Conference Proceedings

Finnish Ecosystem Science Meeting: ICOS, eLTER and AnaEE networks

4-6 May 2021

Table of Content

Session III: Scaling - how to use measurements for modeling at different scales

Conference Organizers

Finnish Ecosystem science meeting: ICOS, eLTER and AnaEE networks is organised by research infrastructures ICOS-Finland, eLTER Finland and AnaEE.

The organising committee: Jaana Bäck, Annalea Lohila, Martin Forsius, Maria Holmberg, Virpi Junttila, Marja Maljanen, Jukka Pumpanen, Terhi Rasilo, Yao Gao, Kukka-Maaria Kohonen, Aki Tsuruta, Eero Asmala

Session I: Biodiversity links to ecosystem functioning

What can nearly 100 years of benthic sampling tell us about ecosystem functioning?

Laura Kauppi[1], Joanna Norkko[1], Alf Norkko[1]

[1] UHEL, Tvärminne Zoological Station, Hanko, Finland, laura.kauppi@helsinki.fi

Long time series are extremely valuable in observing and studying causes and consequences of environmental change. Benthic sampling at two sites near Tvärminne Zoological Station (UHEL), XLIV Storfjärden (35 m) and XXVI Långholmsbranten (20 m) started in 1926 by Professor Sven Segerstråle. Since 1964 the sampling is done twice annually. Storfjärden also features an over 100-year-long time series of conductivity, temperature and depth measurements and regular oxygen, nutrient and chl a samplings since 1990s. The benthos dataset consists of abundances and biomasses of taxa, and sizes of the most common species. Several studies have used these data directly to determine changes in community structural and functional composition and their links to environmental changes, and other as a background for experimental studies. Long-term changes in the community are characterized by significant changes in the abundances and biomasses of the most common taxa, the clam *Limecola balthica* and the amphipod *Monoporeia affinis*, and the introduction of the spionid polychaete genus *Marenzelleria* spp. which have ultimately increased the species and functional diversity at XLIV Storfjärden affecting for instance bioturbation and associated cycling of organic matter. The size structure of the *Limecola* population reveals changes in the species' life history and functional traits such as their lifespan, growth rate and body size over time that are linked to climate change and eutrophication. Changes in these traits have implications on the turnover time of carbon and nutrients respired and stored in the tissue of the animals. All these results can be and are used for ecosystem modelling, the results of which are used in the management of our valuable ecosystems.

National Peatland Restoration Monitoring Network – towards effective restoration

Merja Elo[1], Santtu Kareksela[2], Janne Kotiaho[3]

[1] Department of Biological and Environmental Science, University of Jyväskylä, Finland; School of Resource Wisdom, University of Jyväskylä, Finland; merja.t.elo@jyu.fi

[2] Parks & Wildlife Finland (Metsähallitus), Jyväskylä, Finland

[3] Department of Biological and Environmental Science, University of Jyväskylä, Finland; School of Resource Wisdom, University of Jyväskylä, Finland

In 2021 started the UN Decade of Ecosystem Restoration. Ecological restoration, defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed, is increasingly used to slow down the biodiversity loss and maintain ecosystem services. This calls for reliable information on the effectiveness of restoration. National Peatland Restoration Monitoring Network was established by Metsähallitus and University of Jyväskylä in 2007 to study the effects of restoration of peatlands drained for forestry. The network consists of 150 peatlands, belonging to six peatland types, scattered throughout Finland (Fig. 1a). It represents a BACI-design (Before-After Control-Impact): the peatlands are divided to (i) pristine sites, (ii) sites that had been drained for forestry several decades ago and restored during the project, and (iii) sites that have been drained for forestry and left unrestored (Fig. 1b). Each site contains ten permanent vegetation monitoring plots, inventoried prior to restoration, and two, five and ten years after restoration. The monitoring will continue in 5-year-intervals. A part of the sites also includes hydrological monitoring. Within and in addition to National Peatland Restoration Monitoring Network, peatland restoration is studied through multiple projects in co-operation with Metsähallitus, research institutes (LUKE, SYKE), and Universities of Helsinki, Jyväskylä, Oulu, Turku and Eastern Finland, and funded largely by Boreal Peatland Life and on-going Hydrology Life projects. Hence, National Peatland Monitoring Network presents a large-scale long-term ecological experiment from which data can be used to answer a vast body of questions from theoretical to applied ecology, providing valuable information on the effect of restoration on biodiversity and ecosystem services.

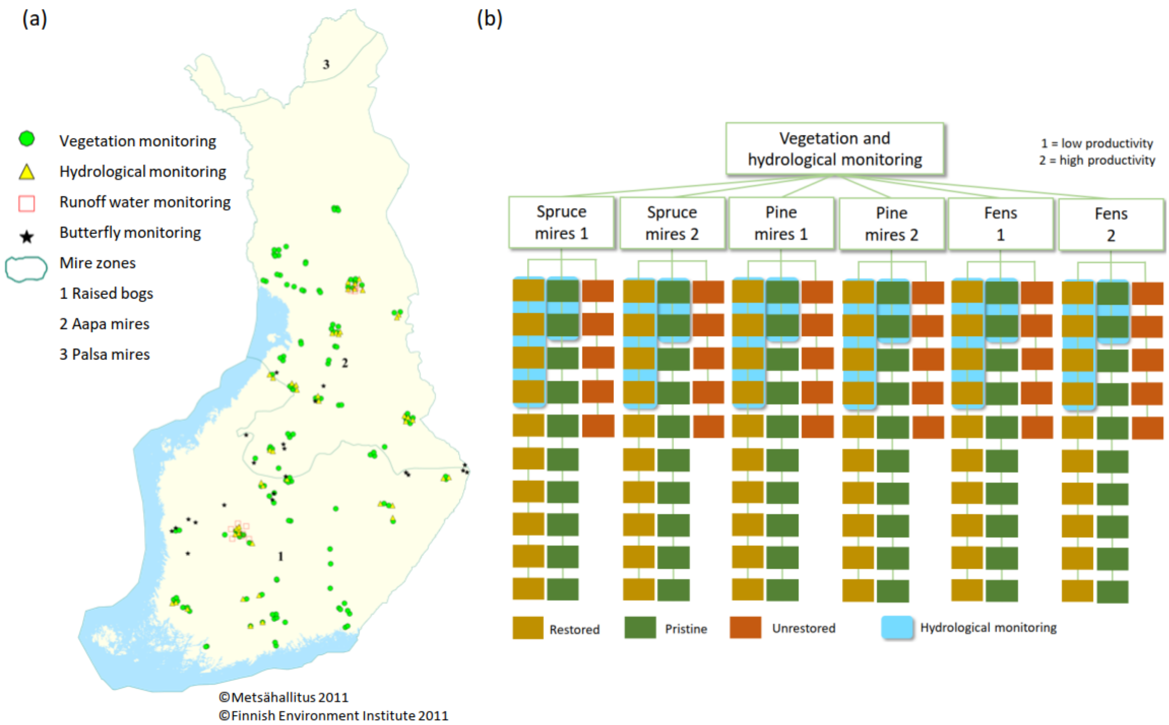


Fig. 1 (a) The location of the monitoring sites, and (b) the study set-up.

Importance of N_2 fixation of bryophyte-cyanobacteria associations to boreal forest nitrogen-budget in changing climate

Maija Salemaa[1], Antti-Jussi Kieloaho[1], Aleksi Lehtonen[1], Antti-Jussi Lindroos[1], Päivi Merilä[2], Raisa Mäkipää[1], Aino Smolander[1] and Samuli Launiainen[1]

[1] Natural Resources Institute Finland (Luke), Latokartanonkaari 9, 00790 Helsinki, Finland; maija.salemaa@luke.fi

[2] Natural Resources Institute Finland (Luke), Paavohavaksentie 3, 90570 Oulu, Finland

Biological fixation of atmospheric nitrogen (N_2) by bryophyte-associated cyanobacteria is an important source of plant-available N in the boreal biome. Information on the driving factors of biological N_2 fixation (BNF) rates is needed for understanding N dynamics of northern nutrient-poor forests under changing climate. Herein we determined the N stock of the bryophyte layer and explained it by the N input of atmospheric deposition, BNF of cyanobacteria (by ARA) and N leachate from recently shed tree litterfall at 12 coniferous forests in Finland. In addition, we estimated how raised temperature and moisture affects the potential N input of bryophyte BNF.

Bryophyte layer formed over half of the total biomass and N stock of the understorey vegetation in most sites. Lower decomposing parts of bryophytes consisted of slightly smaller amount of N than the upper parts. BNF rate of bryophytes increased towards the north (Salemaa et al. 2019). The N quantity in atmospheric deposition was too low to explain the N quantity of bryophytes in the northern sites. However, by adding BNF and N leachate from litterfall to the total N input, the N quantity equaled that of bryophytes. In the southern sites N deposition and leachate were high enough to explain the N quantity of bryophytes. Here BNF was inhibited probably because of high bioavailability of N in ecosystems. In laboratory experiments, estimated N input of BNF increased with increasing temperature and moisture during incubation. This means that contribution of bryophyte layer to the N budget of boreal forests increases if temperature and precipitation levels rise in northern latitudes, supposing that bryophyte abundance stays unchanged.

Salemaa, M., Lindroos, A.-J., Merilä, P., Mäkipää, R. & Smolander, A. 2019. N_2 fixation associated with the bryophyte layer is suppressed by low levels of nitrogen deposition in boreal forests. Science of the Total Environment 653: 995-1004.

The role of boreal old-growth forests in carbon sequestration – an empirical study

Anu Akujärvi[1], Otto Saikkonen[2], Timothy Green[3], Man Hu[2], Francesco Minunno[2], Mikko Peltoniemi[4], Annikki Mäkelä[2]

[1] Finnish Environment Institute (SYKE), Helsinki, Finland; anu.akujarvi@syke.fi

[2] University of Helsinki, Helsinki, Finland

[3] The University of Edinburgh, Edinburgh, The United Kingdom

[4] Natural Resources Institute Finland (Luke), Helsinki, Finland

Boreal old-growth forests are rich in biodiversity and at the same time regulate climate by storing large amounts of carbon in the biomass, litter and soil pools. The carbon sink capacity of old-growth forests is much debated, and the key question is whether they are carbon neutral, sinks or sources. The patterns of growth, mortality and regeneration regulating carbon sequestration are still insufficiently known. Aiming to improve our knowledge about the role of old-growth forests in climate regulation, we investigated the volume growth and net primary production (NPP) of unmanaged forests which are characterized by uneven-aged structure driven by natural mortality and regeneration. The biomasses of living trees, snags and logs were quantified based on a time-series dataset of permanent sample plots from 27 Norway spruce (*Picea abies* (L.) H. Karst.) dominated Finnish forest stands, measured three times from 1990 to 2019. Here we present the observed growth and carbon balance of the studied forest stands. The mean volume growth of the stands was comparable with inventory-based estimates from old forest stands. The NPP increased during the study period indicating that the forests acted as a sink of carbon. The role of natural disturbances and environmental change in explaining the patterns is a subject of further study. The dataset will be used to improve the process-based forest model PREBAS, enhancing its ability to simulate the impacts of alternative land use and climate change scenarios on carbon sequestration. Applying the updated PREBAS model to forested landscapes can importantly help in identifying areas where targets of biodiversity conservation and climate change mitigation could be best reconciled.

Soil microclimatic and plant responses to shifting snow and grazing across boreal habitats

Maria Väisänen[1,2], Torben Christensen[3], Mikhail Mastepanov[3], Juho Lämsä[4], Riku Paavola[4], Anne Tolvanen[5], Jeffrey M. Welker [1, 6]

[1] University of Oulu, Oulu, Finland; maria.vaisanen@oulu.fi

[2] University of Lapland, Rovaniemi, Finland

[3] Aarhus University, Arctic Research Center, Department of Biosciences, Roskilde, Denmark

[4] Oulanka research station, University of Oulu, Oulu, Finland

[5] Natural Resources Institute Finland (Luke), University of Oulu, Finland

[6] University of Alaska Anchorage, Department of Biological Science, Anchorage, AK USA

Boreal biome experiences changes in winter climate, as snowfall may either increase or decrease and is also influenced by the grazing of (semi)domesticated reindeer. Co-occurring changes in winter climate and grazing could induce interactive responses in ecosystem functions. Using grazed and fenced sites in a pine forest consisting of dwarf shrub and lichen dominated habitats and a fen consisting of sedge dominated habitats we studied, how experimentally increased and decreased snowpack influence soil microclimate and vegetation. These experimental setups are part of EcoClimate experiment in Oulanka, northeastern Finland. Our findings showed that similar changes in snowpack induced habitat-specific changes in soil thermal (Figure 1) and moisture conditions. Likewise, variations in snowpack induced habitat-specific responses in vegetation community greenness, which further responded to grazing. The growth of individual plants responded to winter climate and grazing but, again, differently depending on habitat. These findings provide insights about how to compare winter climate manipulations across boreal habitats and, more importantly, how to infer their ecological consequences.

