BIOGEOMON 2022

10th International Symposium on Ecosystem Behavior

26 – 30 June 2022, University of Tartu, Estonia

BOOK OF ABSTRACTS

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Book of Abstracts

Tartu 2022

This publication contains abstracts submitted for the BIOGEOMON 2022 conference.

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Foreword

Dear participants!

BIOGEOMON – the symposium on ecosystem behavior is a regular international forum and meeting point of ecologists and environmental scientists in wide range of topics. The tradition started in 1987 when the first symposium (that time titled GEOMON, as in geologic monitoring) was organized in Prague, Czechoslovakia. It was motivated by a desire to understand the processes governing watersheds chemistry. Five years later, the meeting was retitled BIOGEOMON and its focus broadened towards ecosystem manipulations at various scales, applied biogeochemical research, ecological modelling and other interdisciplinary science. Altogether, there have been 9 BIOGEOMON conferences in Europe and North America: 1987 and 1992 in Prague, 1997 in Villanova, PA, USA, 2002 in Reading, UK, 2006 in Santa Cruz, CA, USA, 2009 in Helsinki, Finland, 2012 in Northport ME, USA, 2014 in Bayreuth, Germany and 2017 in Litomyšl, Czech Republic.

The 10th BIOGEOMON symposium is organized by the University of Tartu, Estonia and the Czech Geological Survey, and takes place in Tartu, Estonia on 26–30 June 2022. It is held in complicated time: the restrictions on the COVID pandemic, which caused postponing the symposium in 2020 and 2021, have just eased, but the new threat and instability caused by Russia's aggression in Ukraine are harassing the international community. Nevertheless, it is gratifying to note that more than 170 scientists and experts from more than 20 countries have gathered in Tartu. These include top researchers in the field as well as many young researchers and postgraduate students. Also, we keep in mind these colleagues who could not come here for any reason. Herewith I have a pleasant opportunity to forward greetings from one of the founders of the BIOGEOMON tradition, Professor Martin Novák.

The focus of BIOGEOMON 2022 is on the biogeochemistry of various ecosystems as influenced by anthropogenic and environmental factors. Empirical and modeling studies on fluxes and processes related to the turnover of major and trace elements at the ecosystem, watershed, landscape, and global scale will be considered. Five thematical sessions focus on nutrient and carbon fluxes at catchment/landscape level, remote sensing of biogeochemical fluxes, biogeochemistry of lakes, rivers and wetlands, fluxes between atmosphere and ecosystems, soil and microbial processes, trace elements and micropollutants, biodiversity issues, ecosystem restoration and rehabilitation, and peatland processes.

We are happy to introduce you our university town Tartu, the European capital of culture in 2024, and our small country, Estonia. Hopefully, the conference will offer pleasant atmosphere both in social and meteorological sense. We wish you fruitful discussions and an enjoyable conference that would result in continuing scientific collaboration and new international projects with the involvement of Estonia. We hope to meet you again if not before then at the next BIOGEOMON. Enjoy the conference!

On behalf of the organizing team

Ülo Mander

BIOGEOMON 2022

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26–30 June 2022

Contents

Local scientific committee (University of Tartu)

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Ivika Ostonen
Jaan Pärn
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Sunday, 26.06.2022

PRE-CONFERENCE PROGRAMME

11:00–15:00	Open Workshop on "Spatio-temporal trend analysis of spatial climate data (temperature and rainfall) using Python" University of Tartu, Vanemuise 46 building, room 202
14:00, 17:00	City tour (45 minutes), Town Hall square
16:00–18:00	Excursion in Estonian National Museum

BIOGEOMON 2022

14:00–18:00	Registration in University of Tartu Delta Centre
18:30–21:30	Welcome reception in University of Tartu Delta Centre
	Mr. Raimond Tamm, Deputy Mayor of Tartu
	Prof. Jaak Vilo, Head of the Institute of Computer Science, Delta Centre, University of Tartu

Monday, 27.06.2022

University of Tartu Delta Centre

PLENARY SESSION IN ROOM 1037

08:30	Opening Prof. Toomas Asser, Rector of the Univeristy of Tartu
08:45	**Plenary presentation: Curt Richardson** PEATLAND CARBON ALCHEMY AND CLIMATE CHANGE SERVICES
09:30	**Plenary presentation: Josette Garnier** NITROGEN CASCADES FROM LAND TO SEA: INTEGRATING THE WATER-AGRO-FOOD SYSTEM
10:15	*Coffee break*
11:00	**Plenary presentation: Kate Lajtha** EXPECTING THE UNEXPECTED AND LEARNING FROM SCIENTIFIC SURPRISES: LESSONS FROM PLANT DETRITAL EFFECTS ON ECOSYSTEM FUNCTION
11:45	**Plenary presentation: Mari Pihlatie** TOWARDS UNDERSTANDING THE DRIVERS AND DYNAMICS OF CANOPY METHANE EMISSIONS OF BOREAL TREES
12:30	*Lunch*

PARALLEL SESSIONS

	ROOM 1037	ROOM 1021
	III **Conveners:** **Junninen, Kasak, Lohila, Machacova, Soosaar**	**I** **Conveners:** **Bodmer, Burdun, Montibeller, Tournebize, Uuemaa**
14:00	**III-O1 Noormets:** WHAT DOES IT TAKE TO SEQUESTER CARBON?	**I-O1 Bodmer:** INTEGRATION OF AQUATIC AND TERRESTRIAL FLUXES TO IMPROVE LANDSCAPE-ATMOSPHERE CARBON EXCHANGE ASSESSMENTS
14:20	**III-O2 Machacova:** EUROPEAN BEECH STEMS SUBSTANTIALLY REDUCE METHANE (CH_4) UPTAKE OF TEMPERATE MONTANE FOREST	**I-O2 Shanley:** PATTERNS OF ORGANIC CARBON QUANTITY AND QUALITY FROM TREE TOP TO RIVER MOUTH
14:35	**III-O3 Ma:** DIURNAL PATTERNS OF WHITE POPLAR (*POPULUS ALBA*) TREE STEM CH_4 AND CO_2 FLUXES USING HIGH-FREQUENCY MEASUREMENTS IN A TEMPERATE UPLAND WOODLAND	**I-O3 Mena Correa:** DISSOLVED ORGANIC CARBON FLUXES IN FORESTS UNDER DIFFERENT RAINFALL REGIMES: COUPLING HYDROLOGICAL AND CARBON FLUXES MODELS
14:50	**III-O4 Kohl:** CAN TREE STEM AND SHOOT EMISSIONS CLOSE THE GAP IN THE METHANE BUDGET OF A BOREAL SCOTS PINE FOREST DURING THE SUMMER MONTHS?	**I-O4 Zhu:** THE ROLE OF TERRESTRIAL PRODUCTIVITY AND HYDROLOGY IN REGULATING AQUATIC DISSOLVED ORGANIC CARBON CONCENTRATIONS IN BOREAL CATCHMENTS

15:05	**III-O5 Tenhovirta:** EFFECTS OF DROUGHT ON THE METHANE EMISSIONS FROM THE SHOOTS OF YOUNG SCOTS PINE SAPLINGS	**I-O5 Klavins:** ASSESSMENT OF ACIDITY AND EUTROPHICATION CRITICAL LOADS IN PRODUCTION FOREST DRAINAGE CATCHMENTS AND AFTER DIFFERENT INTENSITY REGENERATION FELLINGS
15:20	**III-O6 Siljanen:** METHANE DYNAMICS AND MICROBIAL ACTIONS IN BOREAL SPRUCE PHYLLOSPHERE	**I-O6 Stals:** RELATIONSHIPS BETWEEN VEGETATION COMPOSITION AND GROUNDWATER CHEMISTRY IN FORESTED RIPARIAN ZONE
15:35	*Coffee break*	
16:05	**III-O7 Melling:** LONG TERM GREENHOUSE GAS BUDGET IN THE MALUDAM SWAMP FOREST IN SARAWAK, MALAYSIA	**I-O7 Kalbitz:** SPATIAL AND TEMPORAL VARIABILITY OF DISSOLVED ORGANIC MATTER ACROSS THE TERRESTRIAL–AQUATIC CONTINUUM
16:25	**III-O8 Nunes-Souza:** WOOD STRUCTURE IS A MAJOR DRIVER OF METHANE EMISSIONS FROM AMAZONIAN FLOODED FORESTS	**I-O8 Uuemaa:** RANDOM FOREST-BASED MODELING OF STREAM NUTRIENTS AT NATIONAL LEVEL IN A DATA-SCARCE REGION
16:40	**III-O9 Gerin:** N_2O AND CO_2 FLUXES MEASURED BY EDDY COVARIANCE TECHNIQUE IN A SHALLOW DRAINED AGRICULTURAL BOREAL PEATLAND OVER TWO CONTRASTING YEARS	**I-O9 Henine:** LONG-TERM RESEARCH OBSERVATORY OF THE CRITICAL ZONE
16:55	**III-O10 Ranniku:** GREENHOUSE GAS DYNAMICS IN A DRAINED PEATLAND FOREST: ANNUAL CH_4 AND N_2O FLUXES FROM TREE STEMS AND SOIL	**I-O10 Kram:** BIOGEOCHEMISTRY AND ECOTOXICITY OF CHROMIUM IN A FORESTED CATCHMENT
17:10	**III-O11 Krasnov:** SIMPLE METHOD FOR IDENTIFYING THE (B)VOCS SOURCE CONTRIBUTION AREA USING UNMANNED AERIAL VEHICLE (UAV) AND METEOROLOGICAL DATA	**I-O11 Tournebize:** IMPROVING THE ESTIMATES OF NITRATE CONCENTRATIONS AT THE AGRICULTURAL CATCHMENT SCALE: THE POTENTIAL OF VARIATIONAL DATA ASSIMILATION USING A NEW WATER QUALITY MODEL
17:30	**Plenary presentation: Dennis Baldocchi** (online) LESSONS LEARNED FROM LONG-TERM EDDY COVARIANCE FLUX MEASUREMENTS OF CARBON DIOXIDE AND METHANE OVER NON-TIDAL AND TIDAL RESTORED WETLANDS IN THE SAN FRANCISCO BAY-DELTA ESTUARY	
18:15	**POSTER SESSION**	

Tuesday, 28.06.2022

University of Tartu Delta Centre

PLENARY SESSION IN ROOM 1037

08:30	**Plenary presentation: Susannah Tringe** MICROBIAL DRIVERS OF METHANE EMISSIONS FROM SAN FRANCISCO BAY WETLANDS

