Sources and sinks in the Nordic landscape: Overview of results from the Nordic centre for studies of ecosystem carbon exchange and its interactions with the climate system, NECC.


(1) Lund University, Dep Physical Geography and Ecosystems Analysis, Lund, Sweden
(2) University of Helsinki, Dep Physical Sciences, Helsinki, Finland
(3) Umeå University, Dep Ecology and Environmental Science, Umeå, Sweden
(4) Agricultural University of Iceland, Borgarnes, Iceland
(5) Risoe National Laboratory, Risoe, Denmark
(6) University of Kuopio, Dep Environmental Sciences, Kuopio, Finland
(7) Finnish Meteorological Institute, Helsinki, Finland
(8) University of Copenhagen, Institute of Geography, Copenhagen, Denmark
(9) Swedish University of Agricultural Sciences, Dep Ecology and Environmental Research, Uppsala, Sweden
(10) Göteborg University, Dep Plant and Environmental Sciences, Göteborg, Sweden
(11) Swedish University of Agricultural Sciences, Dep Forest Ecology, Umeå, Sweden
(12) University of Helsinki, Lammi Research Station, Lammi, Finland

(1) Department of Physical Geography and Ecosystems Analysis, Lund University, Sölvegatan 12, 223 62 Lund, Sweden
anders.lindroth@nateko.lu.se

Keywords
Boreal landscape, eddy covariance, lakes, forests, mires

Abstract
High latitude ecosystems are identified to be susceptible to climatic change and through several processes tightly connected to both the regional and global climate system. The Nordic ecosystems, in particular forests, wetlands and lakes, play a key role in exchanges of carbon dioxide and methane both at regional and global scale. There are large amounts of organic carbon stored in these ecosystems and concern have been expressed that the expected changes in climate could cause a decrease in today’s sinks and even turn sinks into sources. It has, however, also been suggested that the possible raise in temperature could increase mineralization in forest soils and, thus, increase productivity which in turn would lead to more carbon uptake and increasing sink strength. In order to achieve a better quantification of sinks and sources in the Nordic landscape, the Nordic center for studies of ecosystem carbon exchange, NECC was created in 2003. The key issue is to analyse the exchange processes across different age-classes, soil types and species for forests and for some representative wetlands and lakes in order to increase our understanding of which factors that control the exchanges. Flux measurements have been conducted at more than 25 sites of which the majority are forests but also lakes, mires, agricultural and urban sites are included.

The NECC has now entered the synthesis phase (2006-2007) and the results presented here are the first attempt to provide an overview of the range of variation in annual NEE for the typical Nordic ecosystems, and to scale up the carbon balance, including methane, to the Nordic landscape.
whole Nordic region. We conclude that forests show the largest variability from large sources to large sinks, that lakes are generally emitting carbon with the nutrient status as important control factor, that mires and sub-arctic birch forests seems to be small but consistent sinks and that methane emission is important in terms of radiative forcing but not in terms of carbon exchanges. We also demonstrate the potential of mitigating emissions by applying Kyoto relevant land-uses in form of short-rotation forestry and grass cultivations.
Carbon dioxide exchange between arctic polygonal tundra and the atmosphere at the Lena River Delta, Northern Siberia

Lars Kutzbach (1), Christian Wille (1), Eva-Maria Pfeiffer (2)
(1) Foundation Alfred Wegener Institute for Polar and Marine Research, Research Unit Potsdam
* now at Institute for Botany and Landscape Ecology, Ernst Moritz Arndt University Greifswald
(2) Institute of Soil Science, University of Hamburg
(1) Telegrafenberg A43, D-14473 Potsdam, Germany
* now at Grimmer Straße 88, D-17487 Greifswald, Germany
(2) Allende-Platz 2, D-20146 Hamburg, Germany
kutzbach@uni-greifswald.de

Keywords
Arctic, CO2 exchange, eddy covariance, permafrost, polygonal tundra

Abstract
Arctic tundra plays an important role within the global carbon cycle. The permafrost-affected tundra soils have historically been major global carbon sinks. However, the observed and predicted climate warming in the Arctic might heavily disturb the sensitive tundra ecosystems and turn them from a sink to a source of carbon as reported for Alaskan tundra. While most of the arctic CO2 flux studies have been conducted in North-America and Europe, CO2 flux data for the vast tundra landscapes of Siberia are scarce.

Here, we present the results of two eddy covariance campaigns focussing on the CO2 exchange of arctic polygonal tundra in the North-Siberian Lena River Delta (72’ N, 126’ E). The datasets of the two campaigns, which were conducted from July to October 2003 and from May to July 2004, were combined to characterise the seasonal variation of the CO2 fluxes for a synthetic measurement period including the period of snow and soil thawing as well as the beginning of refreezing.

During the measurement period, the polygonal tundra acted as a substantial CO2 sink with a cumulative net ecosystem exchange (NEE) of -2.0 mol m^-2. The cumulative sum of CO2 uptake by gross photosynthesis was modelled to be -9.8 mol m^-2. The cumulative sum of CO2 release by ecosystem respiration was modelled to be +7.4 mol m^-2. By interpolating the CO2 fluxes between late October and May over the winter, the polygonal tundra was estimated to be also a CO2 sink on the annual basis of about -1.6 mol m^-2.