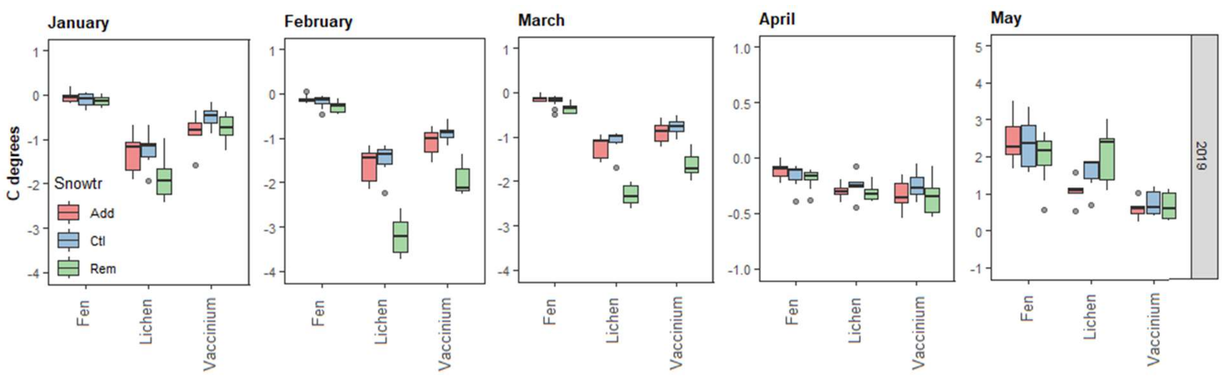


Figure 1. The monthly soil temperatures from winter to late spring 2019 in boreal fen, lichen and vaccinium (dwarf shrub) habitats. Reindeer grazing did not affect winter soil temperatures. Snow treatment abbreviations are: Add = snow addition, Ctl = control (ambient), Rem= snow removal.

Taxonomically and functionally distinct ciliate assemblages inhabiting sea ice

Markus Majaneva[1,2,3,*], Janne-Markus Rintala[2,3,4,֍], Jaanika Blomster[3]

[1] Norwegian Institute for Nature Research (NINA), Trondheim, Norway
[2] Tvärminne Zoological Station, University of Helsinki, Hanko, Finland
[3] Department of Environmental Sciences, University of Helsinki, Helsinki, Finland
[4] Institute for Atmospheric and Earth System Research /Agriculture and Forestry, University of Helsinki, Finland.

[*]Corresponding author: e-mail: markus.majaneva@gmail.com,ORCID: 0000-0003-3884-2548.
֍ Presenting author in FESM: e-mail: janne.rintala@helsinki.fi, ORCID: 0000-0002-3514-6582

Keywords: Ciliophora, Baltic Sea, DNA metabarcoding, mixotrophy, predator prey interactions

Abstract

Ciliates are ubiquitous and diverse phylum of protists. They are an important trophic link, which feed on bacteria and algae, predate protists, parasitize a wide range of organisms, and are important energy resource for higher trophic levels. Many ciliates have acquired phototrophy. Those ciliates catch and harbour phototrophic symbionts or sequester plastids from the captured algae, and are therefore functionally not solely consumers but exhibit different states of the mixotrophic continuum. Therefore, understanding the diversity and functions of ciliates is essential to fully perceive any ecological processes, for example dynamics of trophic networks and carbon cycling.

Sea ice covers 3–6% of the earth's surface annually. It is semisolid matrix of ice crystals and saline water (brine channels and pockets) inhabited by micro-organisms. Sea-ice micro-organisms cover 6–41% of the brine surface area, which is high compared to soils where less than 1% of surfaces are covered by organisms. Sea-ice organisms may restructure brine channels more habitable using extracellular polymeric substances.

Morphological identification of ciliates, depicting their feeding behavior and trophic modes require laborious experiments and microscopic observations. Respectable amount of this work has been performed on ciliates. In this study, we place the ciliate sequences we have gathered during our sea-ice studies in the Baltic Sea on the ciliate 18S rRNA reference tree. With this re-identification we gain more accurate taxonomic information on the sea-ice associated ciliate assemblages and may better than previously consider their ecological roles in the communities. We obtained 480000 ciliate reads (508 unique reads, 220 different OTUs) from our 74 winter-time samples.

We tested three hypotheses: whether sea ice, under-ice water and water column have the same taxonomic and functional ciliate diversity (H1), or similar ciliate assemblages and functions (H2), and whether ciliate diversity, assemblages and functions stay the same through-out the ice-covered season (H3).

Key factors affecting vascular vegetation shoot methane emissions from high frequency and climate-control measurements

Mengyu Ge[1], Markku Koskinen[2], Mari Pihlatie[3], Päivi Mäkiranta[4], Annalea Lohila[5]

[1] University of Helsinki, Department of Agricultural Sciences, Finland

[2] INAR Institute of Institute for Atmospheric and Earth System Research/Forest Sciences University of Helsinki, Finland

[3] Natural Resources Institute Finland, Helsinki, Finland

[4] Finnish Meteorological Institute, Helsinki, Finland; email@fmi.fi

Northern peatlands are a major natural methane (CH_4) source and vascular plants are efficient channels for CH_4 to transfer from soil to the atmosphere. However, the controlling factors affecting plant-mediated CH_4 are still not clear, which is caused by the limited datasets provided by sporadic field measurements and the collinearity among environmental controls.

In this study, we used a controlled-environment chamber system that enabled us to determine the separate effects of temperature, photosynthetically active radiation (PAR), and simulated herbivory on CH_4 emissions mediated by shoots of *Carex rostrata* and *Betula nana* based on high-frequency measurements in a closed-loop setup with a Picarro G2301 CH_4 analyzer (Kohl et al. 2021). We measured the CH_4 emissions in three measurement campaigns, from early growing season to beginning of senescence (June-September 2020), with three specimens per species and campaign.

During the campaigns, CH_4 emissions from *C. rostrata* and *B. nana* ranged from 2.77 to 193.699 mg m^{-2} leaf area d^{-1} and -0.24 to 35.93 mg m^{-2} stem surface d^{-1}, respectively. CH_4 emissions from *C. rostrata* showed a significant seasonal pattern with a peak value in the late growing season when such emissions from Betula nana were negligible, which were the conjunct results of plant physiological factors and soil CH_4 concentration. Temperature effects on CH_4 emission from both species were shown when no limiting factors for plant-mediated CH_4 existed. Simulated herbivory was a robust factor influencing CH_4 emissions from both species during all measurement periods. No correlation was found between CH_4 emissions and PAR for both species. Our results indicate that major factors influencing plant-mediated CH_4 emissions are interactive but simulated herbivory is exceptionally vigorous whose effect is not limited by other factors.

Reference list

Kohl, L., Koskinen, M., Polvinen, T., Tenhovirta, S., Rissanen, K., Patama, M., Zanetti, A. and Pihlatie, M. (2021) An automated system for trace gas flux measurements from plantfoliage and other plant compartments, Copernicus GmbH.

Boreal forest floor CO_2 flux responses to divergent reindeer grazing regimes and altered winter snow depth

Noora Kantola[1], Maria Väisänen[1], A. Joshua Leffler[2], Juho Lämsä[3], Riku Paavola[3], Mikhail Mastepanov[3,4], Jeffrey M. Welker[1,5,6]

[1] University of Oulu, Oulu, Finland; noora.kantola@oulu.fi

[2] South Dakota State University, Department of Natural Resource Management, Brookings, USA

[3] Oulanka Research Station, University of Oulu, Kuusamo, Finland

[4] Aarhus University, Arctic Research Centre, Department of Bioscience, Roskilde, Denmark

[5] University of Alaska Anchorage, Department of Biological Sciences, Anchorage, USA

[6] University of the Arctic, Rovaniemi, Finland

Reindeer grazing intensity varies throughout Finland and the Nordic countries and is known to affect soil and plant processes due to differential vegetation foraging. Whether this landscape use dictates the response of ecosystems to changes in winter climates (i.e., more or less snow) is however, very uncertain. In this study, we are using EcoClimate experiment (Oulanka, Finland) in a dry pine forest to compare how grazing history (i.e., exclusion of 25 years) affects understory ecosystem trace gas feedbacks in response to changes in winter snow depth. Our initial results show that the understory ecosystem was a net carbon dioxide (CO_2) source to the atmosphere and the intensity of CO_2 emissions varied among habitats (lichen vs. dwarf shrub patches). In addition, long-term exclusion of reindeer and one year of snow depth (experimentally deepened) did not affect CO_2 exchange in the following growing season, but through complex interactions, grazing history and prior winter snow depth had a seasonal effect on the intensity of ecosystem CO_2 uptake depending on understory habitat. These findings suggest that the complex herbivore – winter climate change – habitat -interactions are possible and should be included in the future climate change research, when investigating carbon (C) dynamics in boreal forests. Our findings will help to estimate and predict the future C balances and possible positive feedbacks between boreal ecosystems and changing climate. Furthermore, the findings provide tools to mitigate climate change impacts and control C balance, and support decision making in land use management.

The next step in coastal biodiversity and climate change research

Alf Norkko *et al*

Tvärminne Zoological Station, University of Helsinki, Finland; alf.norkko@helsinki.fi

The global climate and biodiversity crises are inextricably linked. Coastal ecosystems are highly productive and dynamic in terms of carbon cycling, greenhouse gas (GHG) fluxes and aerosol formation, but our understanding of links between coastal ecosystems and atmospheric feedback is exceedingly limited. The range of habitats found in coastal ecosystems supports high overall biodiversity with varying magnitudes of organic C production and turnover rates. While we know that biodiversity characteristics, such as biological trait composition, dictate many of these ecosystem processes, we lack a comprehensive understanding of how different elements of coastal biodiversity contributes to C sequestration and atmospheric feedbacks. To resolve the significance of coastal ecosystems, and investigate their potential role in mediating climate change, we hence need new multidisciplinary approaches that link biodiversity elements with coastal C stocks and fluxes and related aerosol production.

We are now in the process of establishing a coastal ecosystem and climate change observatory to take on these critical knowledge-gaps at Tvärminne Zoological Station (TZS). We are building on the globally unique centennial time-scale datasets on coastal biodiversity and environmental change available from TZS. This will now be expanded with mobile seafloor observatory platforms and a network of automated, high-frequency multiparameter sensors in different coastal habitats, and for the first time atmospheric measurements will be coupled to the aquatic measurements at TZS. By bringing together different disciplines and establishing a coastal observatory to start measuring the full suite of variables affecting radiative forcing and hence climate, we will provide a new mechanistic understanding of the relative importance of ecological, biogeochemical and physical processes for coastal areas in climate transition. This has never been attempted across spatio-temporal gradients in the coastal realm, including environments experiencing different degrees of habitat degradation. The integrative approach with simultaneous quantification of biodiversity and air-sea feedbacks will provide an unparalleled opportunity to understand the cumulative effects of the biodiversity and climate change.

Exploring the link between functional diversity and ecosystem functioning: do traits explain spatiotemporal variation in plankton growth dynamics?

