium, phosphorus, potassium and manganese were generally lower. Reclamation treatments tended to have more bare ground, grasses and forbs but less moss, lichen, shrubs, trees or woody debris than natural forests. Rates of litter decomposition were lower on all reclamation treatments. Development of an organic layer appeared to be facilitated by the presence of shrubs.

With repeated applications of fertilizers, measured variables for the peat-mineral amendments fell within the range of natural variability at about 20 years. An intermediate sub-soil layer reduced the need for fertilizer and conditions resembling natural forests were reached about 15 years after a single fertilizer application. Treatments over tailings sand receiving only one application of fertilizer appeared to be on a different trajectory to a novel ecosystem.

Restoring biogeochemical functions in highly degraded riparian wetlands: A comparison of degraded ecosystem responses

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The once tight connectivity of streams and wetlands has become separated in the highly developed landscape of today. For example, riparian wetlands in the North Carolina (NC) Piedmont are often highly impaired due to high N and P inputs, sediment load, coliform bacteria, and the lack of a connected functioning riparian floodplain ecosystem. At Duke University a stream and wetlands assessment park (SWAMP) was created to restore multiple sections of a highly incised Sandy Creek stream and riparian floodplain in a 484 ha watershed to improve water quality and reduce sediment load entering the Jordan Reservoir, increase habitat biodiversity and improve ecosystem functions within the wetland and stream complex. In Charlotte NC a highly degraded urban riparian wetland was fully restored by adding new topsoil and organic matter to enhance vegetation growth and biogeochemical processes like denitrification. Both restorations have created hydrologic functioning riparian and palustrine wetland areas along the restored streams, which now demonstrate varying degrees of denitrification potential (DEA) depending on soil organic matter content, nitrate concentrations and moisture (Table 1). Monitoring of storm events indicates (NO_3- NO_2)-N mass loads were reduced by 64% through the SWAMP project area, a trend which followed increased DEA. In the same storm event a 28% reduction in total phosphorus loads was measured. Importantly, the stream reductions in nutrients and coliform bacteria are minimal unless the adjacent wetlands are connected to water flow during storm events. A new innovative approach to wetland stream connectivity is presented. More information on site design can be found at www.env.duke.edu/wetland.

Table 1. A comparison of soil properties, DEA and microbial biomass at the Charlotte and the SWAMP restoration systems from samples collected from the top 15 cm of soil.

	OM (%)	Moisture (%)	NH_4^+ (ug g^{-1} soil)	NO_3^- (ug g^{-1} soil)	Microbial biomass (ug g^{-1} soil)	DEA (ng N g^{-1} soil hr^{-1})
	Charlotte Wetland Restoration					
Mean	7.36*	26.1*	5.35*	3.18*	418.98	195.97*
(+/- 1 SD)	(2.59)	(16.5)	(10.59)	(12.22)	(160.97)	(251.63)
	Duke Forest SWAMP Restoration					
Mean	11.00*	30.55*	12.15*	17.08*	462.83	541.75*
(+/- 1 SD)	(1.83)	(7.68)	(11.58)	(22.35)	(211.65)	(1066.89)

DEA = denitrification enzyme assay which is a measure of denitrification potential
* = significant difference in the parameter between the two systems ($p < 0.01$)

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The role of afforestation in soil restoration: effects on soil nutrients in degraded volcanic soils in Iceland

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Soil degradation and erosion is a severe problem in Iceland. A large part of this can be attributed to deforestation and the agrarian lifestyle of the first settlers; forest cover of 15–30% before this time (c.AD 874) was reduced to less than 1% of the land area within less than 200 years. With the loss of forests, soil erosion increased, causing the loss of soil organic carbon and thus valuable fertile land. This serious environmental problem continues still today. Afforestation has become an important tool in restoration and protection of Icelandic soils, but organized forestry did not start before 1899, and another 100 years passed before a Regional Afforestation Project Act was announced with the aim of increasing forest cover to 5% of the area below 400 m a.s.l. Afforestation in Iceland has to face many problems, such as the harsh climate, short vegetation periods, frost heaving in winter, damages by grazing sheep and horses, and the poor soils. Icelandic ecosystems are generally nitrogen (N) limited, and phosphorus (P) availability is poor owing to the high P fixation capacity of the volcanic soils. While fertilization can improve survival of seedlings, little is known about nutrients in maturing forests planted on the volcanic soils. The aim of this study was to investigate long-term development of soil nutrients in forest stands in Iceland (Ritter 2007; Ritter 2008).