We presume that the very deep, cold and ice-rich permafrost in Siberia acts as a thermal buffer which prevents the carbon cycle of the Siberian tundra from changing as rapidly in response to climate warming as reported for the Alaskan tundra.
Modeling the disturbance of vegetation by fire in the boreal forest

Cyril Crevoisier (1), Elena Shevliakova (2), Manuel Gloor (3) and Christian Wirth (4)
(1) AOS, Princeton University
(2) EEB, Princeton University
(3) University of Leeds
(4) Max Planck Institute, Jena
Atmospheric and Oceanic Sciences, Princeton University, Sayre Hall, Forrestal Campus, Princeton, NJ 08544, USA
ccrevois@princeton.edu

Keywords
fire, boreal forest, vegetation modeling

Abstract
Boreal regions are important for the global carbon cycle because it is the largest forested area on earth and there are large belowground carbon pools (~1000 PgC). It is also a region where largest warming trends on the globe over the last decades have been observed and changes of the land ecosystems have already started. A major factor that determines the structure and carbon dynamics of the boreal forest is fire. As fire frequency depends strongly on climate, increased fire occurrence and related losses to the atmosphere are likely, and have already been reported. In order to predict with more confidence the occurrence and effect of fire on forest ecosystems in the boreal region, we have developed a fire model that takes advantage of the large on-ground, remote sensing and climate data from Canada, Alaska and Siberia. This prognostic model estimates the monthly burned area in a grid cell of 2 by 2.5 degrees, from four climate (air temperature, air relative humidity, precipitation and soil water content) and one human-related (road density) variables. Parameters are estimated using a Markov Chain Monte Carlo method applied to a dataset of observed burned area for Canada. The model is able to reproduce the seasonality of fire, the interannual variability, as well as the location of fire events, not only for Canada (on which data the model is based), but also for Siberia, for which the results compare well with remote sensing observation, and are in the range of various current estimations of burned area. The fire model is being implemented in LM3V, the new vegetation model of GFDL earth system model, in order to make prediction of future fire behavior in boreal regions, and the related disturbance of the vegetation and carbon emissions.
Carbon dioxide fluxes of a recent large wind throw in the High Tatra forests

Stefano Giorgi(1), Peter Fleischer(2), Beniamino Gioli(3), Olaf Kolle(4), Giovanni Manca(5), Alessandro Matese(3), Alessandro Zaldei(3), Waldemar Ziegler(4), Alessandro Cescatti(6), Franco Miglietta(3), Ernst-Detlef Schulze(4) and Riccardo Valentini(1)

(1) Forest Ecology Laboratory-University of Tuscia, Viterbo, Italy. (2) State Forest of Tatra National Park-Research Station, Vysoke Tatry, Slovakia. (3) CNR Institute of Biometeorology, Firenze, Italy. (4) Max Plank Institute for Biogeochemistry, Jena, Germany. (5) JRC Institute for Environment and Sustainability, Ispra (VA), Italy. (6) Center for Alpine Ecology, Trento, Italy.

(1) Via S.Camillo de Lellis sns, 01100 Viterbo, Italy. (2) Tatranska Lomnica 059 60 Vysoke Tatry, Slovakia. (3) Via Giovanni Caproni,8 - 50145 Firenze, Italy. (4) Hans-Knöll-Str. 10 07745 Jena, Germany. (5)Via E. Fermi 1, I-21020 Ispra (VA), Italy. (6) Viote del Monte Bondone, Trento-Italy.

stefano@unitus.it

Keywords
wind throw, eddy covariance, net ecosystem exchange, natural disturbances

Abstract
On November 2004 the area of the High Tatra foothills (Slovakia) was struck by a violent storm where strongest gusts reached almost 200 km/h. By the total area of the Tatra National Park (TANAP, 74,000 ha) about 15% or 12,000 ha of forest ecosystems were affected by wind throw and about 2.5 million m3 of timber were downed. This dramatic event has created the condition to study the impact of such catastrophic wind throw, and its subsequent management, on carbon dynamic of coniferous forests.

Three experimental sites were chosen:
- EX (extracted): wind throw where every log was extracted for commercial purposes. Standing but seriously damaged trees was cut and removed as well.
- NEX (non-extracted): wind throw where all logs and still standing trees remained on the site.
- IF (intact forest): forest site not affected by wind throw and used as a reference for comparison between disturbed and undisturbed ecosystems.

All sites belong to Lariceto-Picetum forest community consisting mainly in Norway spruce with presence of Scotch pine and European larch.

At each site a tower for net ecosystem exchange measurements by eddy covariance has been set up starting from early Autumn 2005. Each tower is equipped with an open-path CO2/H2O gas analyser and an ultrasonic anemometer.