Veera Norros[1], Marko Laine[2], Timo Tamminen[3], Tom Andersen[4]

[1] Biodiversity Centre, Finnish Environment Institute SYKE, Helsinki, Finland; veera.norros@syke.fi

[2] Finnish Meteorological Institute, Helsinki, Finland; marko.laine@fmi.fi

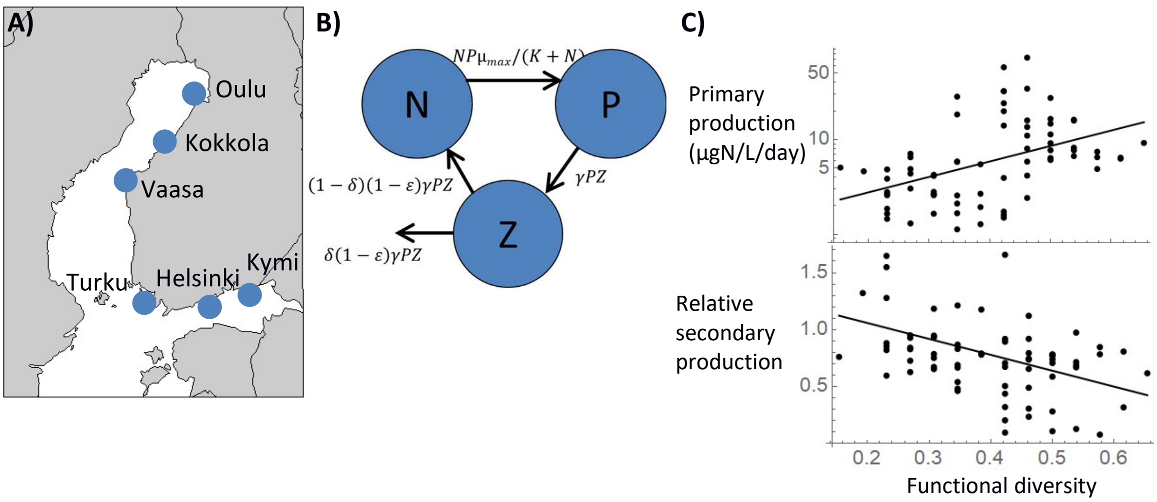
[3] Marine Research Centre, Finnish Environment Institute SYKE, Helsinki, Finland

[4] Department of Biology, University of Oslo, Norway

Ecosystem functions arise from the activities and interactions of individual organisms, but the link between community composition and ecosystem functioning is difficult to quantify particularly in natural systems. We demonstrate a new approach for examining this link: fitting a dynamic model to a collection of local time series data sets and relating the variation in estimated model parameters and ecosystem fluxes to the simultaneously observed variation in community composition. We fitted a dynamic nutrient-phytoplankton-zooplankton (NPZ) model to a series of 152 bioassay experiments conducted at ca. biweekly intervals throughout three growing seasons at five different sites along the Finnish coast of the Baltic Sea (**Fig. 1A-B**). Spatiotemporal variation in NPZ model parameters (phytoplankton maximum growth rate, phytoplankton nutrient uptake affinity, zooplankton grazing rate and phytoplankton C:N and ChlA:N ratios) was quantified by combining the dynamic core model with a hierarchical Bayesian data model that describes the relationship between the different experiments. We then used the parameterized model to estimate *in situ* ecosystem fluxes: primary and secondary production, remineralization and loss to the biologically unavailable nutrient pool. The estimated NPZ model parameters and ecosystem fluxes were related to observed phytoplankton functional diversity and composition.

The NPZ model performed well in reproducing the growth dynamics observed in the experiments. There was significant spatiotemporal variation in the estimated parameter values and ecosystem fluxes. In several cases, the variation was related to phytoplankton functional composition (**Fig. 1C**). Primary production had a positive relationship to functional diversity and an inverse relationship to functional evenness, driven by corresponding patterns in phytoplankton maximum growth rate. Conversely, relative secondary production (the ratio of secondary to primary production) decreased with increasing functional diversity, driven by corresponding patterns in zooplankton grazing rate. Relative secondary production also decreased with increasing phytoplankton cell size. We conclude that hierarchical dynamic modelling is a useful tool for analyzing variation in ecosystem functioning, and that the functioning of natural plankton systems shows variation that is related to phytoplankton functional composition.

***Figure 1. A)** Study sites. **B)** The dynamic nutrient-phytoplankton-zooplankton model. **C)** Estimated ecosystem fluxes plotted against phytoplankton functional diversity calculated from observed species composition.*



Session II: Nature climate solutions - ways forward to enhance land carbon sink and reduce adverse climate impacts of land use

Does tree breeding change the dry mass allocation between the shoot and the root system in *Pinus sylvestris*?

Katri Himanen[1], Pekka Helenius[2], Seppo Ruotsalainen[3] & Jaana Luoranen[1]

[1] Natural Resources Institute Finland, Suonenjoki; katri.himanen@luke.fi

[2] Natural Resources Institute Finland, Jokioinen

[3] Natural Resources Institute Finland, Savonlinna

Genetically improved Scots pine (*Pinus sylvestris* L.) seeds are used extensively in artificial forest regeneration in Finland. The selection of parents for 1.5-generation seed orchards is based on progeny trials, in which characteristics of the tree stems and crowns are measured. However, the effect of selection breeding on root system and thus to soil carbon input is unknown. The aim of this study was to investigate the effect of breeding on the size of the root system and the shoot to root -ratio of young Scots pine seedlings.

31 Scots pine seed lots, originating from controlled pollinations of parent trees from central Finland with known calculated performance levels for height growth were selected for the experiment. The seed lots formed a gradient of average (mother × father) performance levels from below population average to values above average.

Seeds of all the seed lots were weighed and sown in hard plastic trays filled with either peat or fine sand and grown in a greenhouse at Natural Resources Institute Suonenjoki research nursery for approximately two months. Afterwards, height and shoot and root dry mass of the seedlings was measured.

Both shoot and root dry mass increased with increasing performance level averages. However, the shoot dry mass increased proportionally slightly more than the root dry mass.

The results indicate that using genetically improved forest reproductive material not only increases the above-ground but also the below-ground dry mass accumulation compared to unimproved seed sources in young seedlings. However, the altered shoot to root -ratio may slightly increase the risk of drought in artificial forest regeneration.

Understanding the Ecosystem Sink of Nitrous Oxide (ENSINK)

Hem Raj Bhattarai[1], Petra Manninen[1], Saara Lind[1], Katri Henmanen[2], Hanna Ruhanen[2], Arja Tervahauta[3], Annalea Lohila[4,5], Sara Hallin[6], Wolfgang Wanek[7], Yakov Kuzyakov[8], Bahar S. Razavi[9] Reiko Sameshima-Saito[10], Narasinha J. Shurpali[1]

[1]Natural Resources Institute Finland (Luke), Maaninka, Finland, hemraj.bhattarai@luke.fi
[2]Natural Resources Institute Finland (Luke), Suonenjoki, Finland
[1]Natural Resources Institute Finland (Luke), Viikki, Finland
[4]Finnish Meteorological Institute (FMI), Helsinki, Finland
[5]University of Helsinki (UH), Helsinki, Finland
[6]Swedish University of Agricultural Sciences, Uppsala, Sweden
[7]University of Vienna, Vienna, Austria
[8]Georg-August-Universität Göttingen, Götingen, Germany
[9]Christian-Albrechts-Universität zu Kiel, Kiel, Germany
[10]Shizuoka University, Shizuoka, Japan

Nitrous oxide (N_2O) is the most potent greenhouse gas that affects our climate markedly, global warming as well as depletion of stratospheric ozone. Agricultural soils, especially those fertilized with nitrogen (N) are a significant N_2O source globally. However, there are evidences that soil not only produce and emit N_2O but can also act as a N_2O sink by consuming atmospheric N_2O. In the whole biosphere, the only known biological pathway of atmospheric N_2O consumption is microbial reduction of N_2O to N_2 catalysed by nitrous oxide reductase (nosZ) enzyme. ENSINK project aims to understand the ecosystem scale N_2O exchange of a legume-based cropping system at site Anttila, one of the research platforms in Luke Kuopio Maaninka station. To gain the project aims, we will mainly perform microbial analyses (DNA/RNA quantification and sequencing), N_2O pool dilution technique and study the effect of rhizosphere (especially, the root nodules) to the microbial communities associated with N_2O production and consumption. We will focus mainly on understanding the relevance of nosZ (that reduces the N_2O to N_2) by quantifying its activity and diversity in the soil. The data from microbial analysis will be complemented by the N_2O pool dilution experiments, which mainly determines the gross N_2O production and consumption rates. We will also explore the role root nodules by quantifying the activities and microbial communities residing in root nodules and perform the N_2O pool dilution solely on root nodules. We will do laboratory (at LUKE Suonenjoki station) and *in-situ* experiments (at site Anttila) to achieve ENSINK project goals.

On the role of aquatic ecosystems in the greenhouse gas balance of a region

Maria Holmberg[1], Anu Akujärvi[1], Saku Anttila[1], Iida Autio[1], Virpi Junttila[1], Pirkko Kortelainen[1], Annikki Mäkelä[2], Francesco Minunno[2], Katri Rankinen[1], Paavo Ojanen[2], Terhi Rasilo[2], Tapani Sallantaus[1], Pekka Vanhala[1], Martin Forsius[1]

[1]Finnish Environment Institute (SYKE), Latokartanonkaari 11, 00790 Helsinki, Finland
[2]Department of Forest Sciences, P.O. Box 27, 00014 University of Helsinki, Finland

Providing a comprehensive greenhouse gas (GHG) balance of a region involves quantifying fluxes from land cover classes such as forests, fields, peatland, water bodies and the built environment. In a recent study[1], we estimated lakes and rivers to contribute about 7% of the total GHG emissions of a boreal river basin in SW Finland, on the same level as arable land. We calculated the aquatic ecosystems' emissions using area-based coefficients from published studies on fluxes of CO_2 and CH_4 from lakes of different sizes and fluxes of CO_2 from rivers of various width. The total emission of GHGs to the atmosphere from the all lake and river surfaces in the river basin was 0.59 ± 0.10 and 0.54 ± 0.15 Tg CO_2-eq yr^{-1}, respectively. Forests covered about 2/3 of the river basin and provided a considerable carbon sink, about 72% of the river basin's total emissions. The net emissions from all land cover classes amounted to 4.37 ± 1.43 Tg CO_2-eq yr^{-1}. Fluxes of CH_4 mediated by emergent aquatic macrophytes contributed about one tenth of total lake emissions. A small number of lakes (0.2% of the total lake surface area) were invaded by vegetation that covered about 50 to 80% of their area, causing relatively larger CH_4 emissions than from open lakes.

[1]Holmberg et al. 2021. Sources and sinks of greenhouse gases in the landscape: approach for spatially explicit estimates. Science of the Total Environment 146668. https://doi.org/10.1016/j.scitotenv.2021.146668

Carbonyl sulfide as a proxy for photosynthesis

Kukka-Maaria Kohonen[1], Gianluca Tramontana[2], Dario Papale[2,3], Linda Kooijmans[4], Ivan Mammarella[1] and Timo Vesala[1]

[1] Institute for Atmospheric and Earth System Research/ Physics, University of Helsinki, Helsinki, Finland; kukka-maaria.kohonen@helsinki.fi

[2] DIBAF, Department for Innovation in Biological, Agro-food and Forestry Systems, University of Tuscia, Viterbo, Italy

[3] Euro-Mediterranean Center on Climate Change (CMCC), Viterbo, Italy

[4] Meteorology and Air Quality group, Wageningen University and Research, Wageningen, the Netherlands

Traditionally ecosystem scale forest photosynthesis, or gross primary productivity (GPP), is defined from eddy covariance carbon dioxide (CO_2) flux partitioning. While being a well-established method, it comes with deficiencies. Respiration is usually defined from temperature-dependent regressions that are based on nighttime flux measurements. This brings some problems from the assumption that respiratory processes would be the same under solar radiation and without radiation. Also, ecosystem scale flux measurements are not without problems during nighttime.

Lately artificial neural networks (ANN) have been used instead and on top of traditional partitioning methods. ANN uses as input a comprehensive set of drivers and brings an additional data-driven approach for determining GPP and ecosystem respiration without any predetermined assumptions of the drivers.

In recent years, carbonyl sulfide (COS) has been suggested to be a useful proxy for GPP as it shares the same pathway with CO_2 in the leaf stomata but, in contrast to CO_2, is not respired back to the atmosphere. Direct COS flux measurements bring a good and independent GPP estimate when taking into account radiation dependency in leaf relative uptake (LRU) ratio that defines the leaf-scale normalized ratio of COS to CO_2 assimilation rates.