Changes in soil nutrients were investigated in stands of native birch (*Betula pubescens* Enrh.) and introduced Siberian larch (*Larix sibirica* Ledeb.) of increasing age (14 to 100 years) and a treeless heathland in east Iceland. Soils were Andosols derived from basaltic material and rhyolitic volcanic ash. Total C, N and P in soil (0–10 and 10–20 cm depth) as well as base cations and Olsen-P were measured. Results revealed minor changes in the total content of C, N and P with stand age (Ritter 2007). The C content in 0–10 cm soil depth was significantly higher in forest stands older than 30 years than in heath land and the younger forests stands. Changes in the soil C pool were generally less than found in other Icelandic studies on land reclamation with grass. This was partly attributed to the fact that the present soils were already on a moderate C level prior to forest establishment compared to other Icelandic Andosols. Concentrations of N and total P in the mineral soil were not affected by stand age at all. Also soil K contents did not change with stand age, indicating a sufficient K supply (Ritter 2008). There was no significant effect of tree species. The cations Ca, Mg, and Na decreased with time after afforestation, which can possibly be related to the decreasing soil pH. The higher concentrations of Olsen-P and K in the upper soil layer as compared to 10–20 cm depth indicate a higher biotic control as opposed to the geochemical control of the other base cations. Olsen-P increased in the upper soil layer when forest soil developed under the growing forest stands (Ritter 2008). Hence, P supply may become less critical once the seedlings have survived the first years. This indicates that fertilization, which has been found necessary at or during the first years after planting, is not needed in older forest stands. Although changes are generally slow, the development of at least K and the macro nutrients investigated in this study must be considered positive for the growth conditions of the maturing trees. This is helpful to know for afforestation activities and the management of forests on the difficult soils in Iceland.

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Microbially mediated nitrogen transformation processes in restored and channelized sections of a river corridor

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Floodplains are highly appreciated for their ecological services, in particular biodiversity conservation, and flood protection. This has led to increased efforts to restore previously altered or destroyed floodplains. However, there is insufficient knowledge how the restoration affects other functional aspects of the river corridor, in particular to act as filter and buffer for potential water pollutants. The interdisciplinary project cluster RECORD was therefore initiated to increase mechanistic understanding of coupled hydrological and ecological processes in river corridors. A section of the river Thur corridor in Northeast of Switzerland is investigated, a large part of which has been re-naturalised by, e.g., removing embankments. In one of the sub-projects we study microbially-mediated nitrogen transformation processes in order to assess whether the restoration has led to an increase or decrease of the river corridor's ability to act as sink for nitrogen.

The non-restored part of the river corridor is a rather homogenous managed pasture with mowing and grazing practice, while the restored section exhibits high spatial heterogeneity with distinct succession gradients of habitats from thinly-colonised gravel extending to mature forest with a dense reed zone and planted willows as intermediate habitats. In order to obtain an in-depth understanding of nitrogen cycling in the non-restored and restored section, the rates of the following processes are assessed in the various habitats: gross mineralisation, gross nitrification, immobilisation, potential denitrification, all measured in the laboratory, and in-situ soil N_2O efflux. Preliminary results indicate a generally increased microbial activity in the restored section, in particular in the two intermediate habitats (reed zone, planted willows) that are most strongly exposed to periodic flooding and, thus to continuous input of fresh sediments and organic matter (Table 1).