Both disturbed sites (NEX and EX) are showing a net source of CO2 during the period considered due to the suppression of tree photosynthesis. But on a daily basis EX site shows an average uptake of carbon during central part of the day probably caused by the presence of fast growing species which appeared in the herbaceous layer after the heavy disturbance of soil by machinery. Assimilation activity in the NEX site was, in turn, very weak. Here the species composition of the herbaceous layer is more similar to that of an intact forest.
C and N cycling in soils after a wind throw in the High Tatra Mountains

Axel Don, Annette Freibauer, Manuela Bärwolff, Katja Nebelung, Marion Schrumpf, Ernst-Detlef Schulze

Max Planck Institute for Biogeochemistry
Hans-Knöll Strass 10, 07745 Jena, Germany
adon@bgc-jena.mpg.de

Keywords
wind throw, natural succession, forest soil, C- and N-cycling, High Tatra

Abstract
The frequency of extreme weather events like storms is expected to increase in future. Storm events may cause considerable damage to forest ecosystems with a possible negative feedback to the climate system. Enhanced mineralization of soil organic matter may release C to the atmosphere which was stored in the organic layer and the mineral soil and increase nitrogen losses.

In November 2004 a wind throw in the High Tatra Mountains, Slovakia, damaged 12 000 ha of coniferous forest. Our study was conducted in three forest conditions: 1) wind throw where all downed trees have been extracted (EX), 2) wind throw where downed trees remain on the site (NEX), and 3) intact forest unaffected by the storm as reference (IF). C and N-turnover were investigated by repeated soil inventories, litter bag incubations, and measurements of extractable mineral nitrogen, nutrient leaching and trace gas exchange during two vegetation seasons after the wind throw. Additionally litterbags were incubated for 5 months, half of them with Oi-material incubated on the soil surface and the other half with Oa-material incubated in the organic layer.

The complete extraction of the wood at the EX-site caused a rapid mineralization of large parts of the C and N in the organic layer where 75-92% of C was stored. Mass loss of the organic layer at the NEX site was intermediate to the one at the IF and EX site, mirroring the intermediate microclimate between EX-site and a closed forest. The same trend was observed for extractable mineral nitrogen but no mobile nitrate was found in any site. Further analyses are still in progress but will be included in the presentation.

Extraction of downed trees stimulates soil carbon losses as compared to leaving the trees on site for decay. Effects on the nutrient balance, however, are less clear.
Land use dependent GHG exchange and Carbon balance in two grassland sites on eutrophic drained peat soils

Elmar Veenendaal, Arina Schier, Peter Leffelaar, Ko van Huissteden, Frank Berendse
Wageningen University and Research Centre
Free university Amsterdam, Department of Hydrology and Geo-environmental Sciences
Bornse Steeg 69 6708 PD Wageningen, The Netherlands
Elmar.veenendaal@wur.nl

Keywords
Carbon balance, GHG measurements, peatland/wetland, management, Water level manipulation

Abstract
Eutrophic drained peat meadow areas under agricultural exploitation constitute a significant source of CO2 and water level manipulation is being considered to counteract this. We investigated the role of intensive and extensive dairy farm practices on CO2 exchange by means of eddy covariance (EC) measurements and photo-acoustic chamber measurements (CO2, CH4, N2O). Measurements were made in two adjacent farm areas on peat soils in the western part of the Netherlands. One site (Stein) has recently become a meadow bird reserve and is managed predominantly through mowing in June and August. Since September 2005 a water level increase to near the land surface is being implemented as part of the nature management scheme. The second site (Oukoop) is an intensive dairy farm.

During the period September 2004 - August 2005, Both sites were a source of carbon in winter and a sink during summer, with net ecosystem exchange varying between 10 – 60 mmol CO2 m² d⁻¹ in winter to below - 400 mmol CO2 m² d⁻¹ in summer. Periodically both sites became a source during summer after mowing. NEE was closely correlated with LAI management. Annual Net Ecosystem Exchange for Stein was –13.1 mol CO2 m⁻² and for Oukoop - 5.2 mol CO2 m⁻². 55 % of the difference was due to Gross ecosystem production which was lower in Oukoop due to mowing and grazing and 45% due to soil respiration; higher in Oukoop. However when biomass removal and methane emissions (farm based estimates) are taken into account, both sites became a source of 20 – 25 mol C m⁻² a⁻¹. First analysis of the effects of the water level manipulation on the C balance and global warming potential of the two sites will be presented.
Toward a complete carbon budget for a peat covered catchment.

Fred Worrall
University of Durham
Dept of Earth Sciences, Science Laboratories, South Road, Durham, DH1 3LE, UK. Fax: 0191 374 2510, Tel: 0191 374 2535,
Fred.Worrall@durham.ac.uk

Keywords
Peats, C budget, fluvial fluxes

Abstract
Peats are the largest single terrestrial carbon in the UK and as such it is vital that we understand their carbon budget. Most studies of peat carbon budgets have been based either on carbon accumulation studies or fluxes of greenhouse gases. Neither of these methods takes account of the fluvial flux of carbon peat. This study uses detailed observations from a series of upland peat catchments in order to assess a complete carbon budget that includes: soil respiration of CH₄ and CO₂; primary productivity; excess dissolved CO₂; dissolved organic carbon and particulate organic carbon. The measurement of fluvial fluxes can never occur at the point at which the water leaves the peat profile but once the stream is entered both dissolved CO₂ and DOC begin to exsolve and degrade. Therefore in order to get an accurate fluvial flux these in stream process must be accounted for. This study will detail the methods used to account for in stream processes and show that the catchment is near neutral with regard to carbon accumulation.
A 30-month Continuous CO₂ Flux Record from a Semi-Natural Peatland in Central Scotland

Anderson-Dunn, M., Campbell, C.L., Milford, C., Nemitz, E., Ugolini, F., and Sutton, M.A.
Centre for Ecology and Hydrology
Bush Estate, Penicuik, Midlothian, Scotland, UK, EH26 0QB
mana@ceh.ac.uk

Keywords
NEE, peatland, carbon pools.