In this study, we examine how the three different GPP estimates compare in different time sclaes from 30 min to yearly scale. We also examine what are the most important environmental drivers in long and short time scales for GPP derived from CO_2 fluxes using traditional partitioning or ANN method and COS flux measurements in a boreal forest in Hyytiälä, Southern Finland. As all methods describe GPP independently and partly different photosynthesis dynamics, analysing the environmental responses gives new insights to carbon uptake processes under varying environmental conditions from daily to yearly scales.

Solving biogenic carbon cycle in urban environments

Liisa Kulmala[1], Elisa Vainio[2], Minttu Havu[2], Leif Backman[1], Laura Thölix[1], Istem Fer[1], Olli Nevalainen[1], Albert Porcar-Castell[3], Anna Lintunen[3], Yann Salmon[3], Yasmin Fruhauf[2], Jesse Soininen[2], Leena Järvi[2]

[1] Finnish Meteorological Institute, Helsinki, Finland; liisa.kulmala@fmi.fi

[2] Institute for Atmospheric and Earth System Research (INAR), Physics, University of Helsinki, Finland

[3] Institute for Atmospheric and Earth System Research (INAR), Forest Sciences, University of Helsinki, Finland

Cities seek solutions to reduce carbon dioxide (CO_2) emissions and to achieve carbon neutrality and therefore, there is an interest in maximizing the carbon sinks of urban vegetation and soil. Current understanding about the carbon sinks is mainly based on knowledge gained at non-urban environments whereas factors driving the biogenic carbon cycle are altered in cities where the temperature is higher, pollution more common and soil water holding capacity usually lowered compared with non-urban areas. Urban trees have typically limited rooting space but less competition aboveground compared with non-urban areas. In addition, management such as mowing, irrigation and removing litter heavily affect the carbon cycle. To accurately estimate urban carbon sequestration, we need to validate carbon cycle models for urban nature. However, observations on urban carbon cycle are still sparse.

In the CarboCity project, we aim to achieve a thorough understanding about atmosphere-plant-soil carbon dynamics in urban areas, and to find the best practices for designing the green areas to maximize biogenic carbon sinks and stocks. In Helsinki, Finland, we measure urban carbon cycle in detail in 2020–2021 in the footprint area of the SMEAR III ICOS station at three sites: garden, urban forest, and street site. The measurements include photosynthesis, sap flow and fluorescence of predominant trees (*Tilia cordata*, *Betula pendula*) and soil respiration, together with several supporting measurements on the weather and on the characteristics of vegetation and soil. Since late 2020, we have also measured carbonyl sulfide exchange at the neighborhood scale, which can be used as proxy for photosynthesis. In addition to the measurements in Helsinki, we will use data from London, Minneapolis-Saint Paul, Beijing and São Paolo – cities that differ in the climate regions, vegetation types, and management of their green areas. Furthermore, the measurements are used in testing and developing land surface models.

GHG mitigation potential of agricultural management practises on mineral and organic soils

Saara E. Lind[1], Marja Maljanen[2], Merja Myllys[3], Mari Räty[1], Sanna Kykkänen[1], Panu Korhonen[1], Maarit Termonen[1], Narasinha Shurpali[1] and Perttu Virkajärvi[1]

[1]Natural Resources Institute Finland (Luke), Maaninka, Finland, saara.lind@luke.fi
[2]University of Eastern Finland, Kuopio, Finland
[3]Natural Resources Institute Finland (Luke), Jokioinen, Finland

Agricultural soils are a significant source of greenhouse gas (GHG) emissions. To study these emissions and their mitigation options, we are currently building three research platforms that consist of full eddy covariance instrumentation for determination of net ecosystem carbon dioxide exchange and fluxes of methane and nitrous oxide at Luke Kuopio Maaninka station (63.14°N, 27.31°E). These platforms will be completed with supporting weather, plant and soil data collection. Two of our platforms are sites on organic soils with a thick peat layer (>60 cm) and the third one is on a mineral soil (silt loam) (Fig. 1). To study the role of the grassland management practices at these sites, we have initiated ORMINURMI-project in 2020. Here, we will characterize the effects of ground water table (high vs. low), crop renewal methods (autumn vs. summer) and plant species (tall fescue-timothy mixture vs. red glover grass-timothy mixture) on greenhouse gas budgets of grass production. Also effect on yield amount and nutrient quality will be determined. In this presentation, we will introduce these research platforms and our coming plans.

Figure 1. Research platforms for greenhouse gas flux studies at Maaninka. Anttila is a 6.4 ha mineral soil field. Both Särkisuo (7 ha) and Pappilansuo (7 ha) fields are on organic soil. The platforms are located within 3 kilometers from each other.

Water loss through tree bark should not be neglected in estimation of forest evapotranspiration in dry conditions

Anna Lintunen[1], Yakir Preisler[2,#], Itay Oz[2], Dan Yakir[2], Timo Vesala[1], Teemu Hölttä[1]

[1] University of Helsinki, Helsinki, Finland; anna.lintunen@helsinki.fi

[2] Weizmann Institute of Science, Rehovot, Israel

[#] Present address: Harvard University, USA

Plants need a protective barrier to avoid water loss. This barrier tissue is cuticle in leaves, and periderm in the bark of woody tree parts. However, the barrier tissues have pores that provide sufficient exchange of CO_2 and O_2 for plant photosynthesis and respiration. These pores are actively regulated stomata in leaves, and passive lenticels in bark. As an example, lenticels cover 1–4% of bark surface in *Picea abies* based on an earlier study. Water loss through bark has been studied little in trees, although the role of water loss through bark could be physiologically important in conditions where stomata in leaves are closed, but lenticels in bark remain open. We measured evaporation and CO_2 emission from needle-bearing shoots and needle-less branch segments of *Pinus halepensis* at irrigated and control plot in semi-arid Yatir forest in Israel from June to November. We found no difference in evaporation through bark between the plots, but there was a clear difference in the bark CO_2 emission indicating that evaporation through lenticels is a passive process with no active regulation. Water loss rate through bark per surface area was typically ~64% of the shoot transpiration rate per leaf area in the control plot (the stomata in the needles were mainly closed), but could equal or even surpass the shoot transpiration rate during the highest evaporative demand. In the irrigated plot, the stomata were open and thus the average transpiration rate per needle area was 42-fold compared to the bark evaporation rate. We conclude that the role of water loss through bark should be considered as one ingredient in forest water balance especially in dry conditions that are estimated to increase in many areas with climate change.

Environmental impacts of cultivated peatland on an acid sulphate soil

Maarit Liimatainen[1,2], Timo Lötjönen[1], Jarkko Kekkonen[1], Anne Tolvanen[1], Hannu Marttila[2], Anna-Kaisa Ronkanen[2], Iida Höyhtyä[1,2], Tung Pham[2], Miika Läpikivi[2], Markus Saari[2], Markku Yli-Halla[3], Liisa Kulmala[4], Annalea Lohila[3,4], Henriikka Vekuri[4], Stephanie Gerin[4], Tuomas Laurila[4], Seija Virtanen[5], Björn Klöve[2,6], Erkki Joki-Tokola[1]

[1] Natural Resources Institute Finland, Oulu, Finland, maarit.liimatainen@luke.fi

[2] University of Oulu, Oulu, Finland

[3] University of Helsinki, Helsinki, Finland

[4] Finnish Meteorological Institute, Helsinki, Finland

[5] Drainage Foundation sr, Helsinki, Finland

[6] Norwegian Institute of Bioeconomy Research, Ås, Norway

Drained peatlands have been under heated public discussion due to their negative environmental impacts. Drainage changes soil moisture conditions, which further alters decomposition, mineralization and soil microbial processes. As a result, greenhouse gas (GHG) emissions and harmful leaching of elements to downstream watercourses are increased. Especially cultivated peatlands and areas with acid sulphate soils have been observed to cause major environmental impacts and therefore there is an urgent need to find sustainable land use solutions to mitigate environmental effects of these managed peatlands.

Ruukki field station (25.00°E, 64.42°N) administered by the Natural Resources Institute Finland (Luke) focuses on producing new information and tools for managing cultivated peatlands. A 26 ha experimental field site (**Fig. 1.**) was established in 2016 to monitor GHG exchange and nutrient leaching from experimental plots. Peat depth ranges from 15 to 75 cm. Typical to the region, it is located on top of acid sulphate soils. GHGs are measured from all 8 plots and drainage waters are collected from 6 plots. The field has been used for agriculture for approximately 100 years, mainly for grass cultivation.

Environmental effects of cultivated peatlands are interdisciplinarily studied at the site by several organizations, each partner having their expertise. Luke is responsible for agricultural management of the site, GHG chamber measurements and collecting drainage water samples as well as examining soil physicochemical characteristics. University of Oulu is studying hydrological processes and provides water flow modelling. Drainage Foundation has contributed in planning of the study field and further studies there. Finnish Meteorological Institute is studying carbon sequestration and N_2O emissions using mainly eddy covariance tower (**Fig. 1.**). As a result of diverse research lines, different experiments carried out in the leaching field produce a holistic view of the options and possibilities to mitigate environmental impacts of cultivated peatlands.

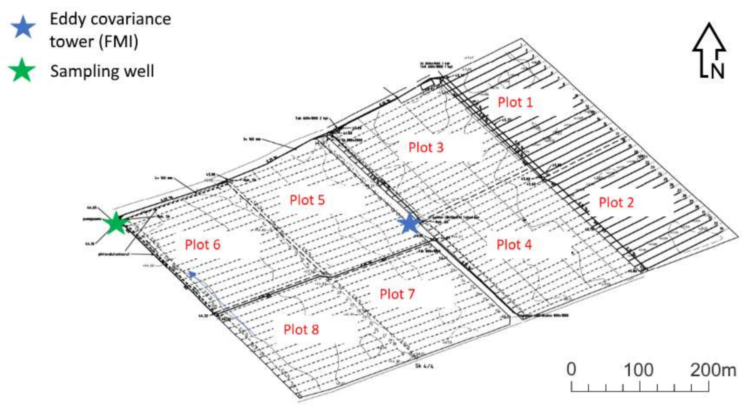


Fig. 1. A map of the experimental field at Ruukki research station showing different plots, location of sampling well where the drainage waters from plots 1-6 are collected and eddy covariance tower (FMI). The area of the whole field is 26 ha and the area of each individual plot is from 2.8 to 3.8 ha.

Using a process-based model to predict multi-layered forest growth, mortality, and regeneration

Man Hu[1*], Francesco Minunno[1], Anu Akujärvi[2], Annikki Mäkelä[1]

[1] Department of Forest Sciences, University of Helsinki, Helsinki, Finland
[2] Finnish Environment Institute SYKE, Biodiversity Centre, Helsinki, Finland
[*] Corresponding author: man.hu@helsinki.fi

Climate change influences the forest management strategies to meet the targets of biodiversity conservation and sustainable forest use. Potential management practices for both purposes include expanding the area of protected forests, lengthening rotations, and thinning intervals or favouring mixed and uneven-aged stands. This places new demands on management-oriented forest models: they need to be applicable to the alternative management scenarios and, consequently, to stands older or more complex than previously. The process-based models have the potential to improve our understanding and prediction of forest growth, but they have been mainly applied to even-aged forests. Therefore, an important step towards simulating the impacts of alternative management strategies is to test the applicability of a particular model for the simulation of untypical forest.

In this study, we used three consecutive measurements from 27 old Norway spruce (*Picea abies* [L.] Karst.) stands to test the performance of a process-based model with a particular interest in multi-layered stands. Specifically, we investigated whether the process-based framework with additional mortality and regeneration modules incorporated is an appropriate approach to simulate the dynamic forest change in a boreal area; and if so, the model should be able to predict forest growth, mortality, and regeneration unbiased. The mortality submodule uses a distance-independent model with the consideration of competition and tree size. The regeneration submodule uses an ingrowth model which predicts the number of trees that exceed the 5 cm dbh threshold during the 5-year period. Furthermore, we evaluate the model by dividing the mean squared error (MSE) into three components by comparing the measurements and model predictions. Ultimately, these analyses generated insights that may inform future process-based model development across the boreal area.