Table 1. *In-situ* gas efflux from different habitats in the Thur river corridor, measured in October 2008 after a long period of low-water conditions (mean ± SE, n = 4)

Habitat	soil respiration	N_2O efflux	CH_4 consumption
	[mmol/m^2/day]	[µmol/m^2/day]	
pasture, non-restored section	225.7	17.0	-6.1
gravel, restored section	42.4	2.5	-1.5
reed, restored section	323.9	38.0	-14.8
willow, restored section	318.4	15.0	-24.9
forest, restored section	192.0	10.9	-57.4

Soil carbon dynamics along a reconstructed Australian jarrah forest chronosequence following bauxite mining

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Soil organic carbon (SOC) is the largest terrestrial pool of carbon on the planet and an increase in the size of this pool by just 5% has the potential to decrease the amount of atmospheric carbon by up to 16% (Baldock 2007). With many governments considering a carbon trading scheme, sequestration of carbon by soils may be economically beneficial and help offset the environmental impact of CO_2 emissions. Therefore, restoring native vegetation and ecosystem processes (such as nutrient cycling) within the soil to pre-mined levels is of high priority. SOC is one aspect of the soil that is affected by the mining and rehabilitation process. Soil organic matter is difficult to isolate and measure because of its complexity and heterogeneity. Many fractionation techniques have been devised to fractionate SOC into conceptual pools based on their turnover times within soil. The measurement of these pools of carbon can give an indication of the methods of stabilisation within an ecosystem.

Accumulation, distribution and soil organic carbon (SOC) quality in post-mined rehabilitation was studied at Boddington Bauxite Mine of Worsley Alumina Pyt. Ltd. in southwestern Australia and benchmarked to adjacent unmined northern Jarrah forest soils. The soil profile was analysed to a depth of 20 cm for five restored forest age-classes ranging from 2 to 15 years. The quantity and quality of SOC in both bulk soils and particle-size based discrete carbon pools showed positive trends towards convergence with native forest levels. Parameters with a fast turnover such as litter layer and labile SOC pools were most successfully returned to pre-mining levels. The litter mass of sites rehabilitated for 15 years marginally exceeded the mass of unmined native forest which is attributed to a more productive plant community or decreased decomposer activity. SOC throughout the soil profile generally responded well to rehabilitation. The more labile (>200 μm) particulate organic carbon (POC) fraction was returned to comparable native forest levels (within significant levels; $P \leq 0.05$) at all depth intervals. Even though, the less labile POC fraction (200–53 μm) and humus (<53 μm) fractions showed some evidence of slowly returning towards native levels; however some significant differences were still evident. $\delta^{13}C$ values of both POC fractions (> 200 μm and 200–53 μm) were consistently greater in rehabilitated sites compared the unmined control. This may be due to differences in floral species distributions; a view supported by the floristic analysis which shows species composition differences between rehabilitated and native forest. As opposed to these parameters, others have not yet returned to natural levels - a significant variance of potential concern was the C:N nutrient ratio for soil depths lower than 2 cm showed values progressively different from the native forest. This altered C:N ratio may be attributed to an increased dominance of N-fixing pioneers in the younger rehabilitated sites. This deviation of the C:N ratio from native forest may eventually be addressed by shifts in plant community with succession processes.

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Lessons gained from French R&D programmes for pesticides dissipation by use of constructed wetlands

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Pesticide pollution is a major treat of surface water quality in France. To comply with the European Water Framework Directive authorities have decided of a Phyto-Pharmaceutic Products (PPP's) reduction plan, the major achievement of which being the50% reduction of intrants by year 2018. This plan only considers actions on farming practices and does not foreseen any actions on transfers in catchments, even if these latest actions are expected to contribute to PPP's reduction. Also, existing anti drift buffer strips have revealed inoperant vs PPP's rural pollutions (and nitrates included) in two well identified situations which represents approximately 40% of the French total arable land: i) subsurface drained areas (the pollution by passes below the buffer) and ii) waterlogged area (pollution over passes when the water table is high). Considering that a significant part of the territory is not protected by the by default standard buffer techniques, and since constructed wetlands have shown efficiency in other countries but under different climatic and hydrologic conditions, the question of their adaptation to the French context raised recently.

Chance has been taken from two R&D research programmes[1] regarding constructed wetlands to improve the state of the art, to assess the performance from both scale pilots and on farm actual constructed wetlands and to find incentive economical, legal, social for further nationwide extension. The pilot requiring energy to recirculate the effluent, fully rustic processes have been installed, i.e. small constructed wetlands at the outfall of drained catchment. The catchments (approx 50 ha) were cultivated by farmers accordingly with as usual crops and practices, the size of the wetlands were minimised to facilitate acceptation, betting on a dynamic control of inflows to wetland as the research showed that the most of the pollution occurs during the very first peak events after PPP's application. The wetlands were installed in parallel of the arterial main drain accordingly with two modalities, one forested and the second vegetated. Two contrasted regions have been chosen as well. In all cases climatic parameters water and PPP's flows in and out have been measured and monitored.