PARALLEL SESSIONS

	ROOM 1037	ROOM 1021
	III Conveners: Junninen, Kasak, Lohila, Machacova, Soosaar	**IV** Conveners: Helm, Imfeld, Öpik, Ostonen, Passeport, Ukonmaanaho
09:15	**III-O12 Junninen:** TERPENE EMISSIONS FROM BOREAL WETLANDS CAN INITIATE STRONGER ATMOSPHERIC NEW PARTICLE FORMATION THAN BOREAL FORESTS	**IV-O1 Clesse:** TREE SPECIES DRIVE SOIL FERTILITY CHANGE DURING THE 43 YEARS AFTER PLANTATION – A DUAL APPROACH (SOIL SAMPLING AND INPUT-OUTPUT MASS BALANCE) STUDY OF THE BREUIL-CHENUE COMMON GARDEN EXPERIMENT (BURGUNDY, FRANCE)
09:35	**III-O13 Lipp:** CONDITIONS FOR NANOPARTICLE CONCENTRATION INCREASE IN THE ATMOSPHERE OF HEMIBOREAL FOREST	**IV-O2 Imfeld:** ACCUMULATION, AGEING AND TOXICITY OF COPPER IN EUROPEAN VINEYARDS IN A CONTEXT OF REGULATORY CHANGE

09:50	**III-O14 Männistö:** EMISSIONS OF BIOGENIC VOLATILE ORGANIC COMPOUNDS FROM A BOREAL FEN AND BOG AS IMPACTED BY VEGETATION AND A PERIOD OF DROUGHT	**IV-O3 Masta:** UNDERSTANDING N_2O PRODUCTION AND CONSUMPTION PROCESSES IN PEAT SOIL WITH THE HELP OF ISOTOPIC AND MICROBIAL ANALYSIS
10:05	**III-O15 Avramov:** SOIL AMMONIA FLUXES FROM MAIZE FIELDS	**IV-O4 Jia:** A DECISION SUPPORT TOOL TO OPTIMIZE THE SELECTION OF ^{15}N ANALYSIS METHODS OF AMMONIUM AND NITRATE IN ENVIRONMENTAL RESEARCH
10:20	**III-O16 Maljanen:** EFFECT OF N-FERTILIZATION AND CUTTING HEIGHT ON GREENHOUSE GAS BALANCE OF GRASSLAND ON MINERAL SOIL IN EASTERN FINLAND	**IV-O5 Tournebize:** TEMPORAL VARIABILITY OF PESTICIDE REMOVAL FROM ARTIFICIAL WETLAND RECEIVING AGRICULTURAL DRAINED WATER
10:35	**III-O17 Escuer-Gatius:** CLOSING THE CARBON AND NITROGEN BUDGETS IN A WINTER RAPESEED FIELD	**IV-O6 Lohila:** ANNUAL CO_2 BALANCE OF A BARLEY GROWING ON CLAY SOIL - COMPARISON OF DIRECT AND INDIRECT MEASUREMENTS
10:50	*Coffee break*	
	V **Conveners:** **Dise, Vile**	**IV** **Conveners:** **Helm, Imfeld, Öpik, Ostonen, Passeport, Ukonmaanaho**
11:20	**V-O1 Dise:** PLANT COMMUNITY RESPONSES TO EXPERIMENTAL CLIMATE MANIPULATION IN A WELSH BOG AND THEIR PALAEOENVIRONMENTAL CONTEXT	**IV-O7 Gebauer:** STABLE ISOTOPES ELUCIDATE MORE AND MORE FACETS OF FUNGUS-TO-PLANT CARBON FLUXES IN SHARED MYCORRHIZAL NETWORKS
11:40	**V-O2 Thayamkottu:** IMPORTANCE OF SOIL WATER CONTENT FOR GHG EXCHANGE IN GLOBAL PEATLANDS	**IV-O8 Hiiesalu:** CONTRASTING DIVERSITY AND SPECIALIZATION PATTERNS OF ARBUSCULAR MYCORRHIZAL FUNGAL COMMUNITIES ALONG A STEEP ELEVATIONAL GRADIENT
11:55	**V-O3 Könönen:** COMPLEX TOOLS TO TACKLE COMPLEX DRAINED PEATLAND FOREST DYNAMICS	**IV-O9 Vazquez:** NITROGEN BUT NOT PHOSPHORUS ADDITION AFFECTS SYMBIOTIC N_2 FIXATION IN GRASSLANDS LOCATED ON FOUR CONTINENTS
12:10	**V-O4 Kinnunen:** EFFECTS OF THE WATER TABLE LEVEL AND GLUCOSE ADDITION ON THE RELEASE AND BIODEGRADABILITY OF DISSOLVED ORGANIC CARBON IN A BOREAL PEAT COLUMN EXPERIMENT	**IV-O10 Hruska:** FOREST GROWTH RESPONDS MORE TO AIR POLLUTION THAN ACIDIFICATION
12:25	**V-O5 Panitz:** CARBON EXCHANGE RESPONSE OF SPHAGNUM DOMINATED PEATLAND TO MULTIPLE ASPECTS OF GLOBAL CHANG	**IV-O11 Navratil:** QUARTER OF CENTURY LITTERFALL RECORD IN NORWAY SPRUCE STANDS HIGHLY IMPACTED BY ACID RAIN (ORE MOUNTAINS, CZECH REPUBLIC)
12:40	*Lunch*	
14:00	**Plenary presentation: Vincent Gauci** TROPICAL TREES AND METHANE EXCHANGE: HOW TREES HELP SOLVE PROBLEMS IN REGIONAL AND GLOBAL METHANE BUDGETS	
	PARALLEL SESSIONS	
	ROOM 1037	**ROOM 1021**
	V **Conveners:** **Dise, Vile**	**II** **Conveners:** **Forsius, Knorr, Vymazal**
14:45	**V-O6 Larmola:** DOES NITROGEN DEPOSITION LEAD TO A WEAKER OR STRONGER CARBON SINK IN NUTRIENT-POOR PEATLANDS?	**II-O1 Forsius:** LINKS BETWEEN CRITICAL LOAD EXCEEDANCE OF N AND S DEPOSITION AND MEASURED IMPACT INDICATORS AT IM-CATCHMENTS IN EUROPE

15:05	**V-O7 Antonijevic:** THE UNEXPECTED LONG PERIOD OF EXTREME CH_4 EMISSIONS FROM AN INUNDATED FEN MEADOW ENDED ONLY WITH CATTAIL	**II-O2 Lau:** ANOXIC AGE AS A NEW TOOL TO PREDICT BIOGEOCHEMICAL CONSEQUENCES OF OXYGEN DEPLETION IN LAKES
15:20	**V-O8 Vile:** EXPERIMENTAL NITROGEN ADDITION ALTERS STRUCTURE AND FUNCTION OF A BOREAL BOG: CRITICAL LOAD AND THRESHOLDS REVEALED	**II-O3 McCarthy:** SEDIMENT NITROGEN TRANSFORMATIONS DURING AN ICE-FREE WINTER IN A LARGE, SHALLOW, EUTROPHIC LAKE
15:35	**V-O9 Ge:** SPECIES-SPECIFIC RESPONSES TO CONTROLS REGULATE PLANT-MEDIATED METHANE EMISSIONS IN A NORTHERN BOREAL FEN	**II-O4 Cremona:** PREDICTING MULTIPLE STRESSOR EFFECT ON ZOOPLANKTON ABUNDANCE, BIOMASS AND COMMUNITY COMPOSITION IN TWO LARGE EUTROPHIC LAKES
15:50	**V-O10 Veber:** SIMPLE EMPIRICAL MODELS BASED ON SOIL, WATER AND VEGETATION PARAMETERS DESCRIBE GREENHOUSE GAS FLUXES ALONG DRAINAGE GRADIENT IN PEATLANDS	**II-O5 Ercoli:** SEASONAL AND SPATIAL VARIATION OF ALLOCHTHONOUS ORGANIC MATTER CONTRIBUTION IN LAKE FOODWEB
16:05	*Coffee break*	
	V **Conveners:** **Dise, Vile**	**I** **Conveners:** **Bodmer, Burdun, Montibeller, Tournebize, Uuemaa**
16:35	**V-O11 Knorr:** ELECTRON ACCEPTING CAPACITIES OF PEAT MATERIALS FROM AROUND THE GLOBE	**I-O12 Peltomaa:** IMPACT OF FOREST HARVESTING INTENSITY ON THE RELEASE AND BIODEGRADABILITY OF DISSOLVED ORGANIC CARBON IN DRAINED BOREAL PEATLANDS
16:55	**V-O12 Espenberg:** COMPOSITION OF N_2O-GOVERNING MICROBIAL COMMUNITIES IN PRISTINE AND MANAGED TROPICAL PEATLANDS	**I-O13 Holmberg:** SOURCES AND SINKS OF GREENHOUSE GASES IN THE LANDSCAPE
17:10	**V-O13 Burdun:** DERIVING TEMPORAL CHANGES IN WATER TABLE DEPTH POSITION IN NORTHERN PEATLANDS WITH OPTICAL SATELLITE DATA	**I-O14 Dambrine:** PARTICULATE ORGANIC MATTER TRANSPORT FROM STREAMS TO LAKES. RELATIONSHIPS TO RESERVOIR GHG EMISSIONS
17:25	**V-O14 Apolinarska:** THE TEMPORAL COMPLEXITY OF CARBONATE DEPOSITION AT PUSZCZA ROMINCKA CUPOLA ALKALINE FEN (NE POLAND) DURING THE HOLOCENE	**I-O15 Jekabsone:** ECOLOGICAL FLOWS AS INDICATOR OF HEALTHY RIVER ECOSYSTEMS
17:40	**POSTER SESSION**	

Wednesday, 29.06.2022

08:00–16:30	6 technical tours (starting from Delta Centre)
19:00–22.00	Symposium dinner (University of Tartu Museum)

Thursday, 30.06.2022

University of Tartu Delta Centre

PLENARY SESSION IN ROOM 1037

08:30	**Plenary presentation: Ilona Riipinen** INSIGHTS INTO FOREST-ATMOSPHERE-CLOUD-CLIMATE INTERACTIONS
09:15	**Plenary presentation: Eri Saikawa** NITROUS OXIDE – LAUGHING GAS IS NO LAUGHING MATTER
10:00	**Pleanary presentation: Pat Megonigal** BLUE METHANE: BIOGEOCHEMICAL LIMITS AND OPPORTUNITIES FOR MANAGING WETLANDS TO MITIGATE CLIMATE CHANGE
10:45	*Coffee break*