New climate change research platform in Luke Suonenjoki

Johanna Riikonen[1], James Blande[2], Raimo Jaatinen[1], Minna Kivimäenpää[2]

[1] Natural Research Institute Finland, Suonenjoki, Finland; Johanna.riikonen@luke.fi

[2] University of Eastern Finland, Department of Environmental and Biological Sciences, Kuopio, Finland

Boreal forests are important global carbon stocks and sinks. Successful forest regeneration requires availability of high-quality seedling material and a functional forest regeneration chain. Luke Suonenjoki research station offers a platform for studying any stage of the cultivation chain of tree seedlings. The platform includes well-equipped tree seedling nursery, freezer storage, greenhouses, field areas and different controllable growth facilities and laboratories.

An establishment of a new experimental field test area will be started in 2021 in Suonenjoki, in collaboration with the University of Eastern Finland, Department of Environmental and Biological Sciences (Funding: Academy of Finland FIRI 2020, Luke and UEF). The platform will include possibility to control above- and belowground temperature and soil humidity. The purpose of the test area is to provide a platform for studying impacts of climate change on growth and physiology of different plant species. The field site was upgraded in 2019 (exchange of mineral soil, fencing, funded by Academy of Finland) and therefore, it will provide an excellent basis for high-quality experiments on impacts of climate change on above- and belowground processes of tree seedlings and agricultural plants.

Greenhouse Gas Emissions from Agricultural Organic Soils of Boreal and Temperate Zones

Olli-Pekka Siira[2], Henriikka Vekuri[1], Liisa Kulmala[1], Annalea Lohila[1,2]

[1] Finnish Meteorological Institute, Helsinki, Finland; Annalea.Lohila@fmi.fi

[2] Atmospheric and Earth System Research (INAR) University of Helsinki, Helsinki, Finland.

Peatlands store large quantities of organic carbon. When converted into organic agricultural soils, peatlands are usually drained. Pristine peatlands sequester atmospheric carbon dioxide in peat layers. In their natural state, peatlands emit methane. After drainage, peatlands turn from carbon sinks to carbon sources in terms of atmospheric carbon dioxide. In contrast, in terms of atmospheric methane, drained peatlands turn from carbon sources to carbon sinks. The oxidation rate of organic soil carbon is related to water table depth. Therefore, emissions from organic soils are also in some extent related to the water table. Other factors which could affect the variation of the emission rates of organic soils are less known. Nowadays, management of organic agricultural soils plays a larger role in Common Agricultural Policy of European Union than before, because of the implementation of LULUCF Directive.

In a literature review, we focus on organic agricultural soils and try to determine the driving factors that cause variation of greenhouse gas emissions from organic soils. We investigate whether the thickness of the peat layer influences the Net Ecosystem Production (NEP). As a case study, we introduce results of soil respiration analyses from the research site of Ruukki, Northern Finland.

In comparison between histosols in Germany, Denmark, and Finland, German wetland soils with thick peat layers stood out in the principal component analysis. In the preliminary analyses we found nonlinear negative relationship between peat layer thickness and NEP. In Ruukki site, we found significant positive relationship between soil temperature and ecosystem respiration; and significant negative relationship between peat layer thickness and ecosystem respiration, using multilinear regression model. The residual analysis of the linear regression model (soil temperature vs. ecosystem respiration), showed that variations were relatively large in the temperature range from 10 to 20 °C, which indicated that there was an unknown factor which was not included in the parameters tested.

Quantifying the effect of thinning on carbon and water cycles in a managed boreal forest

Toprak Aslan[1], Pasi Kolari[1], Jaana Back[2], Timo Vesala[1,2], Ivan Mammarella[1]

[1] Institute for Atmospheric and Earth System Research (INAR)/Physics, Faculty of Science, University of Helsinki, P.O. Box 68, 00014 Helsinki, Finland; toprak.aslan@helsinki.fi

[2] Institute for Atmospheric and Earth System Research / Forest Sciences, Faculty of Agriculture and Forestry, Latokartanonkaari 7, University of Helsinki, Helsinki, Finland

In the even-aged forestry with initial monoculture stand establishment, 2-3 commercial thinnings and final clear-cutting at the end of the 60-100 year rotation period is the conventional management method. Thinning is a standard silvicultural activity in boreal forests. It is performed primarily to manage between-tree competition and allocate growth-limiting resources (e.g. light, water, nutrients) to the remaining trees and to increase their growth rate and vitality. From biophysical point-of-view, thinning changes tree spacing, number, and size distribution. The altered stand structure and decreased foliage density cause modifications of the microclimate, radiation budget and turbulence characteristics within the canopy. Jointly, these physical constraints change the dynamics of biogeochemical cycles and affect mass and energy exchange between vegetation and the atmosphere. Understanding these changes is of great importance especially for Finland, where the majority of the forests are managed. Hyytiälä forest located in southern Finland was thinned in winter 2020. Here, we present the immediate response (i.e. one year post thinning) to the thinning from biogeochemical point-of-view via examining the eddy covariance fluxes at both ecosystem level (i.e. above canopy measurements) and ground vegetation level (i.e. sub-canopy measurements).

Modelling the management effects on CO2 and CH4 fluxes from peatland forest by the JSBACH-HEMMELI model

Xuefei Li[1*], Maarit Raivonen[1], Tiina Markkanen[2], Antti Leppänen[1], Mika Korkiakoski[1], Annalea Lohila[1], Mikko Peltoniemi[3], Timo Vesala[1] and Tuula Aalto[2]

[1]Institute for Atmospheric and Earth System Research (INAR)/Physics, Faculty of Science, University of Helsinki, P.O. Box 68, 00014 Helsinki, Finland

[2] Finnish Meteorological Institute, Helsinki, Finland

[3]Natural Resources Institute Finland, Helsinki, Finland

[*] xuefei.z.li@helsinki.fi

Management practices on peatland forest affect significantly the water table depth (WTD) and greenhouse gas emissions in the ecosystem. We used the land surface model JSBACH coupled with the process-based methane model HIMMELI, to estimate the dynamics of WTD, soil respiration of carbon dioxide (CO_2) and methane (CH_4) flux from a ditch-drained peatland forest in southern Finland under different management practices (non-harvest, partial-harvest and clear-cut). The field measurements from the study site in Lettosuo, were used to validate the model predictive skills.

Compared with daily observations obtained from automatic chambers at the non-harvest and partial-harvest sites, the model performed well in terms of *RMSE* (Root Mean Square Error; 0.07–0.09 m, 0.60–0.65 µmol m^{-2} s^{-1} and 0.25 – 0.26 nmol m^{-2} s^{-1} for WTD, CO_2 and CH_4, respectively) and *Pearson's r* (Pearson correlation coefficient; 0.82–0.87, 0.91–0.92, 0.67–0.70). At the clear-cut site, the *RMSE* and *Pearson's r* for WTD were 0.06 m and 0.72. The model predicted daily mean soil respiration and CH_4 flux of 0.91–2.18 µmol m^{-2} s^{-1} and 0.56-1.39 nmol m^{-2} s^{-1}, respectively, which were in accordance with the 0.85–2.43 µmol m^{-2} s^{-1} and 0.42–0.51 nmol m^{-2} s^{-1} measured by the manual chambers during two growing seasons. Model showed that although 70% of the stand basal area was harvested, partial-harvest management kept the WTD so low that the peatland forest remained a small CH_4 sink (-0.15 g CH_4 m^{-2} yr^{-1}) while it became a CH_4 source (0.38 g CH_4 m^{-2} yr^{-1}) at the clear-cut site. The soil respiration from the partial-harvest site were higher (1.60 kg CO_2 m^{-2} yr^{-1}) than that from the clear-cut site (1.21 kg CO_2 m^{-2} yr^{-1}) due to the lower WTD.

Our work has successfully simulated the management effects on the CO_2 and CH_4 fluxes from peatland forest. The model modification will further be used with another JSBACH version describing dynamic forest growth and clear-cut cycles that accounts for the impacts of changes of the litter input to the soil carbon status.

Session III: Scaling - how to use measurements for modeling at different scales

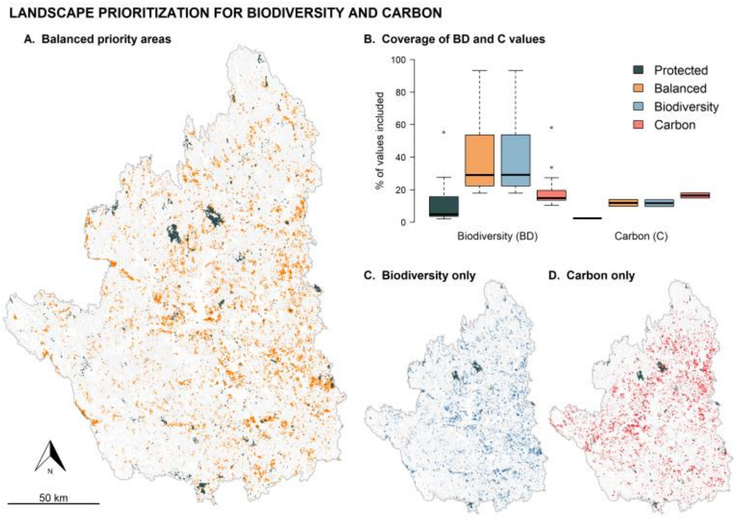
Spatially explicit modelling of combined biodiversity and carbon benefits

Martin Forsius[1] and IBC-Carbon project team[2]

[1] Finnish Environment Institute, Helsinki, Finland; martin.forsius@syke.fi

[2] www.ibccarbon.fi

The challenges posed by climate change and biodiversity loss are deeply interconnected. Successful co-managing of these tangled drivers requires methods that can prioritize and target management actions against multiple criteria, while also enabling cost-effective land use planning and impact scenario assessment. We have developed and applied an integrated multidisciplinary modelling and evaluation framework for carbon and biodiversity in forest systems. By analysing and spatio-temporally modelling carbon processes and biodiversity elements, we determine an optimal solution for their co-management in the study landscape. We also describe how advanced Earth Observation measurements can be used to enhance mapping and monitoring of biodiversity and ecosystem processes. The scenarios used for the dynamic models were based on official Finnish policy goals for forest management and climate change mitigation. The development and testing of the system were executed in a large region in southern Finland (Kokemäenjoki basin, 27 024 km^2) containing highly instrumented LTER stations; these LTER data sources were complemented by fieldwork, remote sensing and national data bases. In the study area, estimated total net emissions were currently 4.2 TgCO_2eq a^{-1}, but modelling of forestry measures and anthropogenic emission reductions demonstrated that it would be possible to achieve the stated policy goal of carbon neutrality by low forest harvest intensity. We show how this information can be further utilised for optimal allocation of set-aside forest areas for nature conservation, which would significantly contribute to preserving both biodiversity and carbon values in the region. Biodiversity gain in the area could be increased without a loss of carbon-related benefits.