Abstract
Net ecosystem exchange (NEE) plus the contribution of soil and vegetation to the carbon budget were quantified at a lowland temperate peatland in central Scotland. NEE was measured using the eddy covariance technique during the period 10/05/2002 to 31/10/2004, which incorporated 3 growing seasons and 2 dormant seasons. Bulk soil respiration (Rs) measurements were made on the peat surface (Rs P), and on the litter (Rs L) underlain by peat, between 8/9/2003 and 10/09/2004. A strong seasonal trend in Rs P, plus a peak corresponding to the 2004 spring/early summer peak in leaf area index (LAI) and standing biomass, was observed. Overall, Rs P was greater than Rs L, which indicated that the presence of litter may have depressed soil CO₂ efflux. The observed effect may be due to either suppression of CO₂ production within the peat, due to a reduction in temperature, or a reduction in transport efficiency as the litter may act as a CO₂ ‘trap’.

For this reporting period we found the peatland had an overall net carbon sink value of -2.1 t C ha⁻¹. However, inter-annual variation was observed; during October 2002 to November 2003 the site was a marginal sink (-0.06 t C ha⁻¹) and during October 2003 to November 2004, a marginal source (0.03 t C ha⁻¹). The observed variation in carbon status may be correlated with variation in meteorological conditions.
Carbon balance of a peat meadow

Dimmie Hendriks, Han Dolman, Ko van Huissteden, Michiel vd Molen
Vrije Universiteit Amsterdam (VUA), Department of Hydrology and Geo-environmental Sciences
Boelelaan 1085, 1081 HV, Amsterdam (NL)
dimmie.hendriks@falw.vu.nl

Keywords
ggh balance, peatland/wetland, flux measurements, hydrology

Abstract
Our research aims to assess the carbon-balance in peat meadow areas. The research site ‘Horstermeer’ is located on former agricultural land in a drained natural lake. The research site has been taken out of agricultural production more than 10 years ago, and has developed into semi-natural grassland with a water-table raised to 10 cm below land surface. The soil consists of peat underlain by Pleistocene sands and overlain with organic rich lake deposits.
GHG fluxes were measured with an eddy-correlation set-up (CO₂) and flux chamber measurements using a gas chromatograph (CO₂, CH₄, N₂O). The eddy correlation set-up performs well, as the spectra, co-spectra and the energy balance show satisfying results. Furthermore, meteorological measurements were carried out as well as hydrological measurements (water-balance and dissolved carbon and methane).
The growing season in 2004 lasts 207 days and has a net CO₂-uptake of 3.41 tonC/ha. Net yearly CO₂-uptake was 2.76 tonC/ha. The growing season in 2005 lasts 198 days and has a net CO₂-uptake of 3.74 tonC/ha. Net yearly CO₂-uptake was 3.01 tonC/ha. Using the soil flux chamber measurements, the relation between ecosystem respiration and soil temperature was determined as: \( R^{eco} = 0.0183 \times e^{0.142(T_{soil})} \). A difference between CH₄ fluxes from water, year-round saturated land and relatively dry land is observed. Yearly CH₄ fluxes are 0.39 tonC/ha, 0.41 tonC/ha and 0.17 tonC/ha respectively. N₂O fluxes were too low to be properly measured.
The carbon-balance consists for the largest part of CO₂ uptake, CO₂ respiration and CH₄ fluxes from land and water. Except for the dissolved CH₄ in the infiltrating soil water (0.02 tonC/ha), the fluxes of carbon through water movements are very small. The net yearly total carbon budget between land and atmosphere for 2005 is an uptake of 2.04 tonC/ha, while in global warming potentials this is an emission of 1.85 tonCO₂-equiv./ha.
The carbon balance of a managed wetland meadow in the Somerset Levels and Moors, UK in 2002

Colin R. Lloyd  
NERC Centre for Ecology and Hydrology  
CEH Wallingford, OX10 8BB, UK  
crl@ceh.ac.uk

Keywords  
Wetland, Ecosystem Management, Water Table, Peat, CO₂ Fluxes

Abstract  
In Europe, agricultural practice on managed peat wetland sites if often a balance between maximising the farm production and a desire to maintain a threatened ecological landscape. In wetland peat soils, there is also the need to adopt a management scheme that will minimise the production of atmospheric greenhouse gases. As part of the CarboEurope project, eddy correlation measurements augmented by radiation and soil physics measurements were made continuously over several years at a wetland meadow peat site subjected to a water level management scheme at Tadham Moor in the Somerset Levels and Moors, UK. These measurements produced estimates of Net Ecosystem Exchange (NEE). Using established models, Gross Photosynthetic Production (GPP) and separate soil and plant respiration were estimated from the measurements and NEE. A relationship between depth to the water table and soil respiration was established which indicated increasing ecosystem respiration as the depth to the water table increased. Annual results for 2002 are presented which also incorporate the hay harvest and cattle carbon gains and losses. In 2002, the site had a significant loss of soil carbon of 59 gC m⁻² y⁻¹ in contrast to the historical long-term carbon uptake of natural peatlands. The current water level management scheme is shown to be ineffective in maintaining the prescribed water levels in the drainage ditches and consequently the desired water levels in the fields are not achieved. Controlling drainage ditch water levels to achieve the prescribed in-field water levels is shown to markedly decrease the annual soil respiration, thus maintaining the current soil carbon stocks without affecting the current farming practice.
Carbon dioxide exchange on three wetlands in Finland