	PARALLEL SESSIONS	
	ROOM 1037	**ROOM 1021**
	IV **Conveners:** **Helm, Imfeld, Öpik, Ostonen, Passeport, Ukonmaanaho**	**II** **Conveners:** **Forsius, Knorr, Vymazal**
11:00	**IV-O12 Passeport:** NATURAL ATTENUATION OF DICHLORONITROBENZENES AND DICHLOROANILINES IN CONSTRUCTED WETLANDS REVEALED BY COMPOUND SPECIFIC ISOTOPE ANALYSIS	**II-O6 Kasak:** HIGH GREENHOUSE GAS EMISSIONS AS TRADE-OFF FOR WATER TREATMENT IN CONSTRUCTED WETLANDS TREATING AGRICULTURAL RUN-OFF
11:20	**IV-O13 Kram:** HIGH-FREQUENCY MONITORING AT THE LYSINA CATCHMENT	**II-O7 Lauringson:** SUMMER GREENHOUSE GAS FLUXES IN DIFFERENT TYPES OF HEMIBOREAL LAKES
11:35	**IV-O14 Galka:** LONG-TERM INSIGHT INTO THE CHANGES OF THE VEGETATION OF PEATLAND ECOSYSTEMS IN ARCTIC ALASKA	**II-O8 Palacin-Lizarbe:** WINTER NITROGEN CYCLING IN SEDIMENTS OF BOREAL LAKES AFFECTED BY BROWNING AND MINING
11:50	**IV-O15 Metrak:** MORPHOLOGICAL AND BIOGEOCHEMICAL CHARACTERISTICS OF BIOLOGICAL SOIL CRUSTS FROM A DRY, HIGH-ALTITUDE GLACIER FORELAND IN THE NE PAMIR (TAJIKISTAN) IN THE CONTEXT OF NUTRIENT ACCUMULATION	**II-O9 Vymazal:** EFFECT OF WATER DEPTH ON CARBON AND NUTRIENTS SEQUESTRATION IN FISHPOND LITTORALS
12:05	**IV-O16 Vejvodova:** EFFECT OF PEAT ORGANIC MATTER ON SULFIDE WEATHERING AND THALLIUM MOBILITY	**II-O10 Kõiv-Vainik:** THE EFFECT OF MACROPHYTES AND BIOCHAR ENHANCEMENT ON THE PERFORMANCE OF COLD CLIMATE TREATMENT WETLANDS IN MITIGATION OF PESTICIDE POLLUTION
12:20	**IV-O17 de Nijs:** CO-COMPOSTING ROSE WASTE, ASSESSING THE POTENTIAL AS SUSTAINABLE WASTE MANAGEMENT STRATEGY	**II-O11 Passeport:** FATE OF TRACE ORGANIC STORMWATER CONTAMINANTS IN A BIORETENTION CELL ASSESSED VIA A FIELD TRACER TEST WITH BENZOTRIAZOLE
12:35	**IV-O18 Boruvka:** DECLINE OF AVAILABLE PHOSPHORUS CONTENT IN MOUNTAIN FOREST SOILS OF THE CZECH REPUBLIC	**II-O12 Perdana:** COMMERCIAL MANGANESE OXIDES AS AN AMENDMENT FOR NATURE-BASED SYSTEMS TREATING GREYWATER IN COLD WEATHER
12:50	**CLOSING SESSION IN ROOM 1037**	
13:30	*Lunch*	

Friday–Saturday, 01.–02.07.2022

POST-CONFERENCE TOUR TO SAAREMAA ISLAND

Friday 08:00	Departure from parking place behind the Town Hall
Saturday 21:30	Arrival in Tallinn

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Plenary speakers

Curtis J. Richardson – John O. Blackburn Distinguished Professor of Resource Ecology and Founding Director of the Duke University Wetland Center in the Nicholas School of the Environment where he has taught wetland ecology, biogeochemistry and ecosystem restoration for the past 40 years. His research for the past two decades has focused on wetland phosphorus cycling in the Everglades and carbon sequestration, GHG changes and restoration of freshwater wetlands and Pocosin peatlands in coastal North Carolina. He has authored over > 200 publications and several books. In 2006, he received the National Wetlands Science Award from the Environmental Law Institute. He is a Fellow of AAAS, SWS and SSSA. He was awarded an honorary Doctorate of Science in 2018 by the University of Waterloo in Canada.

Josette Garnier – Research Director at CNRS with tenure in the field of Biogeochemistry UMR Metis, Sorbonne Université/CNRS, Paris, France**.** Head of an interdisciplinary research federation for the environment gathering 18 laboratories. Has been taken part in an interdisciplinary research programme on the Seine river system (https://www.piren-seine.fr/). Anthropogenic modifications of biogeochemical cycles have become a major driver of her research, leading to interdisciplinary collaboration with historians and social geographers as early as 1991. An objective of her projects, besides basic research towards new frontiers of knowledge, is to respond to societal demands such as the reduction of eutrophication, hypoxia, and organic and nitric pollutions. She actively participated to the development of a biogeochemical modelling approach of land-to-sea aquatic continua (GRAFS-RIVERSTRAHLER Model) allowing to understand the cause of river and coastal zone eutrophication related to human activities in catchments, and to co-construct scenarios with policy makers and stakeholders for alternative management options of the water-agro-food systems at catchment scale. She has been PI of several national and European projects. She supervised 26 Ph-D students and published about 215 articles in journals indexed in the ISI Science Citation index. She co-edited five special issues. She shared the Ruth Patrick award in 2016, with Gilles Billen.

Kate Lajtha – Professor in Crop and Soil Sciences Department at Oregon State University. Editor-in-Chief of Biogeochemistry. Research interests in nutrient cycling in natural and human-disturbed ecosystems, including the attenuation of increased nitrogen inputs to terrestrial ecosystems by soils and vegetation, controls on soil carbon stabilisation and destabilisation, and the dynamics of dissolved organic matter in differing ecosystems and with differing land use scenarios. Her current research focus centres on the role of detrital quality and quantity on soil organic matter dynamics and soil carbon sequestration, and she coordinates a network of field experiments that remove and add differing litters to soil. She currently serves on the Board of Scientific Counselors for the US Environmental Protection Agency, and is active with the American Geophysical Union.

Mari Pihlatie – Associate Professor, University of Helsinki has gained merit in methods of greenhouse gas flux measurement from peatlands, and revealing boreal trees as sources of N_2O and CH_4. Her pioneering work on N_2O exchange of trees stems dates back to 2005 when she demonstrated that tree seedlings are capable of transporting soil-borne N_2O through the transpiration stream, emitting it from the leaves. She leads the CH_4 and N_2O Cycles in Forests research group working at scales from molecular to ecosystem, using state-of-the-art methods, and automated flux measurement systems in controlled environments and the field. She received an ERC starting grant in 2017 for the MEMETRE project (From Processes to Modelling of Methane Emissions from Trees) and an Academy of Finland's prize for social impact (2018). Since 2018 she has acted as the responsible professor in Environmental Soil Science focusing her future research in climate-smart agriculture. Today she coordinates a new measurement station (SMEAR Agriculture) for continuous and long-term measurements of air quality and climate impacts of northern agriculture, and an infrastructure consortium (INAR RI Agriculture) funded by the Academy of Finland, to establish a research station network to study climate-smart northern agriculture.

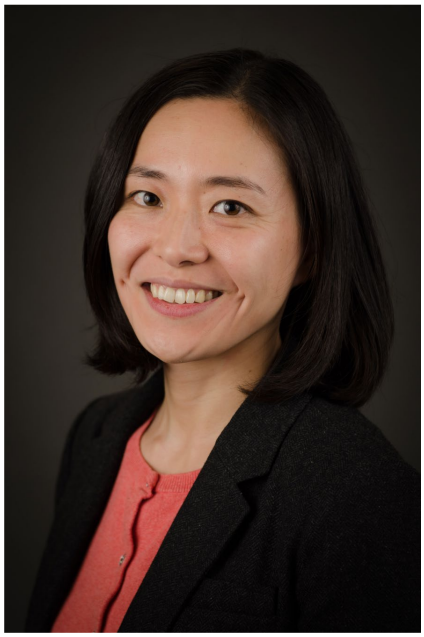
Dennis Baldocchi – Professor of biometeorology, University of California, Berkeley. Principal investigator of Fluxnet since 1997. Co-investigator of Ameriflux. Fellow of American Geophysical Union. Recipient of the American Meteorological Society Award for Outstanding Achievement in Biometeorology. Clarivate Analytics Highly Cited Scientist over multiple years in Agricultural Science and in Ecology/Environment. Conducts experimental and theoretical studies on physical, biological and chemical control of trace gas exchange between vegetation and the

atmosphere. Goals of work: to predict fluxes of carbon, water and energy, mechanistically, everywhere, all of the time. Lines of inquiry: understanding how fluxes of mass and energy between ecosystems and the atmosphere vary along a spectrum of time and space scales in accordance with structure, function, weather and climate and management. Methods used include use of the eddy covariance method to measure net fluxes of mass and energy across the atmosphere-ecosystem interface. Data are interpreted and distilled through the lens of the CANVEG family of models, physiological measurements at the leaf scale and flux measurements across the soil-atmosphere interface.

Susannah Tringe – Deputy Director for User Programs at the U.S. Department of Energy Joint Genome Institute (JGI), where she oversees programs for accepting genomics research proposals relevant to energy and the environment. She heads the Microbial Systems group, which focuses on using nucleic acid sequence data to study communities of microbes from diverse environmental niches and understand their assembly and function. Her major research interests relate to microbial influences on greenhouse gas uptake and release in wetlands and how microbes interact with plants to affect growth, health and disease resistance.
Dr. Tringe received her undergraduate degree in Physics from Harvard University then went on to a Ph.D. in Biophysics from Stanford University. She joined JGI / Berkeley Lab as a postdoc in 2003. There she developed techniques for using DNA sequence data for comparative analysis of whole microbial communities, rather than individual organisms.

Vincent Gauci – Birmingham Professorial Fellow in the School of Geography, Earth and Environmental Sciences. He is interested in the biogeochemistry of carbon-dense terrestrial ecosystems such as forests, wetlands, peatlands, and forested wetlands and peatlands. In particular he is interested in how these ecosystems interact with the atmosphere through the exchange of greenhouse gases with a particular focus on trace greenhouse gases such as methane and N_2O. He is also interested in fluvial losses of carbon from these ecosystems and agroecosystems and, as with his interest in GHG exchange, a unifying theme is the response of these exchanges to various agents of global change including atmospheric CO_2 concentration change, pollutant exposure and deposition and land use change. He has managed projects across Central and South America, Southeast Asia as well as Europe.

Ilona Riipinen – Professor of atmospheric sciences, Stockholm University. She has received funding for her research from many funds as well as the European Research Council.
Riipinen completed her undergraduate and graduate studies at the University of Helsinki within the successful aerosol research collaboration of Markku Kulmala and collaborators. Riipinen gained her doctorate in 2008 from the Department of Physics of the University of Helsinki, with a thesis examining the early stages of atmospheric particulate formation and growth titled. She has held the title of docent at the University of Helsinki since 2011.
Riipinen worked as an assistant professor at the University of Stockholm from 2011 to 2016. Since 2017 she has been a professor of atmospheric sciences at the same university. As a researcher she has published in highly regarded scientific journals (Nature, Science). In 2016 and 2017 she was one of the world's most cited geoscientists included in a group of the world's 3100 most highly cited researchers.