Forsius, M., Kujala, H., Minunno, F., Holmberg, M., Leikola, N., Mikkonen, N., Autio, A. Paunu, V-V., Tanhuanpää, T., Hurskainen, P., Mäyrä, J., Kivinen, S., Keski-Saari, S., Kosenius, A-K., Kuusela, S., Virkkala, R., Viinikka, A., Vihervaara, P., Akujärvi, A., Bäck, J., Karvosenoja, N., Kumpula, T., Kuzmin, A., Mäkelä, A., Moilanen, A., Ollikainen, M., Pekkonen, M., Peltoniemi, M., Poikolainen, L., Rankinen, K., Rasilo, T., Tuominen, S., Valkama, J., Vanhala, P. and Heikkinen, R.K. 2021. Developing a spatially explicit modelling and evaluation framework for integrated carbon sequestration and biodiversity conservation: Application in southern Finland. *Science of The Total Environment*, 775: 145847, https://doi.org/10.1016/j.scitotenv.2021.145847

Evaluating modelled wetland methane emissions in Northern Europe

Tuula Aalto[1], Aki Tsuruta[1], Eleanor Burke[2], Sarah Chadburn[3], Yao Gao[1], Vilma Kangasaho[1], Thomas Kleinen[4], Hanna Lee[5], Antti Leppänen[6], Sebastian Lienert[7], Tiina Markkanen[1], Paul Miller[8], Jurek Mueller[7], Jarmo Mäkelä[6], Daniele Peano[9], Olli Peltola[1], Maarit Raivonen[6], Maria Tenkanen[1], David Wårlind[8], Sönke Zaehle[10]

1 Finnish Meteorological Institute, Helsinki, Finland (tuula.aalto@fmi.fi)
2 Met Office Hadley Centre, Exeter, UK
3 University of Exeter, Exeter, UK
4 Max-Planck-Institute for Meteorology, Hamburg, Germany
5 NORCE Norwegian Research Centre AS, Bjerknes Centre for Climate Research, Bergen, Norway
6 University of Helsinki, Helsinki, Finland
7 Climate and Environmental Physics, Physics Institute, University of Bern, Bern, Switzerland
8 Department of Physical Geography and Ecosystem Science, Faculty of Science, Lund University, Sweden
9 Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, CSP, Bologna, Italy
10 Max-Planck-Institute for Biogeochemistry, Jena, Germany

Wetlands are a large source of methane, which is the second most important greenhouse gas. Temperature and soil water conditions control the methane emissions from wetlands. Precipitation is the primary environmental driver for soil water dynamics during the boreal zone growing season, and the effects are seen immediately on top soil moisture and after a few days or weeks delay on soil water table levels. It is necessary to study how air temperature and precipitation control the wetland methane emissions in order to make better predictions of the responses to climate change. Here we focused on a wetland-rich region in boreal Northern Europe, and compared the wetland process models (JSBACH-HIMMELI, LPX-BERN, LPJ-GUESS, JULES, CLM4.5, CLM5, and a multi-model mean from the Global Carbon Project) to atmospheric inversions of methane (Carbon Tracker Europe - CH4) and up-scaled eddy covariance flux results. Some of the wetland process models were also used as priors in the inversion in order to find out how the inversion attempts to change the temperature and precipitation responses in the posterior. The process models showed strong temperature as well as strong precipitation responses for the region, and the month of maximum emissions ranged from May to September. However, multi-model means, inversions and up-scaled eddy covariance flux observations agreed on the month of maximum emissions, and had rather balanced temperature and precipitation responses. When two models with contrasting response patterns were used as priors to inversion, the inversion attempted to move emissions of both in posterior towards co-limitation of temperature and precipitation. It is therefore important to pay attention on the climate driver responses of the wetland models, and on the set-up of the models for the northern regions.

Modelling seasonal cycle of atmospheric $\delta^{13}C$-CH_4 and their evaluations with $\delta^{13}C$-CH_4 observations

Vilma Kangasaho [1] , Aki Tsuruta [1] , Leif Backman [1] , Sander Houweling [2, 3] , Maarten Krol [2,4,5] , Wouter Peters [4,6] , Ingrid Luijkx [4] , Sebastian Lienert [7] , Fortunat Joos [7] , Edward Dlugokencky [8] , Sylvia Michel [9] , James White [9], Rebecca Fisher [10] and Tuula Aalto [1]

[1] Finnish Meteorological Institute, Finland; vilma.kangasaho@fmi.fi

[2] SRON Netherlands Institute for Space Research, the Netherlands

[3] Vrije Universiteit Amsterdam, Netherlands

[4] Wageningen University & Research, Meteorology and Air Quality, the Netherlands

[5] IMAU, Utrecht University, the Netherlands

[6] University of Groningen, Centre for Isotope Research, the Netherlands

[7] University of Bern, Climate and Environmental Physics, Switzerland

[8] NOAA/ESRL, Global Monitoring Division, USA

[9] INSTAAR, University of Colorado, USA

[10] Royal Holloway, University of London, UK

The atmospheric burden of methane (CH_4) has more than doubled since the pre-industrial era. Currently the abundance of CH_4 in the atmosphere is well known, but the magnitude of emissions from different source sectors including natural and anthropogenic are uncertain. Most CH_4 source have process specific $\delta^{13}C$-CH_4 values, which can be used to broadly identify source sectors and to better understand the changes in atmospheric CH_4 abundance before and after 2006.

This study examines the seasonal cycle of atmospheric $\delta^{13}C$-CH_4 in recent decades by modelling atmospheric CH_4 and $\delta^{13}C$-CH_4 using the TM5 atmospheric transport. TM5 is driven by ECMWF ERA-Interim meteorological fields, and uses pre-calculated OH-fields and reaction rates with Cl and $O(^1D)$ to account for the CH_4 sink processes in the atmosphere. We modified the seasonal cycles of both emissions and atmospheric chemistry sink to investigate the effect to seasonality at different latitudes.

Simulations with modified emissions and sinks are then compared to global observations of atmospheric CH_4 and $\delta^{13}C$-CH_4, provided by NOAA's GMD, the INSTAAR and Royal Holloway, the University of London. By evaluating model results to observations, we can validate how well the model is able to simulate the seasonality of atmospheric $\delta^{13}C$-CH_4. The simulations also provide information on how different emission and sink components influence the seasonality of atmospheric $\delta^{13}C$-CH_4.

Constraining the belowground methane cycle in peatlands with dual isotope analysis

Lukas Kohl, University of Helsinki, Department of Agricultural Sciences

Peatlands are important natural sources of methane whose emissions are likely to increase under a warmer climate. This has led to development of complex process models to simulate the concurrent production and consumption of methane in peatland soil. These models, however, are typically only validated against surface fluxes, which leave us unable to validate how individual below-ground processes are mathematically described and parameterized.

Methane production, transport, and consumption all shape its stable isotope ratios, and can thus provide complementary information about e.g., the source processes responsible for methane formation and the extent of re-oxidation prior to sampling. This is commonly applied using methane and CO2 13C/12C ratios. Such analysis, however, is limited by the multiple processes that influence this isotope ratio (production pathway, re-oxidation, diffusion). Adding a second isotope system (D/H) can alleviate this problem,as D/H isotope ratios are less affected by physical processes like diffusion and provide information complementary to 13C/12C ratios.

In this presentation, I will focus on methane dual-isotope test measurement conducted at the Lompolojänkkä site in September 2020. At this site, 13C/12C and D/H values imply the dominance of acetoclastic methanogenesis and the re-oxidation of approximately 10% of methane prior to reaching the surface. These measurements also showed a distinct difference in 13C/12C ratios of methane emitted through the soil surface and from carex shoots, which can be used to estimate the contribution of plant transport to overall methane emissions at the site level.§

DOMINANT DRIVERS OF CH_4 AND CO_2 EMISSIONS OVER MULTIPLE TIMESCALES IN A BOG-FEN COMPARISON

Laurel Larsen[1,2], *Eeva-Stiina Tuittila*[1], *Janne Rinne*[3], *Aino Korrensalo*[1], *and Elisa Mannistö*[1]
[1] University of Eastern Finland, Joensuu, Finland
[2] University of California, Berkeley, USA
[3] Lund University, Lund, Sweden

Contact: laurel@berkeley.edu

Boreal peatlands are an important global reservoir for carbon and potentially involved in a positive feedback with climate warming. Nonetheless, the nature of this feedback is poorly understood. Many factors interact nonlinearly and over multiple timescales with the effects of climate warming and its potential to increase respiration, including changes in precipitation and water level, as well as changes in organic matter production and evapotranspiration, as mediated by specific vegetation species. Hypotheses about controls on carbon fluxes may be difficult to test with standard linear statistical techniques, due to the nonlinear and potentially threshold-like behavior of the putative processes.

Here we evaluate ten years (2005-2014) of carbon flux data from a flux tower in the Siikaneva fen in southern Finland. We apply mutual information and transfer entropy analyses to quantify information flows among monitored variables, over the time series as a whole and over more localized time periods. These analyses quantify the extent to which knowledge of a “source” variable reduces uncertainty in (i.e., “drives”) the behavior of a “sink” variable (e.g., CH_4, CO_2) but do not presume the functional form of that relationship.

Overall, the measured variables reduced more uncertainty in CO_2 fluxes compared to CH_4 fluxes. As anticipated, temperature served as the dominant driver of long-term CH_4 and CO_2 fluxes in both the bog and fen. However, once seasonal variability was removed, gross primary productivity (GPP) emerged as the dominant driver of short-term fluctuations in fluxes of both gases. In the bog, provisioning of soil microbes with fresh exudates appeared to be the dominant process through which GPP influenced CH_4 fluxes, while in the fen, bypassing of the aerobic zone by CH_4 emitted through aerenchyma during evapotranspiration appeared to be the dominant mechanism. Short-term CH_4 fluxes were also more sensitive to temperature fluctuations when water tables were low. For both CO_2 and CH_4 fluxes, differences in driving processes between the box and fen were attributable primarily to differences in vegetation canopy, the relative abundance of aerenchymatous species in the fen, and the lower nutrient status of the bog.

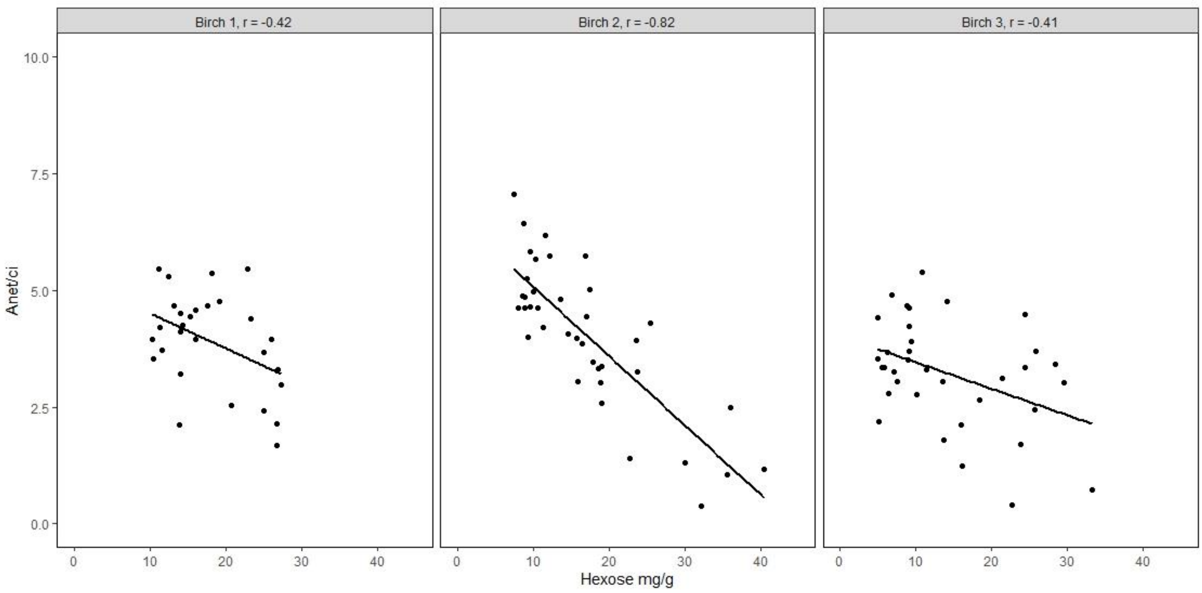
The interactions of non-structural carbohydrates, nitrogen, and water status with leaf gas exchange and phenology of silver birch (Betula pendula Roth.)

Manqing Tian[1], Teemu Hölttä[2], Yann Salmon[3], Anna Lintunen[4]

[1, 2] Department of Forest Sciences, University of Helsinki, Helsinki, Finland; manqing.tian@helsinki.fi

[3, 4] Institute for Atmospheric and Earth System Research (INAR), University of Helsinki, Helsinki, Finland

Abstract: Non-structural carbohydrates (NSC) are photosynthetic products, which also acts as a feedback on regulating leaf photosynthesis and tree phenology together with nitrogen and water. Gas exchange between the leaves and the air (leaf gas exchange) occurs via stomata. Silver birch is a deciduous tree species which is adapted to the boreal climatic conditions, seasonal changes in leaf NSC content are important for silver birch to balance between phenological processes and photosynthetic capacity. How external environmental factors such as light, air temperature, humidity and CO2 concentration control the stomatal opening and photosynthesis have been well studied, however, endogenous controlling factors have been studied much less. We have a 2-year continuously leaf gas exchange measurements together with leaf NSC content, water status and nitrogen content under a natural field condition at SMEAR II forest station. The primary results show that sucrose and starch content of birch leaves decreases in the autumn, on the contrary, hexose content increases dramatically. A strong negative correlation between hexoses and photosynthesis capacity is seen whereas the relationship between sucrose, starch and nitrogen content against photosynthesis capacity is positive. All current results indicate that the accumulation of sucrose, nitrogen and starch is able to promote silver birch photosynthesis in spring and summer, however, accumulation of hexose can decrease photosynthesis capacity and induce leaf senescence.