(1) Finnish Meteorological Institute, Helsinki, Finland
(2) University of Helsinki, Department of Forest Ecology, Helsinki, Finland
(3) University of Helsinki, Department of Physical Sciences, Helsinki, Finland
(4) Finnish Forest Research Institute, Parkano Research Unit, Parkano, Finland

(1) Climate and Global Change Research, Finnish Meteorological Institute, Erik Palménin aukio 1, Helsinki 00560, Finland
mika.aurela@fmi.fi

Keywords
wetlands, carbon balance, eddy covariance, CO2

Abstract
Carbon dioxide exchange between atmosphere and biosphere has been measured by eddy covariance technique on three wetland ecosystems in Finland: Kaamanen subarctic aapa mire, Lompolojänkkä northern boreal aapa mire and Siikaneva southern boreal mire. The mire at Kaamanen (69° 08' 26.5'' N, 27° 17' 42.1'' E, 155 m a.s.l ) has the longest data set with continuous measurements since 1997 and it is a part of the CarboEuropeIP. The measurements at Lompolojänkkä (67° 59' 83'' N, 24° 14' 51'' E, 269 m a.s.l ) started in 2005 and the site is presently a level 3 NitroEuropeIP site. At Siikaneva (61° 48' N, 24° 09' E, 160 m a.s.l) the measurements were started in 2004 and the site is situated close to the CarboEuropeIP forest site Hyytiälä. According to the preliminary results the annual CO2 balance at Lompolojänkkä was -80 gCO2 m^-2 yr^-1 which is practically the same as the 6-year (1997-2002) average of -79 gCO2 m^-2 yr^-1 obtained at Kaamanen. At Siikaneva the net uptake is somewhat higher with an annual CO2 balance of -170 gCO2 m^-2 yr^-1.
The influence of micro-topography on the greenhouse gas emissions of a pristine mire (Biebrza, Poland).

Bert N. Gielen(1), Sara Vicca(1), Tomasz Okruszko(2), Patrick Meire(1), Ivan A. Janssens(1)  
(1) Ecosystem management research group (ECOBE), Department of Biology, University of Antwerp  
(2) Department of Hydraulic Engineering and Environmental Recultivation, Warsaw Agricultural University  
(1) University of Antwerp, Universiteitsplein 1, BE -2610 Wilrijk, Belgium  
(2)University of Warsaw, Ul Nowoursynowska 166, PL-02-787 Warsaw, Poland  
Bert.Gielen@ua.ac.be  

Keywords  
mire, methane, micro-topography  

Abstract  
Emissions of CO₂, CH₄ and N₂O from wetlands are known to depend strongly on oxygen content (soil moisture) and soil temperature. Because these abiotic conditions are strongly modified by the micro-topography, models of greenhouse gas emissions (or uptake) should take this micro-topography into account. Micro-topography in the mire we studied (tall sedge community, upper Biebrza basin, north-eastern Poland) consists mainly of tussocks (Carex caespitosa) that develop as a strategy to escape from anoxic conditions during inundation. The tussocks differ from intertussock areas in temperature and oxygen availability. Moreover, exudation of labile carbon compounds from the dense root system within and beneath the tussocks may stimulate peat decomposition, and the aerenchym in the roots may transfer methane through the aerobic zone such that the methane escapes oxidation. Thus, micro-topography co-determines the emissions of CO₂ and CH₄ from wetlands.  
Greenhouse gas fluxes from tussocks and inter-tussocks were measured with 6 closed-chambers connected to a portable Photo Acoustic Infra Red Gas Analyzer (Brüel & Kjaer Multi-gas Monitor Type 1302) in combination with a 6-channel multi-sampler. Complementary gas samples were taken with vacutainers and analyzed by a gas chromatograph to make a calibration curve for the portable gas analyzer. Soil temperatures were measured at 4 different depths together with the moisture content in the upper 5cm, redox potential at 5cm, and ground water level. In addition, peat samples were taken from within and between the tussocks for determination of the potential methanogenesis. In this poster presentation, we will analyze results from two field campaigns and the laboratory incubation experiment.
Carbon Fluxes in a Boreal Oligotrophic Minerotrophic Mire

M. Nilsson¹, J. Sagerfors¹, I. Buffam¹, A. Grelle², L. Klemedtsson³, H. Laudon⁴, P. Weslien³ and A. Lindroth⁵.

¹ Department of Forest Ecology, Swedish University of Agricultural Sciences, .
² Department for Ecology and Environmental Research, Swedish University of Agricultural Sciences,
³ Department of Plant and Environmental Sciences, University of Gothenburg,
⁴ Department of Ecology and Environmental Science, University of Umeå,
⁵ Department of Physical Geography and Ecosystems Analysis, University of Lund,