Eri Saikawa – Associate Professor, Department of Environmental Sciences, Emory University. She is also an affiliated faculty in the Institute for Quantitative Theory and Methods, the East Asian Studies Program, as well as in the Center for Study of Law, Politics and Economics. She conducts interdisciplinary research on the environment. She works on diverse research areas including: 1) atmospheric chemistry (modeling air pollution, mainly fine particulate matter and tropospheric ozone, in Asia); 2) environmental health (measuring exposure in Tibetan households due to indoor air pollution and assessing the adverse health impacts due to ambient air pollution); 3) biogeochemistry (modeling global soil nitrous oxide emissions); 4) climate science (estimating emissions of greenhouse gases by modeling and through observations); 5) heavy metal soil contamination (conducting soil testing in West Atlanta and assessing the effectiveness of community-based phytoremediation); and 6) environmental policy/politics (analyzing the impacts of environmental standards and trade as well as analyzing policymaking processes).

BIOGEOMON 2022

10th International Symposium on Ecosystem Behavior

26–30 June 2022

Pat Megonigal – Senior Scientist and Associate Director of Research at the Smithsonian Environmental Research Center. Ecosystem ecologist with research interests in carbon cycling and greenhouse gas dynamics in wetlands and forests, particularly as they relate to global climate change. Director of the Smithsonian's Global Change Research Wetland, a long-term research site dedicated to understanding the stability of tidal wetlands faced with accelerated sea level rise and biogeochemical interactions between wetlands and estuaries. Director of Coastal Carbon Research Coordination Network, a global community committed to sharing data and expertise to accelerate the pace of discovery in coastal wetland carbon science. A founding a member of the International Scientific Working Group on Blue Carbon convened by Conservation International and the International Union for the Conservation of Nature, an initiative dedicated to conserving coastal wetlands for their unmatched capacity to storage and preserve carbon.

Oral presentations

In the order of appearance. Click on the name to read the abstract.

PLENARY PRESENTATIONS

PL-1 Curt Richardson
PEATLAND CARBON ALCHEMY AND CLIMATE CHANGE SERVICES

PL-2 Josette Garnier
NITROGEN CASCADES FROM LAND TO SEA: INTEGRATING THE WATER-AGRO-FOOD SYSTEM

PL-3 Kate Lajtha
EXPECTING THE UNEXPECTED AND LEARNING FROM SCIENTIFIC SURPRISES: LESSONS FROM PLANT DETRITAL EFFECTS ON ECOSYSTEM FUNCTION

PL-4 Mari Pihlatie
TOWARDS UNDERSTANDING THE DRIVERS AND DYNAMICS OF CANOPY METHANE EMISSIONS OF BOREAL TREES

PL-5 Dennis Baldocchi
LESSONS LEARNED FROM LONG-TERM EDDY COVARIANCE FLUX MEASUREMENTS OF CARBON DIOXIDE AND METHANE OVER NON-TIDAL AND TIDAL RESTORED WETLANDS IN THE SAN FRANCISCO BAY-DELTA ESTUARY

PL-6 Susannah Tringe
MICROBIAL DRIVERS OF METHANE EMISSIONS FROM SAN FRANCISCO BAY WETLANDS

PL-7 Vincent Gauci
TROPICAL TREES AND METHANE EXCHANGE: HOW TREES HELP SOLVE PROBLEMS IN REGIONAL AND GLOBAL METHANE BUDGETS

PL-8 Ilona Riipinen
INSIGHTS INTO FOREST-ATMOSPHERE-CLOUD-CLIMATE INTERACTIONS

PL-9 Eri Saikawa
NITROUS OXIDE – LAUGHING GAS IS NO LAUGHING MATTER

PL-10 Pat Megonigal
BLUE METHANE: BIOGEOCHEMICAL LIMITS AND OPPORTUNITIES FOR MANAGING WETLANDS TO MITIGATE CLIMATE CHANGE

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INTEGRATION OF AQUATIC AND TERRESTRIAL FLUXES TO IMPROVE LANDSCAPE-ATMOSPHERE CARBON EXCHANGE ASSESSMENTS

I-O2 Shanley
PATTERNS OF ORGANIC CARBON QUANTITY AND QUALITY FROM TREE TOP TO RIVER MOUTH

I-O3 Mena Correa
DISSOLVED ORGANIC CARBON FLUXES IN FORESTS UNDER DIFFERENT RAINFALL REGIMES: COUPLING HYDROLOGICAL AND CARBON FLUXES MODELS

I-O4 Zhu
THE ROLE OF TERRESTRIAL PRODUCTIVITY AND HYDROLOGY IN REGULATING AQUATIC DISSOLVED ORGANIC CARBON CONCENTRATIONS IN BOREAL CATCHMENTS

I-O5 Klavins
ASSESSMENT OF ACIDITY AND EUTROPHICATION CRITICAL LOADS IN PRODUCTION FOREST DRAINAGE CATCHMENTS AND AFTER DIFFERENT INTENSITY REGENERATION FELLINGS

I-O6 Stals
RELATIONSHIPS BETWEEN VEGETATION COMPOSITION AND GROUNDWATER CHEMISTRY IN FORESTED RIPARIAN ZONE

I-O7 Kalbitz
SPATIAL AND TEMPORAL VARIABILITY OF DISSOLVED ORGANIC MATTER ACROSS THE TERRESTRIAL–AQUATIC CONTINUUM

I-O8 Uuemaa
RANDOM FOREST-BASED MODELING OF STREAM NUTRIENTS AT NATIONAL LEVEL IN A DATA-SCARCE REGION

I-O9 Henine
LONG-TERM RESEARCH OBSERVATORY OF THE CRITICAL ZONE

I-O10 Kram
BIOGEOCHEMISTRY AND ECOTOXICITY OF CHROMIUM IN A FORESTED CATCHMENT

I-O11 Tournebize
IMPROVING THE ESTIMATES OF NITRATE CONCENTRATIONS AT THE AGRICULTURAL CATCHMENT SCALE: THE POTENTIAL OF VARIATIONAL DATA ASSIMILATION USING A NEW WATER QUALITY MODEL

I-O12 Peltomaa
IMPACT OF FOREST HARVESTING INTENSITY ON THE RELEASE AND BIODEGRADABILITY OF DISSOLVED ORGANIC CARBON IN DRAINED BOREAL PEATLANDS

I-O13 Holmberg
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I-O14 Dambrine
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II-O4 Cremona
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II-O9 Vymazal
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IV-O4 Jia
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IV-O6 Lohila
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IV-O7 Gebauer
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IV-O8 Hiiesalu
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V-O3 Könönen
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V-O4 Kinnunen
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CARBON EXCHANGE RESPONSE OF SPHAGNUM DOMINATED PEATLAND TO MULTIPLE ASPECTS OF GLOBAL CHANG

V-O6 Larmola
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V-O7 Antonijevic
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V-O8 Vile
EXPERIMENTAL NITROGEN ADDITION ALTERS STRUCTURE AND FUNCTION OF A BOREAL BOG: CRITICAL LOAD AND THRESHOLDS REVEALED

V-O9 Ge
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V-O10 Veber
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V-O11 Knorr
ELECTRON ACCEPTING CAPACITIES OF PEAT MATERIALS FROM AROUND THE GLOBE

V-O12 Espenberg
COMPOSITION OF N_2O-GOVERNING MICROBIAL COMMUNITIES IN PRISTINE AND MANAGED TROPICAL PEATLANDS

V-O13 Burdun
DERIVING TEMPORAL CHANGES IN WATER TABLE DEPTH POSITION IN NORTHERN PEATLANDS WITH OPTICAL SATELLITE DATA

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SHORT-TERM EFFECT OF PRE-COMMERCIAL THINNING ON THE CARBON CYCLING IN FERTILE BIRCH (*BETULA* SP.) STANDS IN HEMIBOREAL ESTONIA

III-P3 Chen
IMMEDIATE AND CARRY-OVER EFFECTS OF DROUGHT AND LATE SPRING FROST ON FOREST GPP CAPACITY IN THE NORTHERN HEMISPHERE

III-P4 Daniel
TOPOGRAPHY LEADS TO A SHIFT IN METHANE (CH_4) AND NITROUS OXIDE (N_2O) FLUXES FROM TREE STEMS AND SURROUNDING SOILS IN A TROPICAL FOREST

III-P5 Heeren
PERFORMANCE ASSESSMENT OF THE MOBILE G4301 CAVITY RING-DOWN SPECTROSCOPY ANALYZER FOR ATMOSPHERIC CO_2, CH_4 AND H_2O MEASUREMENTS

III-P6 Kangur
TOWARDS ENVIRONMENTAL AND FOREST DATA SCIENCE

III-P7 Kerttula
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III-P8 Krasnova
HEMIBOREAL FORESTS' CO_2 FLUXES RESPONSE TO THE EUROPEAN 2018 HEATWAVE

III-P9 Kukumägi
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III-P10 Lohila
NEW FLUX MEASUREMENT SITES TO STUDY MITIGATION OF GHG FLUXES IN DRAINED PEATLANDS

III-P11 Mander
LONG-TERM CO_2, CH_4 AND N_2O FLUXES FROM SOIL, TREE STEMS, AND ECOSYSTEM IN A RIPARIAN ALDER FOREST

III-P12 Mölder
ECOSYSTEM N_2O AND CH_4 FLUXES OF A BOREAL FOREST PRIOR TO CLEAR-CUTTING

III-P13 Sardar
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III-P14 Sepaste
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III-P15 Soosaar
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III-P16 Tamme
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III-P17 Uri M
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III-P18 Uri V
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IV-P3 Espenberg
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IV-P4 Frymark-Szymkowiak
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IV-P5 Fuss
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IV-P6 Gadegaonkar
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IV-P7 Hints
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IV-P9 Kazmi
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IV-P11 Kuusemets
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IV-P14 Novak
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IV-P18 Sell
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ON THE RELATIONSHIP BETWEEN FOREST STATUS FOLLOWING BARK-BEETLE DISTURBANCE AND MINERAL NITROGEN IN SOILS OF UNMANAGED MOUNTAIN CATCHMENTS

IV-P21 Teikari
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V-P2 Kiełczewski
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V-P3 Kim J
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V-P4 Kim Y
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V-P14 Welpelo
METHANE EMISSIONS FROM A REWETTED BOG – ANNUAL BALANCES, IMPACT OF VASCULAR PLANTS AND ROLE OF PLANT FUNCTIONAL GROUPS

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Plenary presentation abstracts