Using SAR-based spatiotemporal estimates of soil moisture to calibrate a spatially distributed hydrological model

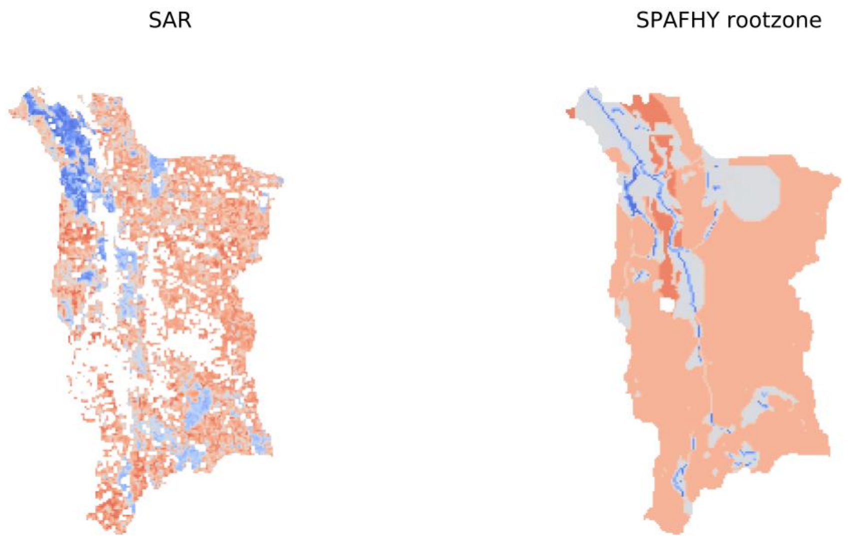
Jari-Pekka Nousu[1,2], Samuli Launiainen[2], Hannu Marttila[1], Pertti Ala-aho[1], Kersti Leppä[2], Terhikki Manninen[3]

[1] Water, Energy and Environmental Engineering Research Unit, University of Oulu, Finland

[2] Bioeconomy and Environment, Natural Resources Institute Finland, Helsinki, Finland

[3] Finnish Meteorological Institute, Helsinki, Finland

Surface soil parameters, especially soil moisture has a key role in soil nutrient cycling, greenhouse gas emissions, vegetation water use as well as energy and water exchanges between land and the atmosphere. In this study, we use Synthetic Aperture Radar (SAR) soil moisture maps to develop and calibrate a spatially distributed hydrological model Spatial Forest Hydrology (SpaFHy) in a subarctic Pallas catchment covered by boreal forests and peatlands. SAR images have been commonly used to monitor soil parameters in large areas, especially in agriculture with no canopy cover. Thanks to the sensitivity of SAR signal to soil water, it is well suited to estimate the topsoil moisture. However, different topographic and vegetation settings create challenges for SAR signals to capture the properties of soil, and thus, SAR soil moisture estimates have not been as widely used in forested areas. The increasing amount of open access high resolution GIS data together with remote sensing products and other environmental data forms a solid platform for testing and developing spatially distributed models in the fields of land surface and hydrological modelling. Such spatial models can be used to upscale point-scale processes to e.g. catchment scale. The modular modelling framework of SpaFHy allows us to develop the model to better capture the soil moisture dynamics found in SAR images. We demonstrate the value of these spatiotemporal datasets to upscale processes regulating soil moisture conditions to spatially distributed models. Furthermore, the potential for such datasets to be used in data assimilation routines of operational hydrological models is identified.



Tree root turnover rates are affected by soil conditions

Tapani Repo[1], Timo Domisch[1], Jouni Kilpeläinen[1], Tarja Lehto[2], Sirpa Piirainen[1], Leena Finér[1]
[1]Natural Resources Institute Finland (Luke), Natural Resources, Joensuu
[2]University of Eastern Finland, School of Forest Sciences, Joensuu

Forest ecosystem models demand knowledge of tree-derived belowground carbon sequestration and storage. Tree roots have a key role in this process since a high proportion of the annual net assimilation is projected to roots, and especially to the short-living fine roots with high turnover rates (1). There is strong uncertainty how the turnover rate of different tree species is affected by soil conditions, e.g. temperature, moisture, fertility and aeration (2), all factors that have strong seasonal, as well as latitudinal and longitudinal variation within the boreal zone.

In the Joensuu root laboratory (3), we have carried out a series of experiments where we manipulated the soil conditions at different stages of the annual cycle of trees (4,5,6,7,8). Using minirhizotron imaging we assessed the fine root longevity (inverse of the turnover rate) separately for short roots (first order) and long roots (higher than the first order), and how it is affected by waterlogging and soil freezing during dormancy (4,8), and by waterlogging and different soil temperatures during the growing season (5,6,7). In the presentation, a summary of the estimates for the longevities in different conditions are given. In addition, the results of the laboratory experiments are discussed in relation to the root longevities in the field conditions.

References

1. Helmisaari H-S et al. 2002. For Ecol Manag 165: 317–326. https://doi.org/10.1016/S0378-1127(01)00648-X
2. Repo T et al. 2014. For Ecol Manag 313: 112–122. http://dx.doi.org/10.1016/j.foreco.2013.11.002
3. Finér L et al. 2001. Plant Soil 231: 137-149.
   http://www.springerlink.com/content/v75m335u6236q6kg/fulltext.pdf
4. Roitto M et al. 2019. Tree Physiol 39: 805-818. https://doi.org/10.1093/treephys/tpz003
5. Kilpeläinen J et al. 2019. Can J For Res 48: 1441-1452. https://doi.org/10.1139/cjfr-2019-0190
6. Domisch T et al. 2020. Tree Physiol 40: 869-885. https://doi.org/10.1093/treephys/tpaa036
7. Repo T et al. 2020. Can J For Res 50: 510-518. https://doi.org/10.1139/cjfr-2019-0163
8. Repo T et al. 2021. Tree Physiol (in print). doi.org/10.1093/treephys/tpab002

ABSTRACT FOR FINNISH ECOSYSTEM SCIENCE MEETING: ICOS, ELTER AND ANAEE NETWORKS

BLOCK OF SCALING - HOW TO USE MEASUREMENTS FOR MODELING AT DIFFERENT SCALES

TITLE: Design and validation of a new technique for estimating canopy parameters: UAS-based spherical (360°) photography describing the forest canopy from inside.

AUTHORS: Vicent Agustí Ribas Costa, Jon Atherton, Albert Porcar-Castell, Thomas Matthew Robson.

ABSTRACT: Canopy light environment parameters such as the Leaf Area Index (LAI) are used to model carbon assimilation and storage at the ecosystem level. Direct or indirect methods can be used to obtain LAI, and related parameters such as Leaf Area Density and clumping indices. Direct measurements are destructive and usually neither logistically nor economically viable, consequently indirect approaches are typically applied. Optical methods are the most used, including digital hemispherical photography, which is an ICOS ancillary vegetation measurement. Hemispherical photography consists in taking photos with a single reflex lens (SLR) camera and a wide-angle lens, from the ground looking upwards to the canopy. Very recently, a new technique using spherical photography has been developed. Spherical photography provides a 360° view of the canopy and is not restricted to SLR systems, as images are stitched together using computational methods to render the extended field of view. In this study, we analysed the potential of drone-based spherical imagery to estimate Plant Area Index (PAI). This new approach was very suitable for taking spherical images and it was feasible to fly through the canopy creating PAI transects. As a result we could obtain vertical profiles of PAI and Plant Area Density from spherical images at different heights of a spruce stand in Helsinki.The results of drone-based spherical imagery and validation data from traditional digital hemispherical photography on the ground were highly correlated (R^2 = 0.89). We are currently identifying the sources of the deviation between the two methodologies, to isolate projection, resolution and exposure errors. Overall, compared to classical digital hemispherical photography, drone-based spherical imagery gave very good results and we found this approach very promising for future quick accurate PAI measurements in forest canopies.

Northern High Latitudes' Methane Emissions: Cold Season And Permafrost

Maria Tenkanen[1], Aki Tsuruta[2], Kimmo Rautiainen[2], Jurek Müller[3], Fortunat Joos[3], Tuula Aalto[2]

[1] Finnish Meteorological Institute, Helsinki, Finland; maria.tenkanen@fmi.fi

[2] Finnish Meteorological Institute, Helsinki, Finland

[3] University of Bern, Bern, Switzerland;

The high northern landscape is dominated by forest and peatlands in which a quarter of the landmass is underlain by permafrost. This permafrost withholds up to 60 % of the world's soil carbon which, due to climate change, could be released into the atmosphere as methane, a greenhouse gas which is tens of times more powerful as carbon dioxide.

In addition to the permafrost, the seasonality is an important characteristic of the northern wetland methane emissions: the emissions are high in summer when the soil is thaw and moist and low in winter when the soil is frozen. Still, the emissions are non-zero during the cold season (from soil freezing to thawing), and also large burst of methane have been observed during the soil freezing and thawing. Even though, the methane flux during the cold season is small compared to the summer flux, the cold season might cover a large part of the year in high northern latitudes and thus, the cold season emissions might add up and be a significant part of the yearly total emissions. Due to the lack of flux measurement during the cold season, these cold season methane emissions still have high uncertainties.

With the help of in-situ measured methane mole fractions, including those from the ICOS stations, we estimate the methane emissions in the northern wetlands with the inversion model CarbonTracker Europe – CH_4 (CTE-CH_4). Our study concentrates on the cold season methane emissions, and also how the mole fraction measurements can be used to study effects of underlying permafrost on the methane emissions.

Application of ground-based atmospheric CH_4 data for estimation of global and regional CH_4 fluxes based on atmospheric inversion

Aki Tsuruta[1*], Tuula Aalto[1], Leif Backman[1], Tuomas Laurila[1], Juha Hatakka[1], Hannakaisa Lindqvist[1], Janne Hakkarainen[1], ICOS team, H2020 VERIFY team

[1] Finnish Meteorological Institute, Helsinki, Finland; *aki.tsuruta@fmi.fi

Atmospheric inverse models can be used to infer information from atmospheric greenhouse gas (GHG) observation data to estimate global and regional GHG fluxes. The model is based on a Bayesian probability theory, widely applied with variety of Bayesian methods, atmospheric transport models used as an observation operator, and input data. In contrast to bottom-up methods such as process-based models and statistical based inventories, the inverse models can estimate the total fluxes which are consistent with the atmospheric data. Therefore, regional budgets, trends and seasonal cycles driven from the inverse models help better understand the discrepancies and missing information in the current GHG flux estimates from those bottom-up methods.

In this study, we present an example of such inverse models, CarbonTracker Europe - CH_4 (CTE-CH_4), where global and regional methane (CH_4) fluxes are estimated from ground-based and satellite atmospheric CH_4 data. CTE-CH_4 optimises fluxes based on an ensemble Kalman filter, and the global Eulerian atmospheric transport model TM5 is used as an observation operator. As a priori flux fields, the CH_4 fluxes from natural (e.g wetlands, biomass burning, soil sinks) and anthropogenic (e.g. fossil fuels, agriculture, landfills) sources are taken into account, where estimates from process-based models and inventories are used. We show that the ICOS atmospheric CH_4 data can be used for constraining and evaluating flux estimates derived from the model and satellite data.