Results of the programmes after one year of data are given here. Heavy PPP's concentrations (up to 100 µg/l) have applied on the scale pilot with satisfactory reductions rates (between 50 and 80%) showing that on farm process is feasible if more rustic processes would show poor performance. The forested wetland has worked properly showing nil traces of PPP's at the outfall back to the main drain. The vegetated wetlands had promising performance, but redesign has been operated to increase residence time and PPP's dissipation. The result of this second campaign will be available for the congress. There is no aid and no by law obligation for such wetlands and heavy administrative engineering had to be applied to find incentives for farmers. Sociologic approaches and amenities assessments have revealed unsuspected relations of the farmers with the society and the environment, and vice versa. In the both cases the project have resulted of a co-construction where each actor had personal involvement. Even if Co-construction should be a driving line, solutions for appropriate incentives and land reallocation tools should be fought with politics and authorities in order to facilitate further realisations.

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[1] **ARTWET**, EC life Project N° LIFE06 ENV/F/000133, acronym of ARTificial wetlands for PPP»s reduction, and **TRUSTEA** project, acronym of RUStic Treatment of Agricultural Water, a Cemagref funded project for involving Human and Social Sciences in engineering processes and risk management policies

Tree species affect soil metal redistribution: implications for phytoremediation

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Metal polluted soils pose serious risks for the ecosystem and public health, through leaching of metals to groundwater and dispersion in the food chain. Conventional soil sanitation techniques are technically and financially seldom feasible because of the spatial extent of metal pollution. Therefore, those degraded ecosystems are often afforested. Forests showed to play an important role in metal cycling and partitioning. But what are the limitations and possibilities for phytoremediation of metal polluted soils? This contribution will discuss the possibilities and limitations of phytoextraction, bioavailable contaminant stripping and phytostabilization, on the basis of *in situ* research. The phytoextraction technique showed great promise, but is in our opinion still limited to be applicable in the field. It was calculated that natural phytoextraction is limited due to the fact that, at present, no species is found that combines high metal uptake with high biomass. Moreover, there are practical implications as metal availability decreases upon successive croppings. For most trace elements, the technique of phytoextraction thus needs significant improvements to become practically feasible. A possible ameliorative variant of the phytoextraction technique is 'bioavailable contaminant stripping', which aims at the extraction of only the most labile, bioavailable metal pools. However, in order to apply this technique efficiently and safely, it is necessary to assess the kinetics of replenishment of the bioavailable metal pools in the long term. Nevertheless, even when the phytoextraction technique would be improved, applicability in the field might be restricted as metal uptake in aboveground biomass causes an important risk of contaminating the food chain or surrounding environments. Whenever phytoextraction is not applicable, phytostabilization might be a more promising technique, by aiming at reducing the metal mobility and thus the dispersion of the metals in the ecosystem. Trees seem well suited for phytostabilization purposes, due to their extensive root systems and high transpiration capacity. But on the other hand, tree growth might enhance metal leaching, because of soil acidification and production of dissolved organic matter. Hence, it is very important to select tree species for phytostabilization purposes that cause low soil acidification and do not translocate high amounts of metals to their leaves.

The tree species effects on metal redistribution in the ecosystem were investigated on 2 metal polluted sites, differing in soil characteristics as well as pollution source and forest age. On the one hand we investigated the redistribution of soil metals under 4 tree species on a dredged sediment disposal site with 33-year-old trees (poplar, oak, ash, maple). On the other hand we investigated the effects of 6 different tree species on Cd and Zn compartmentalization after 10 years of tree growth on agricultural, sandy soil near a former Zn-smelter (aspen, oak, silver birch, black locust, Scots pine, Douglas fir). The contrasting soil characteristics of the 2 investigated sites might give rise to other dynamics in metal fluxes. The dredged sediment site had a high pH (c. 7.7) and a high cation exchange capacity (CEC), while the sandy site had a low pH (c. 4.7) and a typical low CEC. Both studies revealed a clear redistribution of metals in the soil profile that was dependent on the tree species. These metal redistributions were more pronounced on the oldest site.