PL1

PEATLAND CARBON ALCHEMY AND CLIMATE CHANGE SERVICES

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Peatlands at COP26, received renewed attention for their potential in regulating regional and global carbon (C) cycles, with particular emphasis on peatland C sequestration and restoration (rewetting). Peatlands have the highest amount of C storage per hectare of any soils on the globe, thus providing a vital ecosystem service as C regulators, but many of these peatlands have lost this function as they have been drained, burned, fertilized and are now under intensive agricultural or forestry practices. While considerable attention has been paid to restoring peatlands in the Northern regions of the world far less is known about the effects of climate change, drainage and rewetting on C storage and cycling in subtropical and tropical peatlands. The primary mechanisms responsible for peatland formation in boreal regions are typically attributed to cool and uniformly wet soil conditions that limit microbial respiration. However, peatlands are widespread outside of boreal regions and continue to accrete C despite higher temperature, seasonal drying of root-zone soil strata and recurring patterns of wildfire. This implies additional regulatory mechanisms constrain rates of organic matter decomposition, and are often one of the primary controllers of C accretion and GHG fluxes, especially in subtropical and tropical peatlands. Biogeochemical and biological mechanisms that down-regulate decomposition rates in peatlands to be examined in conjunction with hydrologic conditions needed to optimize C sequestration and reduce GHG emissions are: (1) the higher production of polyphenolic and aromatic compounds in the litter of low-latitude shrub/tree communities than found in northern Sphagnum/Carex communities (Wang et al., 2015) and (2) selective removal of labile C and buildup of recalcitrant pyogenic OM (hydrochar) produced by frequent low-intensity wildfires in the native-fire-adapted wetland communities (Flanagan et al., 2020), (3) dominance of slow-growing vs fast growing microbial populations and related decomposition rates (Wang et al., 2021), and (4) how these often overlooked factors can be managed to increase peatland C services, which are relevant to global climate forcing and peatland C budgets worldwide. Finally, we demonstrate how the rapidly expanding C market can be used to reverse peatland development trends and fund restorations by turning black C into gold.

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PL2

NITROGEN CASCADES FROM LAND TO SEA: INTEGRATING THE WATER-AGRO-FOOD SYSTEM

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Using the GRAFS approach (Generalized Representation of Agro-Food Systems) a detailed budget of nitrogen (N) flows associated with agricultural land N fertilization, vegetal and animal production, human consumption and waste management has been established at the regional scale (NUTS2) for the West of Europe (W-EU i.e., France, Spain and Portugal). The environmental losses associated to these N flows to the atmosphere (as NH_3 and N_2O) have been also assessed. To further determine N losses to the hydrosphere the biogeochemical model, RIVERSTRAHLER, which simulates water quality in hydrological networks, was coupled with GRAFS, for all the W-EU river basins flowing to the Atlantic coast. These W-EU river basins indeed represent a wide area for studying nitrogen inputs, transformations, emissions to groundwater and to the atmosphere and deliveries to the coastal zones. Typically this regional area represents a mosaic of intensive agricultural systems, specialized either to crop farming or to livestock breeding, the disconnection of these activities leading to large losses of N to the environment.

Whereas GRAFS provides agronomic evaluations, e.g., in terms of indicators such as N surplus, N use efficiency, N autonomy …, RIVERSTRAHLER allows to quantify environmental N fate, e.g. nitrate contamination of inland water and ICEP, an indicator of coastal eutrophication potential. ICEP is defined from the N:P:Si stoichiometry of the riverine nutrient deliveries and has been widely used in literature; it has been recently included in the 14th Sustainable Development Goal "Life below water". These coupled models well represent the present situation of surface water quality.

An agroecological scenario was established for 2050 based on the projection for the population and no change in land uses (forest, grassland and arable cropland), activating three mains levers: i) long and diversified crop rotations including legumes, ii) reconnection of crop and livestock farming , and iii) a reduction of animal product consumption in human diet. Explored at the scales of the NUTS2 of the West European regions, this scenario showed a biophysical capability for a vegetal and animal production feeding the human population, while strongly reducing the losses to the atmosphere, in terms of N_2O greenhouse gas and NH_3 irritating pollutant. Running this scenario with RIVERSTRAHLER led to efficiently decrease nitrate contaminations of surface waters along the aquatic continua of the W-EU Rivers, and the French, Spanish and Portugal Atlantic coasts, thus reducing the potential of coastal eutrophication. However, high and imbalanced riverine nutrient fluxes have not the same effect depending on the characteristics of the marine system receiving the freshwater inputs (morphology, flushing rate…).

GRAFS-RIVERSTRAHLER describing the terrestrial agro-food system of the watershed, and the ecological functioning of the river networks (in terms of nutrient balance or imbalance), represents an integrated view of not only the land-to-sea continuum, but also the water-agro-food system. Such a tool can help actors in multiple sectors (farming, fisheries, tourism, etc.) and policy-makers (water authorities, etc.) to make harmonized choices for a sustainable environment.

PL3

EXPECTING THE UNEXPECTED AND LEARNING FROM SCIENTIFIC SURPRISES: LESSONS FROM PLANT DETRITAL EFFECTS ON ECOSYSTEM FUNCTION

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Science starts with clear mechanistic hypotheses, which are statements about what we expect to find and why we expect certain results. True progress is made when our hypotheses are rejected. I will discuss three examples of results that initially made no sense and that were questioned, but that led to significant advances in our thinking of how plant detrital inputs influence nutrient cycles and soil carbon (C) and nitrogen (N) sequestration.

The first two "surprises" came from the Detrital Input and Removal Treatment (DIRT) network. In this experiment, plant litter treatments include the doubling of litter, removal of aboveground litter, removal of all above and below ground litter, removal or roots, and doubling of woody inputs. Existing models predicted that increases in litter inputs would lead to increased soil C sequestration. However, the first few full network experiments showed that C sequestration did not increase with aboveground litter additions, and in fact some showed slight losses of soil C. Although these results were initially assumed to be erroneous, data from soil respiration measurements suggested that unexpectedly high priming of soil C by aboveground litter inputs may outweigh the positive effects of C inputs to soil, except in soils that are initially highly depleted in C.

The second puzzling result was the observation that removal of all belowground inputs did not lead to significant decreases in soil C, even after several decades. In fact, "no root" plots showed significant increases in mineral associated organic matter. Although initially attributed to sampling error and spatial variability, we soon realized that the removal of live roots had led to the cessation of priming by the rhizosphere, and the large influx of dead roots allowed for greater microbial stabilization of soil detrital inputs. These results also showed an outsized role of priming by the rhizosphere. They also suggests that C saturation of soils may never exist, and that the concept of saturation should be replaced by models of equilibrium between microbial stabilization and destabilization of C stores.

The focus on detritus also led to a potential understanding of a modern paradox, namely that of the recent oligotrophication of streams across New England. Classic conceptual models suggest that these maturing forests should experience lower N demand and thus greater N losses to streams compared to younger aggrading forests. In order to explain the unexpectedly lowering NO_3^- losses from maturing forests, we developed a new conceptual model with the hypothesis that tree turnover and the resulting increased coarse woody debris input to the forest floor with forest maturation would lead this high C:N detritus to act as an N sink, thus lowering N losses. Taken together, these data show that plant litter can have unexpected and unexplored effects on ecosystem biogeochemistry, and that data surprises can lead to new advances in ecosystem theory.

PL4

TOWARDS UNDERSTANDING THE DRIVERS AND DYNAMICS OF CANOPY METHANE EMISSIONS OF BOREAL TREES

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Still today, 17 years after the first finding of aerobic methane (CH_4) emissions from plants (Keppler et al., 2006), CH_4 production processes in plant foliage are poorly understood and their importance to the global CH_4 cycle remains unresolved. Laboratory studies have reported small emissions or zero fluxes of CH_4 from plant leaves, and that these emissions occur under solar radiation and high temperatures, where they are stimulated by plant stress. Importantly, most published studies to date have been based on manual measurements that give snapshots of the CH_4 exchange, neglecting day-to-day and hourly variability in the CH_4 fluxes. We have developed an automated measurement system that can record CH_4 and other trace gases from tree shoots at hourly intervals across multiple replicate chambers. We have tested this setup in controlled climate chamber and greenhouse conditions with tree saplings and refined our protocol to avoid any disturbance to the trees which might otherwise perturb their natural CH_4 fluxes.
Here, I will present some of the technical challenges we have overcome during the process of building and implementing the automated system to measure tree shoot CH_4 fluxes. I will give examples of these fluxes from boreal tree saplings and mature trees growing in the field, and show how this work integrates with our research on plant microbes and process modelling. These approaches give insights about the potential for *in-situ* CH_4 production/consumption in plant tissues and the role of CH_4 transport from soil to the canopy in boreal upland trees. With these steps, we are closer to understanding the processes behind aerobic CH_4 emissions from tree canopies, which will eventually enable us to estimate their contribution to whole-forest CH_4 exchange.

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PL5

LESSONS LEARNED FROM LONG-TERM EDDY COVARIANCE FLUX MEASUREMENTS OF CARBON DIOXIDE AND METHANE OVER NON-TIDAL AND TIDAL RESTORED WETLANDS IN THE SAN FRANCISCO BAY-DELTA ESTUARY

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We have been making measurements of greenhouse gas fluxes over a network of restored wetlands since 2010. One set of sites includes non-tidal freshwater wetlands of varying ages and degrees of development. They include one site established in 1997, another in 2010, and others established in 2015 and 2017. The first years of establishment can produce huge pulses in respiration and can sustain extremely high rates of methane production. As the ecosystems age, we are finding that they manage to be strong net carbon sinks, and their methane fluxes have dropped by half. Hence, their timeline to become greenhouse gas sinks using the Sustained Greenhouse gas Warming Potential model dropped from about 250 years to 80 years. Our other set of sites included two tidal wetlands that span the salinity gradient of the bay estuary. These sites were breached in October 2021, so results on their performance are preliminary. However, by comparing long-term eddy flux measurements with soil carbon accumulation rates, we have learned that lateral losses of carbon are important in tidal wetlands and that eddy flux measurements and soil accretion match in non-tidal wetlands. One challenge of studying tidal wetlands is the need to measure lateral flows of carbon. The second challenge is associated with the spatial mosaic of vegetation and water that changes with time and wind direction. By combining flux footprint theory with our long-term flux measurements, we are able to detect and quantify methane fluxes from hot spots, which paves the way to improve our understanding of the biogeochemical processes leading to high methane emissions.