¹ 905 86 Umeå, Sweden
² Box 7072, SE 750 07 Uppsala, Sweden
³ P.O. Box 461, SE 405 30 Gothenburg, Sweden.
⁴ 905 83 Umeå, Sweden
⁵ Sölvegatan 12, SE 223 62 Lund, Sweden

MatsNilsson@sek.slu.se

Keywords
mire, carbon, budget, methane, TOC,

Abstract
Boreal and sub-arctic peat-lands cover some 3% of the global land area but represent a considerable store of carbon, equivalent to ~40-60% of the roughly 750 Gt C currently held in the atmosphere as CO₂. Boreal mires also represent a most significant source of atmospheric methane. The carbon net exchange in boreal mires is dominated by three major fluxes: 1- land – atmosphere CO₂ exchange; 2 – land – atmosphere CH₄ exchange; 3 – carbon export through water run off. Each of these fluxes is controlled by different combinations of environmental factors. Still very few studies including all major fluxes are available.

The study aim was to make a complete carbon budget for a boreal minerotrophic mire. The study was conducted at Degerö Stormyr, (64°11’ N, 19°33E), a mixed acid mire system with an area of 6.5 km². The climate of the site can be defined as cold temperate humid. The vertical CO₂ flux was measured with the eddy covariance technique. Methane emission was measured by static chambers during the snow free season. Stream discharge was measured continuously and water samples were taken regularly and analyzed for total organic carbon, CO₂ and CH₄.

The average annual (2001-2005) land atmosphere CO₂ exchange was 54 ± 6 g CO₂-C m⁻² yr⁻¹. The main determinant for the annual net exchange was the length of the growing season, and most important was how early the soil frost left and allowed a net CO₂ uptake. The low but relatively stable CO₂ loss during the winter accounted for approximately 40% of the annual uptake. The net loss of CH₄-C to the atmosphere, plus DOC and DIC through stream outflow during 2004-2005 accounted for approximately 20-30 g C m⁻² yr⁻¹ making the mire a net carbon sink of approximately 25 g C m⁻² yr⁻¹.
Greenhouse Gas Dynamics in a Natural, Ombrotrophic Bog

Magnus Lund, Torben R. Christensen, Anders Lindroth, Lena Ström
Department of Physical Geography & Ecosystems Analysis, Lund University
Geocentrum II, Sölvegatan 12, SE-22362 Lund, SWEDEN
Magnus.Lund@nateko.lu.se

Keywords
Peatlands; Carbon dioxide; Methane; Nitrous oxide; Fertilization

Abstract
Mires play an important role in the global greenhouse gas budget. In their natural state, they are net CO₂ sequesters due to prevailing anaerobic and nutrient-poor conditions. During Holocene, the net C accumulation in peatlands has resulted in a soil C pool of 270-455 Pg C, around half the amount of C contained in the atmosphere. From a perspective of climate forcing, CH₄ and N₂O released from anaerobic decomposition and denitrification act to counterbalance the CO₂ uptake. This delicate greenhouse gas balance is threatened in a changing climate. Raised temperature, altered precipitation patterns and increased N deposition can have significant impacts on all constituents of the greenhouse gas balance in mire ecosystems.

Within the scope of NECC (Nordic Centre for Studies of Ecosystem Carbon Exchange and its Interactions with the Climate System), we have established a long-term flux study site on Fäjemyren, a south Swedish, ombrotrophic bog located in the cold temperate climate zone. This type of wetland ecosystem has hitherto been underrepresented in long-term flux studies. With the use of the eddy covariance technique, fluxes of CO₂, H₂O and energy as well as additional climatic and soil physical parameters have been monitored continuously since the summer 2005. Small-scale measurements of CO₂, CH₄ and N₂O are performed using dynamic chambers connected to infrared multigas analyzer.

During 2006, a long-term experiment with N and P fertilization will be initialized. The effects on vegetation characteristics and greenhouse gas dynamics will be investigated. This experiment will also be carried out in a sub-arctic bog in northernmost Sweden, in order to get comparison data from a mire ecosystem that has not been influenced by increased N deposition. Preliminary results from Fäjemyren point towards increased CO₂ respiration rates as a response to N fertilization. Very high N₂O emissions have also been detected in the N fertilized plots.
Variation of methane emission from a boreal fen

Janne Rinne(1), Mari Pihlatie(1), Terhi Riutta(2), Mika Aurela(3), Sami Haapanala(1), Juha-Pekka Tuovinen(3), Eeva-Stiina Tuittila(2) & Timo Vesala(1)

(1) Department of Physical Sciences, University of Helsinki, Finland
(2) Department of Forest Ecology, University of Helsinki, Finland
(3) Climate and Global Change Research, Finnish Meteorological Institute, Helsinki, Finland

Department of Physical Sciences, PL 68, FI-00014 University of Helsinki, Finland
janne.rinne@helsinki.fi