Poplar and aspen took up high amounts of Cd and Zn and this was associated with increased Cd and Zn concentrations in the upper soil layer. Silver birch took up Zn in its leaves, which was reflected in a slight accumulation of Zn in the top soil. The other tree species contained normal metal concentrations in their tissues and caused no metal accumulation in the top soil. Oak acidified the soil more than the other species and caused a decrease in the concentration of metals in the upper soil layer. Black locust had also been acidifying, although this was not represented in a decrease of metal concentrations in the top layer. Other soil parameters as organic matter (OM) and CEC might be the reason for that. Hence, poplar and aspen should be excluded in further afforestations and the acidifying species should be mixed with other species, in order to minimize the risk of metal dispersion in the ecosystem.

Hydrochemical and hydrobiological studies of lakes in the southern part of Arkhangelsk region of Russia

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One of the major environmental problems is the preservation of high-quality fresh waters stored in large lakes of northern territories of Russia. However, small lakes, notable those located in the territory of National Parks, deserve a special attention because they may serve as a much faster indicator of global anthropogenically-induced processes occurring in the boreal environment. Small lakes investigated here have glacial origin, and they are represented by different types of reservoirs, characteristic for northwest of the European part of Russia, with distinct morphometric and hydrographic characteristics. Lakes of Rotkovetsky group have the surface area from 0.13 up to 2.1 km^3 and the maximal depths from 3.7 up to 16.0 m. According to their thermal stratification, they belong to epi- and metatermal types. Lakes of the southern part of Kenosersky national park have the area of 2.7 to 3.4 km^3 and the maximal depths of 6 up to 18 m are characterized by intra-reservoir hydrological exchange processes. In terms of thermal stratification, they belong to epi- and and hypothermic types. In this work we present results of hydrologo-hydrochemical study conducted in July, 2007 on 3 lakes of Kenozersky National Park (Lekshmozero, Maselgsko, Vilno) located in the middle taiga zone southwest from Arkhangelsk, and 2 lakes situated in the Geobiopsheral station of Russian Academy of Science “Rotkovets” (Svjatoe, Beloe).

Our study revealed low mineralization of waters; specific conductivity is equal to 50, 100, 125, 55, 200 μS cm^{-1} in lakes Maselgskoe, Lekshmozero, Svjatoe, Vilno, and Beloe, respectively. Due to lakes stratifications, intensive exchange processes between water and sediments occur under anaerobic conditions thus bringing about marked increase of concentration of the following components: Si: from 130μg l^{-1} at the surface to 946 μg l^{-1} at the bottom in the lake Maselgskoe; from 573 to 1232 μg l^{-1} in the lake Lekshmozero; from 1056 to 2795 μg l^{-1} in the lake Svjatoe; phosphates: from 2.7 up to 9.5 μg l^{-1} in the lake Maselgskoe, from 4.5 up to 16 μg l^{-1} in the lake Lekshmozero and from 7.7 to 16.7 μg l^{-1} in the lake Svjatoe. Nitrates dominate the stock of dissolved mineral nitrogen in the lakes. Only in benthic anaerobic layer, the nitrate concentration increases up to 8 μg l^{-1}. Surface layer concentration of ammonium ranges from 15 to 42 μg l^{-1} and from 26 to 54 μg l^{-1} in lakes Lekshmozero and Maselgskoe, respectively. In the in deep anaerobic a layer, ammonia concentration increases up to 106 and 321 μg l^{-1} in lakes Lekshmozero and Maselgskoe, respectively.