PL6

MICROBIAL DRIVERS OF METHANE EMISSIONS FROM SAN FRANCISCO BAY WETLANDS

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Wetlands are important global carbon sinks, yet many have been destroyed and converted to other uses over the past few centuries, including farming and industrial salt making. A renewed focus on the ecosystem services wetlands provide, including flood control and wildlife habitat, has resulted in efforts to convert and restore wetland environments to a more natural state. We have investigated the impact of restoration projects on wetland microbial community composition and metabolic functional potential, along with associated changes in greenhouse gas fluxes, at sites of varying salinity across the San Francisco Bay-Delta region. While methane fluxes generally declined with salinity, reflecting the outcompetition of methanogens by sulfate reducers with increasing seawater-derived sulfate, methane emissions were unexpectedly high in both oligohaline (~3 ppt salinity) and hypersaline (>40 ppt) sites. Taxonomic and functional gene data from sediment core DNA suggested multiple mechanisms of methane production and consumption are at play, with different processes dominating in different locations. In the freshwater and oligohaline wetlands of the Sacramento-San Joaquin Delta, structural equation modeling based on microbial abundances and biogeochemical features indicated that complex interactions among carbon and nitrogen cycling microorganisms dictate net measured methane fluxes. In restored and unrestored industrial salt ponds of the South San Francisco Bay, metagenomic analysis and substrate incubation experiments suggested that methane generation results from a combination of archaeal methanogenesis and bacterial degradation of methylphosphonates, a nontraditional pathway of methane production recently found to be important in marine and other environments. Finally, the impact of restoration on methane flux was dependent on local biogeochemical factors, reinforcing the importance of developing a predictive understanding of methane production to maximize climate benefits of restoration projects.

PL7

TROPICAL TREES AND METHANE EXCHANGE: HOW TREES HELP SOLVE PROBLEMS IN REGIONAL AND GLOBAL METHANE BUDGETS

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Methane, the second most important greenhouse gas after carbon dioxide has seen recent rapid growth in atmospheric concentration. If this increase continues at the current rate it is likely to add an additional 0.5 W/m^2 to Earth's radiative balance by 2100 which would threaten our ability to meet Paris Agreement climate obligations. Given the role of this powerful, but short-lived greenhouse gas in determining future climate there is increased interest in fully understanding the methane cycle including natural contributions to the atmospheric methane burden. However, there have been problems, chiefly surrounding resolving regional and global methane budgets and reconciling the ways they are calculated via so called 'bottom up' and 'top down' approaches.
I will present findings that shed light on how the woody surfaces of trees that dominate productivity in tropical ecosystems such as peatlands, seasonal floodplains and upland forest, each of which were previously thought to be neutral in the exchange of methane, are now known to be important mediators of this trace gas. These interactions are examined in detail at a range of scales as they present opportunities in helping to quantify and account for prior gaps in regional budgets while also identifying sources of new complexity and uncertainty with work needed to understand hydrological, species and within and between-tree variability.
In this talk, I demonstrate the importance of understanding tree methane exchange for SE Asian peatlands and the Amazon methane budget, and present new findings that show how riparian trees can remain sources of methane when not flooded with implications for broader tropical methane budgets. I further present findings on methane exchange in upland tropical trees, about which there has been much conflicting information. This new evidence, spanning climate gradients, further implicates upland trees in determining past changes in atmospheric methane concentration with examples drawn from specific times in Earth history. I conclude by highlighting future areas of importance in this growing area of ecosystem biosphere/atmosphere exchange research at a time when forest expansion is promoted in order to meet Paris agreement targets.

PL8

INSIGHTS INTO FOREST-ATMOSPHERE-CLOUD-CLIMATE INTERACTIONS

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Climate determines to large extent the living conditions on Earth – for humans, plants and animals. The biosphere is in constant interaction with the other components of the Earth system: the atmosphere, hydrosphere, cryosphere and geosphere. Through these interactions the biosphere can in turn influence the climate and participate in various climate feedback mechanisms. These feedbacks are still poorly quantified although potentially important for e.g. accurate projections of future climate and hence also needed for designing effective policy measures for reaching the targets of the Paris agreement. In my presentation, I will focus on interactions between the forest ecosystems and the atmosphere. More specifically, I will present recent studies that investigate the links between forests, atmospheric chemistry, atmospheric aerosol properties and loadings, clouds, precipitation and climate.

It has been proposed that under the warming climate, emissions of volatile organic compounds (VOCs) from forests will increase, which will lead to enhanced production of secondary organic aerosol (SOA). Depending on how the SOA material is distributed within the atmospheric aerosol size distribution, the increased emissions might lead to increase in the numbers of atmospheric Cloud Condensation Nuclei (CCN) which could lead in turn to enhanced Cloud Droplet Number Concentrations (CDNC), influencing the radiative properties of clouds and hence potentially feeding back to a climate forcing (e.g. Kulmala et al., 2013). While first experimentally-based evidence of the presence of this feedback have been presented (e.g. Yli-Juuti et al., 2019), the total magnitude of this feedback is still uncertain (e.g. Sporre et al., 2020). In my presentation, I will highlight some of our recent work towards understanding the key processes associated with this feedback (particularly linked to aerosol-cloud interactions) and their representation within present global models. Although a large focus has recently been on the ways that forests potentially influence clouds and precipitation, it should also be borne in mind that clouds and precipitation also influence the lifetimes and transport of atmospheric aerosol particles and their precursor vapors. Finally, I will also discuss these mechanisms and recent advances on the topic (e.g. Bardakov et al., 2021) as part of my presentation.

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PL9

NITROUS OXIDE – LAUGHING GAS IS NO LAUGHING MATTER

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Nitrous oxide (N_2O) is the third most potent greenhouse gas (GHG) and its mixing ratio is increasing steadily, at approximately 2 per cent per decade. In addition to its climate impacts, the N_2O emissions weighted by ozone-depletion potential (ODP) are the largest of all ozone-depleting substances, making it crucial for mitigating stratospheric ozone depletion. Despite its importance, there are significant uncertainties in the global estimates of N_2O emission sources and sinks. Natural and agricultural soils are considered major sources of N_2O globally, with emissions from Asia being recognized as the leading contributor. However, when the agricultural impacts on climate are considered, the discussion is often focused on carbon dioxide (CO_2) and carbon sequestration, neglecting the importance of N_2O, methane (CH_4), and ammonia (NH_3). Although N_2O is known as a laughing gas, it is not a laughing matter and the recent growth in N_2O emissions highlights the urgency to mitigate them. In this talk, I will first present recent findings related to estimates of N_2O emission sources and magnitudes using both top-down and bottom-up approaches. Then, I will discuss results from a climate-smart agriculture project that aims to mitigate all four trace gases (CO_2, CH_4, N_2O, and NH_3) simultaneously in a maize field, while keeping the yield intact.

PL10

BLUE METHANE: BIOGEOCHEMICAL LIMITS AND OPPORTUNITIES FOR MANAGING WETLANDS TO MITIGATE CLIMATE CHANGE

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Tidal marshes, mangroves, and seagrasses provide opportunities to mitigate greenhouse gas emissions while also incentivizing conservation, management, and restoration of these ecologically important ecosystems. However, there are significant barriers to translating this potential into action. Chief among these is the challenge of understanding and quantifying methane emissions. High-salinity coastal wetlands are very attractive for blue carbon projects because the sulfate in seawater supports sulfate-reducing bacteria that effectively suppress methanogenesis, but many coastal ecosystems occur at low salinity levels and emit substantial amounts of methane. From a climate perspective the most successful and profitable blue carbon activities maximize sequestration while minimizing methane emissions. Yet, the biology and ecology of the plants and microbes that inhabit these ecosystems puts significant limits on our ability to optimize for greenhouse gas mitigation. There is a strong tendency for actions that increase the capacity of coastal wetlands to sequester carbon dioxide to also increase methane emissions. We need a more nuanced understanding the biogeochemical processes by which methane is produced, oxidized, and emitted to defeat the tendency toward greenhouse gas homeostasis.

Methane oxidation can be enhanced by increasing the amount of time the water table is below the soil surface, or by favoring plant species that transport oxygen into otherwise anoxic soils at very high rates. The effects of water table or flooding manipulation are well known, but there is little known about the ability of plants to reduce methane emissions by transporting oxygen. Attention to methane-reducing plant traits may be advantageous for coastal carbon restoration projects. However, certain plant traits, such as rapid oxygen transport, may stimulate soil organic matter decomposition through oxygen-priming effects, offsetting a portion of the greenhouse gas benefits of lower methane emissions.

The high global warming potential of methane can be an advantage in cases where the project reduces emissions. Impoundments created by building dikes, roads, and similar activities isolate coastal wetlands from tidal flooding and the delivery of sulfate. The restoration of tidal flooding reconnects wetland and aquatic habitats and often lowers methane emissions. Recent inventory work shows there is significant potential in the United States to restore impounded coastal wetlands while also reducing greenhouse gas emissions.

Implementing blue carbon inventories or projects requires a full accounting of greenhouse gas sinks and sources. The sinks are relatively well constrained by plant biomass and soil carbon stocks, but accurate budgets for methane remain a challenge. A variety of data-model integration projects are underway aimed at providing tools that improve the spatial resolution of coastal wetland carbon stocks, stock change, and methane emissions. Advances in blue carbon science demand that we delve deeper into the causes of spatial and temporal variability in greenhouse gas emissions and translate knowledge into tools to support blue carbon projects.

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Oral presentation abstracts

I SESSION

Nutrient and carbon fluxes at catchment/landscape level,
remote sensing of biogeochemical fluxes

I-O1

INTEGRATION OF AQUATIC AND TERRESTRIAL FLUXES TO IMPROVE LANDSCAPE-ATMOSPHERE CARBON EXCHANGE ASSESSMENTS

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Atmospheric carbon dioxide and methane concentrations have greatly increased since pre-industrial times due to anthropogenic emissions, leading to a global change crisis. Developing effective strategies to mitigate global change requires an improved understanding of the different sources and sinks of atmospheric carbon (C) across the globe. Carbon exchange between the continents and the atmosphere is the most uncertain component of regional and global carbon budgets. One of the main sources of this uncertainty is that the continental landscape is made up of a heterogeneous mosaic of elements (e.g., forests, wetlands, and inland waters) that each has its own set of ecosystem properties and processes. This heterogeneity has led to the compartmentalization of the landscape C budget with each element treated independently from the other. Nevertheless, this compartmentalized perspective tends to overlook aspects of the structure and functioning of the landscape that link these elements together, such as lateral C exchange. Therefore, current bottom-up estimates of the landscape-atmosphere C exchange may be biased. We are working towards a more holistic framework that not only integrates the main landscape elements but also the exchange of C between them. More specifically, this framework effectively integrates the origin, lateral movement, and the fate of C across the landscape, using the watershed as a natural, directional spatial unit. Based on this framework, we propose a new indirect approach to estimate the watershed-atmosphere C exchange based on constraining the net accumulation of C in the watershed with the lateral export to the ocean through rivers. This novel approach provides a complementary perspective to landscape-atmosphere C exchange estimates provided by top-down and bottom approaches and may contribute to constraining these estimates and reducing their current uncertainty. Furthermore, the proposed framework offers a platform to increase communication and synergy between the different terrestrial, aquatic, and atmospheric research communities as well as a guide to defining research challenges and opportunities across disciplines.