Keywords
Methane emission, wetland, eddy covariance, soil chamber

Abstract
We have conducted measurements of methane emission from a boreal fen using eddy covariance method continuously since February 2005. The measurements are conducted on an oligotrophic fen growing mosses (Sphagnum sp.) and sedges (Carex sp. and Eriophorum vaginatum) using a tunable diode laser (TDL) as the methane analyzer. Chamber measurements of methane emissions were conducted during growing seasons 2004 and 2005 and occasional snow gradient measurements during wintertime. The climate at the site is characterized by sub-zero temperatures in the winter and a relatively warm summer. The length of the snow covered period is four to five months. During the winter the frozen peat layer reaches the depth of 10-20 cm. The methane emission measurements show highest fluxes during the summer and low but upward fluxes during the winter. An emission pulse during the snow melting period is clearly detectable but of minor importance. Of the environmental parameters measured, the best correlation with the methane emission was with the peat temperature at the depth of 35 cm, which was also below the water table during the whole measurement period. However, even this parameter could not explain all the variation of the emission, giving systematically different results at some periods. We will present an analysis of the methane emission time series measured continuously over two growing seasons and a winter, in relation to the environmental parameters.
Influence of climate change on the carbon and greenhouse gas balance of a fen.

Sara Vicca, Ivan A. Janssens and Patrick Meire
Ecosystem Management Research Group, Department of Biology, University of Antwerp.
Universiteitsplein 1
2610 Wilrijk
Belgium
sara.vicca@ua.ac.be

Keywords
peatland; climate warming; groundwater level; greenhouse gas emissions

Abstract
Increasing temperature and lowering of the groundwater level are two important factors of global change. In order to investigate the influence of both global change factors on the carbon and greenhouse gas balance of a fen, an experimental platform containing 36 mesocosms was established at the University of Antwerp (Belgium). These mesocosms are divided over nine greenhouses, which are exposed to different temperatures: ambient, ambient +3 °C and ambient +6 °C. In each mesocosm, groundwater level is controlled. During wintertime groundwater reaches the surface in all mesocosms, whereas from April until November water levels are adjusted at 5, 10, 17 or 24 cm below the surface (each greenhouse contains one mesocosm with each groundwater level).

Since the experiment has just started, we cannot present any results yet. Our expectations are that higher temperatures will enhance microbial activity and thus production of for instance CO₂, CH₄ and N₂O. However, changes in groundwater level are expected to be of much more importance for the carbon and greenhouse gas balance than temperature. We expect that the mesocosms exposed to lower groundwater levels will exhibit higher CO₂ effluxes on the one hand (CO₂ is produced in aerobic environments), but will reveal lower emission rates of CH₄ on the other hand (CH₄ production is an anaerobic process). The efflux of N₂O might be largest at intermediate groundwater levels, because both nitrification (aerobic process) and denitrification (anaerobic process) are needed for the production of N₂O. Water level drawdown and warming might thus as well enhance or mitigate global warming, depending on the relative contributions of the different greenhouse gasses.
Project outline: Eurasian peatlands in a changing climate (EURAPECC) – the methane component

Martin Wilmking, Lars Kutzbach, Thomas Becker, Inke Forbrich, Daniel Jager, Julia Schneider
Institute for Botany and Landscape Ecology, Ernst Moritz Arndt University Greifswald
Grimmer Straße 88, D-17487 Greifswald, Germany
wilmking@uni-greifswald.de

Keywords
CH₄ fluxes, boreal peatlands, ebullition, Siberia

Abstract
Boreal Eurasian peatlands have both been long term carbon sinks, and important sources of CH₄ to the atmosphere. However, no long-term, continuous observations of the spatial and temporal variation in CH₄ emissions in these peatlands exist. The EURAPECC project proposes to narrow this knowledge gap by building a network of four sites along a maritime-continental transect spanning from Finland to the largest peatlands on earth in Western Siberia. At each site we will 1) combine chamber measurements and eddy covariance towers to quantify the importance of each pathway of CH₄ emission (diffusion, plant mediated, ebullition/bubbling); 2) scale plot based results up using high resolution kite and zeppelin aerial photography and IKONOS imagery; 3) use stable isotopes and surface level recorders to quantify the importance of deep ebullition events. This novel set-up of methods combined with the spatial extent of the investigation area promises a comprehensive analysis of the spatial and temporal variation in CH₄ emissions in Eurasian peatlands. The west – east transect of the EURA-PECC project is complemented by cooperations with the EU funded project “CarboNorth”, a German project on the Yamal peninsula, both working along north-south transects, and a U.S. funded project aimed at quantification of CH₄ emissions from boreal lakes, thus building a network of sites to better understand the contemporary magnitude of the boreal CH₄ source. Additional innovative aspects include: Measurement of annual CH₄ fluxes in an area with nearly no history of flux measurements, quantification of ebullition and use of a detailed scaling ladder for extrapolation.
Carbon and Energy fluxes of a Mediterranean Macchia ecosystems in response to increasing and decreasing water availability.

N. Arriga(1), G. Alberti(2), D. Papale(1), F. Mazzenga(1), F. Miglietta (3), M. Reichstein(4) and R. Valentini(1).

(1) Dipartimento di scienze dell'Ambiente Forestale e delle sue Risorse (Di.S.A.F.Ri.), Università degli Studi della Tuscia.
(2) Dipartimento di Scienze Agrarie e Ambientali, Università di Udine.
(3) Istituto di Biometeorologia, Consiglio Nazionale delle Ricerche (IBIMET-CNR).
(4) Max-Planck Institut fur Biogeochemie.