Session IV: Lateral element transport between ecosystems and fluxes across boundaries

Understanding interacting dynamics of hydrology, carbon cycle and greenhouse gas fluxes in Arctic watersheds

Kaisa-Riikka Mustonen[1], Hannu Marttila[2], Kaisa Lehosmaa[3], Iina Koivunen[3], Jeffrey Welker[3,4], Annalea Lohila[5,6], Jussi Jyväsjärvi[3]

[1]Ecology and Genetics Research Unit, University of Oulu, Finland; **kaisa.mustonen@oulu.fi**
[2]Water Resources and Environmental Engineering Research Unit, University of Oulu, Finland
[3]Ecology and Genetics Research Unit, University of Oulu, Finland
[4]Department of Biological Sciences, University of Alaska Anchorage, USA
[5]INAR Institute for Atmospheric and Earth System Research, University of Helsinki, Finland
[6]Finnish Meteorological Institute, Climate System Research, Helsinki, Finland

Carbon -water interactions are critical components of Arctic freshwater ecosystems. Dissolved organic matter (DOM) is the basis for in stream biological processes and is the foundation of biogeochemical linkages between terrestrial and aquatic landscapes and between the river bodies and the atmosphere via outgassing. Quantity and quality of DOM is strongly related to the microbial communities, as microbes play an important role in the freshwaters biochemical cycle converting DOM into nutrients, and mineralizing carbon into carbon dioxide (CO_2) and methane (CH_4). Despite the importance of streams in carbon cycle, Arctic streams are under-represented in global atmospheric GHG emission estimates owing to a lack of measurements in Arctic conditions. In this study we used combination of multiscale measurements to quantify carbon availability (DOC/DIC concentrations) and quality (water absorbance, $SUVA_{254}$ index), water sources (stable H_2O isotope proxies), microbial community structure (rRNA sequencing), and CO_2 and CH_4 fluxes and concentrations. Our study site is typical groundwater influenced peatland dominated second order watershed located at Pallas-Yllästunturi National Park. Sampling was conducted three times during summer 2019 at 21 locations along the stream gradient. Preliminary results indicate that all sampling sites were constant sources of CO_2 and CH_4 to the atmosphere. Lowest CO_2 fluxes but highest concentrations were measured at groundwater influenced sites, whereas highest CH_4 concentrations seemed to be focused on the same locations as highest CH_4 fluxes. Microbial contribution to carbon dynamics was evident as increased DOC loads due to late spring snowmelt dominated runoff from surrounding peatland was mineralized and DIC amount increased towards midsummer, which is also supported by higher CO_2 concentrations in July compared to June. Catchment wide studies conducted in Arctic and Boreal regions including interactions between aquatic and terrestrial ecosystems are especially needed today as northern areas are experiencing unprecedented extreme warming, precipitation changes and shifting snow depths.

Methane flux measurements by EC on lake Pallasjärvi during ice-off

Joonatan Ala-Könni[1], Ivan Mammarella[1]

[1] Institute for Atmospheric and Earth System Research (INAR)

Boreal lakes emit a large fraction of their total annual budged of carbon into the atmosphere during ice-off, when all the gases accumulated in the lake over the winter are released during a short and intense period of mixing. Finnish Meteorological Institute (FMI) has been operating an eddy covariance site on northern boreal lake Pallasjärvi for over six years now, and last summer it was updated with a Contros methane sensors to measure the flux of methane from the lake as well. Our research on the site is aimed at quantifying gas fluxes out of the lake during ice-off and thus understanding the carbon dynamics of seasonally ice covered lakes better in general. EC measurements are supplemented by a thermistor chain, PAR sensors and surface water pCO2 measurements to bring out a more holistic picture of the effects of stability, mixing and primary production on the fluxes. Spring 2021 is the first melting period measured by the new setup, and preliminary results can be expected after ice-off.

Decline of aquatic macro invertebrates as a consequence of water browning

Céline Arzel [1 &2], Clarisse Blanchet [1&2], Petri Nummi[2], Lauri Arvola[3], Hannu Pöysä[4], Aurélie Davranche[5], Martti Rask[3], Mikko Olin[6], Sari Holopainen[2], Risto Viitala[7], Eeva Einola[8] and Sanni Manninen-Johansen[8].

[1] Department of Biology, University of Turku, Finland; celine.arzel@utu.fi

[2] Department of Forest Sciences, University of Helsinki, Helsinki, Finland

[3] Lammi Biological Station, University of Helsinki, Lammi, Finland

[4] Natural Resources Institute Finland (Luke), Joensuu, Finland

[5] LETG-UMR CNRS 6554, University of Angers, Angers, France

[6] Natural Resources Institute Finland (Luke), Helsinki, Finland

[7] HAMK University of Applied Sciences Evo Campus, Evo, Finland

[8] Vanajavesi Center, Hämeenlinna, Finland

Abstract text.

Surface waters are becoming browner throughout the Northern hemisphere and beyond. While the reasons behind this process are still not completely understood, it was proved that changes in soil chemistry due to past acid rain, increased precipitation due to climate change and land use practices are factors promoting water browning by increasing the release of dissolved organic matter and other components in run off. We are providing evidence that the brownification process is altering the biodiversity, structure and functioning of aquatic ecosystems. Our study location is the Evo Natura 2000 area, Southern Finland (61°120N, 25°070E). It has a long history of research projects in forestry and environmental sciences. Long term surveys of water quality, flora and fauna have been conducted at several lakes providing a rigorous field knowledge. We tested the link between lake water color and aquatic invertebrate parameters. We established that water colour has increased in the area over the past three decades. We linked the invertebrate abundance dramatic decrease to brownification. Aquatic invertebrates are key components of the aquatic food web. Thus, our result leads to concerns especially for species which are foraging on them, such as fish and waterbirds.

This presentation is based on the results published in: Arzel C., Nummi P., Arvola L., Pöysä H., Davranche A., Rask M., Olin M., Holopainen S., Viitala R., Einola E. and Manninen-Johansen S. Science of the Total Environment. Invertebrates are declining in boreal aquatic habitat: the effect of brownification? 724, 138199.

Identifying factors driving water browning of lakes in a Finnish forest landscape

Clarisse BLANCHET[1,2]

[1] Department of Biology, University of Turku, FI-20014 Turku, Finland

[2] Department of Forest Sciences, University of Helsinki, P.O. Box 27, FI-00014 Helsinki, Finland

Abstract:

Brownification, i.e. change in water colour towards a yellow-brown colour, occurred in many surface waters in the boreal environment in the last decades. It is a well-known fact that water colour is strongly related to dissolved organic matter (DOM) or carbon (DOC) of terrestrial origin. However, factors driving their transfer to waters are still to be fully understood. The aim of this research was to highlight mechanisms controlling the browning of lakes in the Evo area, Southern Finland. I investigated the contribution of beaver impoundments, lake cover and forestry practices to brownification. This study had two approaches: one at the scale of a lake catchment with accurate forestry data on the long-term, and one at a larger scale (several catchments) with less accurate forestry data on a shorter term, i.e. based on tree canopy cover.

At the large scale, the number of upstream lakes and clearcutting surface in a catchment significantly influenced water colour between 2011 and 2017. The more upstream lake there is in a catchment, the less coloured the lake is, which indicates DOM retention along the lake chain. Moreover, clearcutting activity was correlated to lake water colour increase, showing that forestry practices substantially contribute to the transfer of DOM to surface waters, hence browning.

At the scale of one lake, beaver-flood disturbance was the main factor influencing changes in water colour between 1993 and 2018. Water colour of the lake was systematically higher when the lake was in a flood phase (less than three years after a beaver flood). This demonstrates the potential of beavers to modify the biogeochemistry of waterbodies to such level that it overrides and hides the effect of other potential drivers.

Further research is needed to tell apart the effect of natural and anthropogenic catchment disturbances and parameters on changes in water colour.

From landscape to field scale and lab level with new water research infrastructure at Luke Kuopio Maaninka research station

Perttu Virkajärvi[1], Mari Räty[1], Pauliina Taimisto[1], Jorma Heikkinen[1] and Kirsi Järvenranta[1]

[1]Natural Resources Institute Finland, Maaninka, Finland, perttu.virkajarvi@luke.fi

The focus here is on nutrient losses from ruminant and crop production in eastern Finland. With the existing and newly build research platforms, we can study the losses at the catchment level, field level and laboratory level. Kirmajärvi is a small, 3.2 km^2 agricultural and forested catchment where the land use is typical to North-Savo area. On Kirmanjärvi catchment area there will be possible to monitor the discharge, water quality and nutrient loss dynamics in two points along a drainage system. In addition, a surface runoff and lysimeter field at the Maaninka station allows us to study both the surface and drainage flow at 16 different plots of 60 m^2 each with varying agricultural treatments. The samplings will be automated and information on discharge and water quality will be recorded. Finally, at the smallest scale, undisturbed top-soil mats of 0.25 m^2 are removed from the interested field and transferred to the SIMU chamber, where temperature, light, precipitation, and snow conditions can be controlled while collecting the discharge automatically. In the future, we will also be able to house monolith samples (Ø 16 cm, height 40 cm) and run similar studies as with topsoil samples.

With this infrastructure, we can study losses of dissolved organic carbon and nutrients, losses related to fertilizer use (type, timing, amount) and climatic factors as well as compare differences between perennial and annual cultivation systems. In this presentation, we will introduce these three research infrastructure platforms and our ongoing work.

Figure 1. Building of the new surface runoff and lysimeter field at Luke Kuopio Maaninka station. It contains 16 individual study plots. The field will be in test use during summer 2021.

Using ^{13}C isotope tracer to study how sink limitation affects *Betula pendula* sugar translocation

Xin Zhuang[1,2], Teemu Paljakka[1], Morgane Merlin[1], Teemu Hölttä[1], Yann Salmon[1]

[1]University of Helsinki, Helsinki, Finland
[2]xin.zhuang@helsinki.fi

In plants, photoassimilates are mainly produced by leaf mesophyll, and translocated through phloem. The driving force of phloem mass flow is generally seen as an osmotically generated pressure gradient, caused by sugar loading at the C source and unloading at the C sink. However, mechanistic understanding of loading-transport-unloading processes and the influence of carbon sink strength on phloem transport remains understudied.

We aim to understand the effects of sink limitation on canopy gas-exchange and phloem transport by first applying 4°C cooling treatment to silver birch (*Betula pendula*) sapling root systems to decrease sink activity. We used ^{13}C-enriched CO_2 pulse labelling to trace sugar transport. To measure phloem velocity and lateral unloading, we tracked the ^{13}C enrichment in different tissues and at different axial positions along the stem by measuring stem CO_2 efflux in-situ with an isotope and gas concentration analyzer (Picarro), and by sampling phloem sap and tissues for measurment with a $\delta^{13}C$ isotope-ratio mass spectrometry ex-situ. CO_2 assimilation rate in photosynthesis, along with osmotic potential was also measured on canopy leaves.

By tracing $^{13}CO_2$ of stem bark respiration and leaf/phloem sap ^{13}C-sugar, our initial results show a typical pattern of the after-pulse ^{13}C enrichment: A $^{13}CO_2$ peak of stem respiration usually comes 1-2 days after the pulse. Compared with control saplings, the $^{13}CO_2$ peak came 18-30 hours later on the soil-cooled saplings, indicating a slower carbon transport velocity under sink limitation. Leaf gas exchange results show that the assimilation rate of control saplings leaves was significantly higher than that of soil-cooled ones, suggesting that weakened sinks might debilitate possibly by slowing down the unloading process.

Modelling of long term brownification process in Southern Finland

Katri Rankinen[1], Maria Holmberg[1], José Cano Bernal[1] and Anu Akujärvi[1]

[1] Finnish Environment Institute, Helsinki, Finland; katri.rankinen@syke.fi

Browning of surface waters due to increased terrestrial loading of organic carbon is observed in boreal regions. It is explained by large scale changes in ecosystems, including decrease in sulphur deposition that affects soil organic matter solubility, increase in temperature that stimulates export of dissolved organic carbon (DOC) from organic soils, and increase in precipitation and thus runoff. Land use changes and forestry measures are also observed to be one reason for increased transport of DOC. The effects of brownification extend to ecosystem services like water purification, but also freshwater productivity through limiting light penetration and creating more stable thermal stratification. We studied past trends of organic carbon loading from catchments based on observations since early 1990's. We calibrated and made simulations of loading by the physical Persist and INCA models to three small catchments (25-81 km^2) at the Lammi LTER area. One of the catchments is dominated by agricultural, others by forested land use. We upscaled simulations to the Kokemäenjoki river basin (17 950 km^2). Even though river processes did not play a role in small catchments, they had influence on DOC concentration at the whole river basin. Brownification was driven mainly by the change in climate and decay of organic matter in soil, with smaller impact of land use change on organic soil types. Decrease in sulphur deposition had only minor effect on brownification. River processes seem to be important in buffering the excess DOC loading in lake-river chains in large river basins.