I-O2

PATTERNS OF ORGANIC CARBON QUANTITY AND QUALITY FROM TREE TOP TO RIVER MOUTH

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Our group has investigated organic carbon cycling in the Connecticut River basin in the northeastern USA. We tested the pulse-shunt concept, which puts forth that during high flow, dissolved organic matter (DOM) can travel long distances through the stream network with little degradation or change in quality. In throughfall from the forest canopy, fluorescent DOM averaged 65% humic-like and 35% protein-like. In streamwater, these fractions shifted to 80-90 % humic-like and 10-20% protein-like. During storm events, the protein-like fraction increased, and the humic-like fraction became increasingly aromatic. The dissolved organic carbon (DOC) flux in throughfall was dominated by small events, and over the growing season was 2-3 times greater than stream DOC flux, which was dominated by large events. In the forested headwaters, DOC increases sharply from ~1 mg/L to nearly 20 mg/L during high flow when groundwater rises and flushes organic-rich near-surface soil horizons. Slow travel time of this DOM within the subsurface causes DOC to peak on the falling limb of the hydrograph (counterclockwise hysteresis). The magnitude of hysteresis increases through the mesoscale (~1000 km^2) due to increasing travel times within the river network. Larger-scale rivers in the basin trend toward chemostasis as allochthonous DOM entering at high flows progressively degrades and is balanced by autochthonous DOM at low flow in warmer months. Photomineralization accounted for less than 10% of DOM loss from the Connecticut River system. These dynamics are superimposed on a long-term stream DOC increase from soil particle disaggregation in response to acid rain recovery.

I-O3

DISSOLVED ORGANIC CARBON FLUXES IN FORESTS UNDER DIFFERENT RAINFALL REGIMES: COUPLING HYDROLOGICAL AND CARBON FLUXES MODELS

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The omission or lack of representation of certain processes such as carbon losses by leaching, and the temporal/spatial distribution of carbon fluxes contribute to uncertainties in soil carbon fluxes simulations. It is also known that dissolved organic carbon (DOC) export is strongly affected by hydrological processes. These fluxes are not limited to plot or field scale, but they occur at larger spatial scales; they need thus to be considered in simulations. In the last years, several efforts have been made to tackle these limitations and reproduce DOC dynamics. However, most of these models are detailed physically based, being computationally expensive, or they are empirically based. Therefore, this study aims to use conceptual modeling to represent the spatial and temporal distribution of DOC fluxes as a response to rainfall regimes and variability of landscape features. This should allow the quantification of DOC export specifically at two ICOS experimental sites (Brasschaat and Vielsalm forest areas in Belgium) as part of a catchment system where water interactions occur. This approach pursues performing relatively fast calculations while considering the interaction between atmosphere, biosphere, and aquatic components in a simplified manner. The main hypothesis of this study is that rainfall regimes, together with phenology are the main drivers of DOC export. For accomplishing this goal, the coupling of hydrological and soil organic carbon (SOC) models using PCRASTER software was performed. The hydrological spatially distributed model is based on disaggregation of lumped parameters based on landscape characteristics, such as the rainfall-runoff module (VHM). In addition, there is a submodule that includes a multilayer soil moisture representation. The soil organic carbon was simulated based on the RothC scheme, and the DOC will be simulated based on the JULES-DOCM and ORCHIDEE-SOM conceptualization. Production and decomposition processes of SOC and DOC, as well as DOC leaching, were considered per user-defined layer. Carbon dynamics were simulated up to 2 m depth, considering the globally available data per depth such as soil texture and root distribution. The model does not include a dynamic vegetation model, but accounts for the seasonal and vertical distribution of plant residues based on literature values. Preliminary results showed that the spatial patterns of SOC, from which DOC is derived, are in accordance with SOC patterns observed for regional and global maps, such as SoilGrids. Furthermore, results for Brasschaat showed that the magnitude and seasonal distribution of heterotrophic respiration, actual evapotranspiration, and to some degree soil moisture is in accordance with field observations. Based on the further implementation of the DOC module, it will be possible to analyze the interactions with DOC export and hydrology, and the potential influence of future rainfall events in the context of climate change scenarios in these fluxes.

I-O4

THE ROLE OF TERRESTRIAL PRODUCTIVITY AND HYDROLOGY IN REGULATING AQUATIC DISSOLVED ORGANIC CARBON CONCENTRATIONS IN BOREAL CATCHMENTS

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The past decades have witnessed an increase in dissolved organic carbon (DOC) concentrations in the catchments of the Northern Hemisphere. Increasing terrestrial productivity and changing hydrology may be reasons for the increases in DOC concentration. The aim of this study is to investigate the impacts of increased terrestrial productivity and changed hydrology following climate change on DOC concentrations. We tested and quantified the effects of gross primary production (GPP), ecosystem respiration (RE) and discharge on DOC concentrations in boreal catchments over 3 years. As catchment characteristics can regulate the extent of rising DOC concentrations caused by the regional or global environmental changes, we selected four catchments with different sizes (small, medium and large) and landscapes (forest, mire and forest-mire mixed). We applied multiple models: Wavelet coherence analysis detected the delay-effects of terrestrial productivity and discharge on aquatic DOC variations of boreal catchments; thereafter, the distributed- lag linear models quantified the contributions of each factor on DOC variations. Our results showed that the combined impacts of terrestrial productivity and discharge explained 62% of aquatic DOC variations on average across all sites, whereas discharge, gross primary production (GPP) and RE accounted for 26%, 22% and 3%, respectively. The impact of GPP and discharge on DOC changes was directly related to catchment size: GPP dominated DOC fluctuations in small catchments (<1 km^2), whereas discharge controlled DOC variations in big catchments (>1 km^2). The direction of the relation between GPP and discharge on DOC varied. Increasing RE always made a positive contribution to DOC concentration. This study reveals that climate change-induced terrestrial greening and shifting hydrology change the DOC export from terrestrial to aquatic ecosystems. The work improves our mechanistic understanding of surface water DOC regulation in boreal catchments and confirms the importance of DOC fluxes in regulating ecosystem C budgets.

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I-O5

ASSESSMENT OF ACIDITY AND EUTROPHICATION CRITICAL LOADS IN PRODUCTION FOREST DRAINAGE CATCHMENTS AND AFTER DIFFERENT INTENSITY REGENERATION FELLINGS

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As forest drainage systems often commence the local hydrological network, good water quality in runoff is important to maintain connected waterbodies in good condition. Forestry activities e.g., drainage system maintenance or regeneration fellings may alter the water quality in catchments as well as in runoff. In Latvia, most of the anthropogenic pollution to ecosystems is air-borne and comes from transboundary sources while in drained forested catchments elevated concentrations of plant nutrients may be leached due to management induced disturbances. To evaluate the impact and determine if ecosystem may be at risk, critical load (CL) modelling approaches are handy and already used in several countries. CL are quantitative estimates of an exposure to pollutant deposition.

The main objectives of the study were to evaluate acidification and eutrophication risks in runoff of five relatively small forested drained peatland catchments (30-131 ha) and in three locally typical forest site types (oligotrophic, mesotrophic, eutrophic) after different intensity regeneration fellings (stem only harvesting (SOH), whole tree harvesting (WTH) and control (C) where stands were left intact). The *Steady-State Water Chemistry* (SSWC) and *First-Order Acidity Balance* (FAB) models were used for the estimates. Observations in the catchments date back to 1997; observations in the regeneration felling sites date back to 2012 (one year prior fellings).

All five drainage system catchments presented high mean acidity critical loads (CL(A)) (890-1867 $mEq \cdot m^{-2} \cdot yr^{-1}$), high mean S critical loads (CL(S)) (958-1840 $mEq \cdot m^{-2} \cdot yr^{-1}$) and high mean N critical loads (CL(N)) (3872-4588 $mEq \cdot m^{-2} \cdot yr^{-1}$). Generally, since 1997 all three CL values were gradually declining, but in the latest years of observations (2015-2020) they increased significantly in all catchments. Factual mean S loads by precipitation ranged from 17 to 20 $mEq \cdot m^{-2} \cdot yr^{-1}$, while mean N loads by precipitation ranged from 21 to 41 $mEq \cdot m^{-2} \cdot yr^{-1}$ and mean N loads in runoff ranged from 6 to 74 $mEq \cdot m^{-2} \cdot yr^{-1}$. Catchments during all observation years have been providing good buffering capabilities because of organic soils in combination with high basic cation concentrations.

In the plots of the felling sites mean CL(A) ranged from 73.1 $mEq \cdot m^{-2} \cdot yr^{-1}$ in oligotrophic site to 845 $mEq \cdot m^{-2} \cdot yr^{-1}$ in eutrophic site. Mean CL(S) ranged from 84 $mEq \cdot m^{-2} \cdot yr^{-1}$ in oligotrophic site to 886 $mEq \cdot m^{-2} \cdot yr^{-1}$ in eutrophic site while factual mean load from precipitation was 12 $mEq \cdot m^{-2} \cdot yr^{-1}$. Mean CL(N) ranged from 144 $mEq \cdot m^{-2} \cdot yr^{-1}$ in oligotrophic site to 1518 $mEq \cdot m^{-2} \cdot yr^{-1}$ in eutrophic site while factual mean load from precipitation ranged from 18 to 39 $mEq \cdot m^{-2} \cdot yr^{-1}$ and mean load in runoff ranged from 21 to 392 $mEq \cdot m^{-2} \cdot yr^{-1}$. Following the regeneration fellings all three CL values decreased in WTH plot of the eutrophic site and in SOH and WTH plots of the mesotrophic site. CL(S) and CL(N) increased in SOH and WTH plots of the oligotrophic site, but CL(A) increased only in WTH plot. No exceedances of CL(A) and CL(S) were observed. Exceedances of CL(N) in runoff were detected in SOH and WTH plots of the mesotrophic site two to three years after felling and in SOH plot of the oligotrophic site almost for all period of observations.