Potential negative tendencies of ecosystem development in lakes Maselgskoe and Lekshmozero are controlled by formation of oxygen deficiency in the bottom layers of deep-water stations during period of summer stagnation. The anoxic conditions are often formed in deep water layers of many productive small lakes of the region. The uptake of oxygen triggers the processes of anaerobic respiration which accumulates the reduced organic substances. The increase eof oxygen uptake on the oxidation of organic matter characterizes the intensity of mineralization processes both in water and bottom sediments. For example, in lake Maselgskoe, the aerobic mineralization of organic substances in the bottom horizon was maximal (0.07 mg C m^{-3}×day), while this parameter in the water column is only 0.01 mg C m^{-3}×day. Total mineralization of organic matter was evaluated to be 16.4 mg C m^{-3}×day, whereas the primary production was significantly higher and close to 260 mg C m^{3}×day, that testifies the accumulation of organic substances in the lake Maselgskoe.

The concentration of dissolved organic carbon (DOC) in lakes of Kenozersky National Park revealed the maximal concentration which varied with the depth of the water column within the range of 14 to 21 mg l^{-1}. In shallow lake Vilno the DOC concentration was almost constant as a function of depth and equal to 9.0 - 9.1 mg l^{-1}, in accord with constant distribution of biomass with the depth. In the stratified lake Svyatoe, the DOC content varied from 5.8 to 16.6 mg l^{-1} whereas in the lake Beloe, this parameter is equal to 16 mg l^{-1}.It is concluded that long-term monitoring complex monitoring is necessary, in order to establish regular time trends in the evolution of chemical composition, hydrological characteristics and production-mineralization processes and their link with climate change.

Effects of phosphatic amendment and acidic watering on the mobility and phytoavailability of Cd, Pb and Zn in highly contaminated kitchen garden soils

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For more than a century, the Metaleurop Nord lead smelter (closed in 2003) has contaminated the soils located in its neighbourhoods by its atmospheric emissions. Another smelter, located in the nearest town of the first one, have been in service since 1869 and produces zinc. The emissions generated by these two smelters have led to an important contamination of the surrounding soils. The main pollutants were Cd, Pb, Zn but also to a lesser degree Ag, As, Bi, Cu, Hg, In, Ni, Sb, Se, Sn, Tl. Compared with the regional agricultural values, Sterckeman et al. (2002) showed that the concentrations of metallic elements could be multiplied by a factor of 1 to 50. More recently Douay et al. (2008) showed a higher contamination level of urban soils than those of the agricultural ones in similar environmental context. This is the case for As, Bi, Hg, In, Ni, Sb, Sn but also Cd, Pb and Zn for which a transfer from the topsoil to the deeper layer was suspected. The authors explained that by the cultivation practices, the addition of ashes and various chemical products such as pesticides, herbicides. Moreover, previous works showed a transfer of Cd, Pb and Zn from the soil towards the roots and the foliar parts of different plants (grass, vegetables, trees) grown in this area (Bidar et al., 2007; Pruvot et al., 2006).

Based on these results, the objective of this study was to evaluate the effectiveness of phosphatic amendment on the mobility and phytoavailability of Cd, Pb and Zn in two contaminated kitchen garden soils located nearby these two smelters in comparison with an agricultural soil considered as a control. The chosen amendment was a mixture of hydroxyapatite and phosphate diammonium. In order to understand the behaviour of these pollutants in the selected soils, different extraction protocols were used. Firstly, mobility of the pollutants on the amended and non-amended soils was evaluated according to the Standards, Measurement and Testing programme and the selective extractions ($CaCl_2$, CH_3CO_2H and citric acid). Secondly, the step was supplemented by an evaluation of the impact of the amendment on the phytoavailability by using ryegrass (*Lolium perenne L.*). Two experiments were carried out. In the first one, soils and ryegrass were watered with distilled water (pH = 7). In the second one osmosed water (pH = 5.5) was used to evaluate the effects of the system acidified water – phosphatic amendment on the mobility and phytoavailabily of Cd, Pb and Zn. After a two month incubation period, the selective extraction showed that the effectiveness of the studied amendment depended on the element, on the soil and on the pH of watering water. In a surprising way, the acid extractabilitiy of Pb in the soils watered with acid water is lower than those obtained with distilled water. Phosphatic amendment increased the biomass of ryegrass on the three soils on which distilled water was used. However, the biomass of ryegrass on two amended soils decreases with the acidity water. The results showed high concentrations of Zn in ryegrass grown on the amended soils. The increasing of the Cd phytoavailability in the second experiment was lower than in the first. For Pb, the results depend on the watering conditions and the physico-chemical parameters of the soils.