(1) Via S. Camillo de Lellis, s.n.c. 01100 Viterbo, Italia
(2) Via delle Scienze, 208. 33100 Udine, Italia
(3) Via Caproni, 8. 50145 Firenze, Italia.
(4) P. O. Box 100164, 07701 Jena, Germany
arriga@unitus.it

Keywords
carbon and energy exchange; soil water content; water manipulation; summer drought;

Abstract
Climate-induced changes in regional precipitation could have important implications for the carbon, water and nutrient cycles of forest ecosystem. However, few studies have investigated the response of Mediterranean vegetation to increases or decreases in precipitation. Therefore, a throughfall displacement experiment was established in 2004 to examine the sensitivity in terms of carbon, latent and sensible heat exchanges of an Arbutus unedo coppice forest to wet (i.e. soil moisture above 10%) and dry (~20% of the incoming precipitation) conditions. Two 1 ha plots were established and two complete eddy covariance systems were set up to provide a quantification of fluxes and relative meteorological driving forces. The comparison among cumulative GPP, NEE and TER showed a clear difference between the two treatments due to the different soil water content. Furthermore, night time carbon fluxes in the wet plot during 2005 were up to 50% higher than in the dry one for high temperature (T>16°C), while these differences seemed to be undetectable during summer 2004 when the experiment was set up but the treatments were limited to the exclusion of precipitation and the effects of irrigations were negligible. Results showed a strong relationship between soil water content and NEE: the increase in soil water availability due to irrigations stimulates ecosystem respiration with a global reduction of net ecosystem exchange.
Experimental drought and functional changes in the mediterranean *Quercus ilex*

*Rambal, S; Rodriguez, R; Rocheteau, A; Misson L*  
CNRS - CEFE  
1919 Route de Mende, 34293 Montpellier Cedex 5 France  
lisson@nature.berkeley.edu

**Abstract**

In the water-limited environments of the Mediterranean-type climate area, water availability strongly controls leaf lifespan, leaf quantity and leaf functions. Important are the timing of rainfall and drought events, the quantity of rainfall, the storage capacity of the soil and the type of vegetation growing on a site. Part of the rainfall is stored in the soil and available for further transpiration by plants. As a consequence, an equilibrium should exist between climate, soil retention properties, vegetation type and leaf area. In addition, rainfall is unevenly distributed throughout the year resulting in marked seasonality in water availability. Our throughfall displacement experiment (MIND project) modified the drought regime and further helps us to understand how trees modified growth patterns and functions to cope with larger and unpredictable drought. In the case of *Quercus ilex*, an evergreen broadleaf species that dominates Mediterranean landscapes, the responses are complicated by its long leaf lifespan. Leaves can be supported by the branches more than two years. Trees in the dry plot showed lower leaf water potential, stomatal conductance, transpiration and assimilation rates compared to the control plot. We observed changes in the growth patterns, with cambial activity and twig lengthening being delayed by the drought. As a consequence, trees have a shorter period for accessing the available soil resources (water and nutrients). Compensations have also been observed, with leaves in the dry treatment increasing their mass per area, lifespan and displaying larger integrated water use efficiency because they lowered maximal stomatal conductance.
Vegetation Productivity as indicator for desertification vulnerability assessment in Sardinia Island (Italy): an integrated modelling approach

Santini M. (1), Papale D. (1), Valentini R. (1)
DiSAFRi - University of Tuscia - Viterbo (ITALY)
via S. Camillo de Lellis sn - 01100 VITERBO (Italy)
monia.santini@unitus.it

Keywords
vulnerability, desertification, vegetation productivity, G.I.S.

Abstract
About land degradation assessment and forecast, a model based methodology appears suitable to monitor processes and to plan mitigation actions. This approach is applied for desertification risk evaluation in Sardinia Island (Italy), providing tools to analyse land degradation and its potential impacts. The developed methodology combines many desertification indicators for the Mediterranean area on a modelling basis, integrating them into a final one representing the general area vulnerability. This study highlights the importance of vegetation productivity inside the integrated modelling framework.

To achieve this aim, CENTURY, a process-based model of plant-soil nutrient cycling which allows to simulate carbon and nutrient dynamics, has been used to derive past trends and future simulations of soil nutrient content and vegetation productivity, according to land use, management and climate changes and scenarios. Required multi-thematic datasets about soil, climate, vegetation and land use for the study area have been acquired; these data have been processed and re-arranged in a GIS environment in order to supply the inputs to the models.

The output contains information on carbon and nitrogen fluxes, net primary production and soil organic matter, and it will allow for a better knowledge of plant response to environmental changes in an area that represents Mediterranean ecosystems well.

Like the input, the model results can also be combined and spatialized to provide “vulnerability maps” about soil and vegetation. The derived degradation index was operated, again in a GIS-oriented approach, with other ones, provided by different degradation process models like soil erosion, overgrazing pressure and groundwater salinization. In this way it is possible to consider different phenomena of desertification, their magnitude and their development rates on a temporal basis.

It will then be possible to supply a useful instrument for predisposing prevention, adaptation or mitigation measures against land degradation from environmental vulnerability assessment and jointly with socio-economic analysis of land use trends.