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Nitrogen mineralization in rehabilitated quarries in Hong Kong

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Mineral N flux in soil was studied using an *in situ* soil incubation technique at different rehabilitated phases of three quarries in Hong Kong: Turret Hill (TH), Lam Tei (LT) and Shek O (SO). The three quarries were rehabilitated progressively and consequently had different phases in terms of restoration date. One phase (rehabilitated in 1994) was studied in TH; three phases (rehabilitated in 1998, 2001 and 2004) in LT; four phases (rehabilitated in 1998, 2001, 2004 and 2006) in SO. Results show that ammonification predominated over nitrification in TH and LT, while nitrification predominated in SO. Net NH_4 mineralization was significantly higher ($p<0.05$) in LT01 and LT04, and net NO_X mineralization was highest ($p<0.05$) in SO98. Net N mineralization increased with increasing restoration age in SO, while these trends were not obvious in LT and TH. Leaching loss of N occurred in all phases, except LT04 and SO01 for NH_4. LT98 and SO98 had the highest leaching of N, while others had no significant difference ($p>0.05$). Plants took up more NO_X than NH_4 in LT98, LT01, SO98, SO01 and SO06. Because of high leaching of N in summer, N uptake by vegetation only occurred in LT04 and SO04, while there were no significant differences among others ($p>0.05$). N flux fluctuated with the ecological development of vegetation and soil (Chu, 2003). Exotic species that are fast growing and tolerant to adverse conditions were mostly preferred in the revegetation of quarries in Hong Kong. With secondary succession that takes place after planting, N flux changed with site age and species planted. N deficiency is a potential problem in restored quarries as a consequence of high nitrification coupled with excessive leaching loss.

Table1 N mineralization, leaching and uptake (µg g^{-1} day^{-1}) in soils of different phases in three quarries.

Sites	Net N mineralization		Leaching of N		Uptake of N	
	NH_4	NO_X	NH_4	NO_X	NH_4	NO_X
TH94	0.149b	-0.076d	0.202b	0.039b	-0.181bc	-0.026b
LT98	-0.056cd	0.143cd	0.969a	0.204b	-0.319c	0.005ab
LT01	0.680a	0.170c	0.200b	0.180b	-0.200bc	0.050ab
LT04	0.528a	0.122cd	-0.054cd	0.067b	0.221a	0.045ab
SO98	-0.192d	1.266a	0.063bc	1.092a	-0.573d	-0.484b
SO01	-0.159d	0.464b	-0.152d	0.248b	-0.368c	0.181a
SO04	0.160b	0.205c	0.129bc	0.149b	0.148a	0.039ab
SO06	0.081bc	0.168c	0.084bc	0.147b	-0.114b	0.063ab

Mean values followed by the same letter in a column are not significantly different at p=0.05 level by the Tukey's HSD test

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Impact of hydrological process on ecosystem services in mitigation wetlands: Case studies in Ohio, USA

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Mitigating the loss of a wetland requires an understanding wetland ecosystem services (e.g., water storage, water quality improvement, vegetation succession, aquifer maintenance, climate mitigation) is needed. This study provides case studies at the Olentangy River Wetland Research Park and others mitigation wetlands in Ohio, USA, demonstrating hydrological dynamics, water quality and vegetation succession after mitigation wetlands are created or restored. The mitigation wetlands at the Olentangy River Wetland Research Park receive 7 to 15 flood pulses each year, while other mitigation wetlands have less than 15 cm of standing water and are dominated by *Eleocharis obtusa*, *Typha sp., Juncus sp*., *Leersia oryzoides*. *Eleocharis obtusa*, and *Cyperus strigosus*. Net sediment deposits range from 127±17 g-dry wt m^{-2} to 149±23 g-dry wt m^{-2} for bottomland hardwood forested mitigation site. Mean retention rates for total nitrate-nitrite and total phosphorus (TP) were 60% and 80% respectively for riparian mitigation wetland. Pulsing events may accelerate biogeochemical processes from flooded sediment to surface soils. Restoration of seasonally flooded mitigation wetlands could stimulate potentially large nutrient releases, which would eventually lead to enhanced ecosystem services.