I-O6

RELATIONSHIPS BETWEEN VEGETATION COMPOSITION AND GROUNDWATER CHEMISTRY IN FORESTED RIPARIAN ZONE

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As a result of increasing anthropogenic impacts and climate change, pollution and eutrophication has become one of the most serious environmental quality problems in recent decades. The quality of surface water continues to deteriorate worldwide. To implement efficient protection measures and mitigation strategies, knowledge on different factors influencing it is of utmost importance.
Vegetation of riparian zones may reduce the adverse impacts of nutrient leaching and coastal erosion, at the same time maintaining and enhancing many aspects of biodiversity. For this reason, protection zones are established around water bodies and watercourses in order to restrict economic activities in the vicinity of water and to limit management-related intervention.
Recent studies have demonstrated that coastal vegetation has a major impact on the quality of a river ecosystem. Riparian zone vegetation controls groundwater inputs to rivers by regulating nutrient leaching into groundwater, but research on how different vegetation composition and plant species affect the chemistry of riparian groundwater is still incomplete. However, these impacts need to be studied in order to be able to plan successful and sustainable buffer zones and prevent the negative impact of the environment.
In this research we focus on the relationship between riparian vegetation and groundwater chemical composition in the hyporheic zone which is the part of riparian zone where groundwater is mixing with surface water. Study was done in 1,4 km long section of river Tora in Aģe river sub-basin (part of the Gauja small river basin district) located in the northern part of Latvia. In total 7 transects representing forests of different tree species, ages and structures were established along the selected section of the river Tora. Vegetation was identified in each transect in a 50-meter strip from the watercourse, while groundwater samples in each transect were collected over a 9-month period, from May 2021 to March 2022. The chemical parameters investigated were pH, electrical conductivity, dissolved organic carbon, total nitrogen, $N\text{-}NO^{3-}$, $N\text{-}NH^{4+}$, $P\text{-}PO_4^{3-}$, K^+, Ca^{2+} and Mg^{2+}.
First results of this research shows that coniferous and deciduous trees have different effects on riparian groundwater chemistry due to amount, composition and decomposition of litter. Transects where deciduous trees dominate over coniferous trees are characterized by higher groundwater concentrations of dissolved organic carbon, total nitrogen, and nitrates. Some chemical parameters differed significantly between seasons. Also increased concentration of $N\text{-}NH4^+$ was observed in those transects where logging residues were left. At the same time, none of the analyzed nutrients exceeded limit values indicating efficient nutrient retention capacity in the forested buffer zone.
The study was performed within the frames of project "Implementation of River Basin Management Plans of Latvia towards good surface water status" (LIFE 18 IPE/LV/000014).

I-O7

SPATIAL AND TEMPORAL VARIABILITY OF DISSOLVED ORGANIC MATTER ACROSS THE TERRESTRIAL−AQUATIC CONTINUUM

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Dissolved organic matter (DOM) is an important component in carbon and nutrient cycles in terrestrial and aquatic ecosystems. For three decades, concentrations of dissolved organic carbon (DOC) have been increasing in European and North American surface water bodies. The increase has been mainly attributed to export of DOC from terrestrial ecosystems. Depending on the hydrological regime in a catchment (stormflow vs. baseflow conditions), the flow pathways through different soil horizons are varying and in result, the drivers determining the amount and chemical composition of DOM vary as well. By studying soil water and surface water at the catchment scale, we aim at identifying the main sources and environmental conditions driving the ongoing trend of increasing DOM in aquatic ecosystems.

To understand the spatial and temporal variations of the export of DOM from soils to surface waters a catchment in the Ore Mountains (Germany) was monitored along the terrestrial−aquatic continuum for 1 ½ years. We installed plate lysimeters and suction cups to collect soil water at three depths, including topsoil organic and subsoil mineral horizons at four different sites (peatland, degraded peatland, cambisol and podzol) representing the potential terrestrial DOM sources within the catchment. In addition, two tributaries of the reservoir were equipped with fluorescence-based probes to continuously monitor DOC. All soil and stream water samples were analyzed for DOC, dissolved organic nitrogen (DON), as well as inorganic cations and anions. To identify possible DOM sources, the DOM composition was additionally analyzed by fluorescence spectroscopy (Excitation-Emission-Matrices – EEMs).

We found the different soils contributed differently to the aquatic DOM, depending on seasons and hydrological conditions. The high DOC concentrations in the organic layer and mineral horizons of the podzol did not correspond with high average DOC concentrations in the stream. The stream strongly affected by the peatland had much higher DOC concentrations. All organic topsoil horizons had low DOC concentrations in winter and high concentrations in summer, but only streams fed by peat soils followed this pattern. During stormflow events (snowmelt and strong rainfall), both monitored streams showed DOC concentrations 5 to 6 times higher than the average, illustrating the large potential of all soils (i.e. peatlands, cambisols, podzols) for DOM export. The DOC:DON ratios clearly reflect the differences in DOM composition of the different soils, with high proportions of plant-derived DOM in soil water and the corresponding streams. In conclusion, our research indicates that organic soils, such as peatlands, contribute most to stream DOM under baseflow conditions, while under high-flow conditions, as during snowmelt or rainstorms, mineral soils become additional strong DOM sources. Ongoing analyses of the DOM composition will provide further insights into specific DOM sources and the related spatial and temporal variations of DOM export from soils to surface waters.

I-O8

RANDOM FOREST-BASED MODELING OF STREAM NUTRIENTS AT NATIONAL LEVEL IN A DATA-SCARCE REGION

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Nutrient runoff from agricultural production is one of the main causes of water quality deterioration in river systems and coastal waters. Water quality modeling can be used for gaining insight into water quality issues in order to implement effective mitigation efforts. Process-based nutrient models are very complex, requiring a lot of input parameters and computationally expensive calibration. Recently, ML approaches have shown to achieve an accuracy comparable to the process-based models and even outperform them when describing nonlinear relationships. We used observations from 242 Estonian catchments, amounting to 469 yearly TN and 470 TP measurements covering the period 2016--2020 to train random forest (RF) models for predicting annual N and P concentrations. We used a total of 82 predictor variables, including land cover, soil, climate and topography parameters and applied a feature selection strategy to reduce the number of dependent features in the models. The SHAP method was used for deriving the most relevant predictors. The performance of our models is comparable to previous process-based models used in the Baltic region with the TN and TP model having an R^2 score of 0.83 and 0.52, respectively. However, as input data used in our models is easier to obtain, the models offer superior applicability in areas, where data availability is insufficient for process-based approaches. Therefore, the models enable to give a robust estimation for nutrient losses at national level and allows to capture the spatial variability of the nutrient runoff which in turn enables to provide decision-making support for regional water management plans.

I-O9

LONG-TERM RESEARCH OBSERVATORY OF THE CRITICAL ZONE

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The long-term research Orgeval observatory (https://gisoracle.inrae.fr/) is one of the oldest French observatories of the critical zone. The study site, of ~100km² surface area, is located 70 km east of Paris. To understand the structure, functions and the reactivity of the critical zone (soil, surface, groundwater and atmosphere), measurement of water quality and quantity are carried out at different points and time steps.
The observatory implements a multi-scale observation strategy (from 1 km² to 100 km²), thanks to the nested instrumented sub-catchments, intensively instrumented, to quantify the response of the critical zone system to human activities and metrological events. The meteorological, hydrological or chemical measurements relate to more than 80 measurement stations. They allow long-term observations at different time intervals (hourly, daily or weekly) of precipitation, surface water and groundwater. The reference measurement allows continuous quantification of water and solutes from the soil surface, river stations and groundwater. These measurements include:

- River discharge, river temperature and water sampling stations, for quality analysis purpose, at the outlet of six sub-catchments;
- Precipitation measurement stations supplemented by those of Météo-France;
- Meteorological stations for air temperature, humidity and radiation measurements;
- Soil moisture and soil temperature measurement stations from the soil surface to 1.5 m depth;
- Piezometers along the plateau-valley cross section to monitor the temperature and the hydraulic head variations in the aquifers;
- Local monitoring stations measurements of the stream-aquifer exchanges including: two shallow piezometers, two hyporheic zone temperature profiles located close to each river bank and one water level and temperature monitoring system in the river;
- Geophysical survey (high-resolution time-lapse seismic acquisitions, ERT, optic fiber) to characterize the sedimentary heterogeneities of the critical zone and water table fluctuation.

The monitoring includes a RiverLab prototype installed in June 2015, allowing real time and high frequency (every 30 minutes) measurement of the major ions comprising water quality. A complement ad hoc monitoring, event-based measurement campaign and measurement specific for each research are available. The data collected is available free of charge to the scientific community, with a simple registration on the website (https://bdoh.irstea.fr/).
The observatory is representative of sedimentary basins and artificially drained hydromorphic soils, in the context of intensive agriculture, changes in agricultural policy and climate change. Since its creation in 1962, for floods and erosion issues, the observatory was able to adapt to other societal and environmental issues. The problem of diffuse pollution of agricultural origin, initiated in 1975, has contributed to a better understanding of the interactions between agricultural activities and the chemical quality of surface water and groundwater. Since the 2000s, the problem of pesticides and scientific questions linked to biology and biodiversity have been added. It is also an exploratory platform for technological innovations, such as high-frequency measurement in biogeochemistry and hydrogeophysics.
The observational data support the development and use of numerical models for impact studies and territorial management. This basin is used to test experimental protocols as well as numerical methodologies to be used on a larger scale (e.g. Seine basin).

I-O10

BIOGEOCHEMISTRY AND ECOTOXICITY OF CHROMIUM IN A FORESTED CATCHMENT

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Pluhův Bor (PLB), a small catchment underlain by ultramafic silicate bedrock (serpentinite) and dominantly forested by Norway spruce was monitored for more than 30 years mainly for atmospheric deposition and streamwater chemistry. Comparison of the catchment input and output fluxes in 2015-2021 indicated a significant net flux of chromium (Cr) generated by geogenic sources (Novák et al., 2017). Atmospheric deposition (2 g/ha/yr) accounted for only 3% of the annual streamwater flux (71 g/ha/yr). Mafic and felsic catchments in the vicinity (Na Zeleném and Lysina) exhibited much smaller streamwater fluxes, only 3 and 4 g/ha/yr, respectively. The mean streamwater Cr concentration was 18 µg/L and the discharge-weighted mean was 30 µg/L at PLB thus reflecting a positive correlation with discharge. Streamwater Cr values > 10 µg/L were detected in 85% of cases. Standard dissolved fraction (<0.45 µm) was 90% of total Cr (Fig. 1). However, a pilot study performed during baseflow in the end of 2021 using ultrafiltration (3 kDa; n=4) showed that truly dissolved fraction was much smaller in streamwater, only in the range of 7-20% (Salles et al., 2022), therefore, suggesting important role of fine colloids. Measurements made in-situ with DGT (Diffusive Gradients in Thin Films), which do not capture colloids, showed toxic hexavalent Cr(VI) concentrations of 1.2-1.5 µg/L and Cr(III) concentrations around 0.65 µg/L. Therefore, the probable no effect concentrations (PNEC; WHO 2009, 2013; 10 µg/L for Cr(III), 4 µg/L for Cr(VI)) were not overrun at PLB. In-situ measurements during high flow events are necessary to assess objectively ecotoxicity of Cr, which will be carried out in the future.

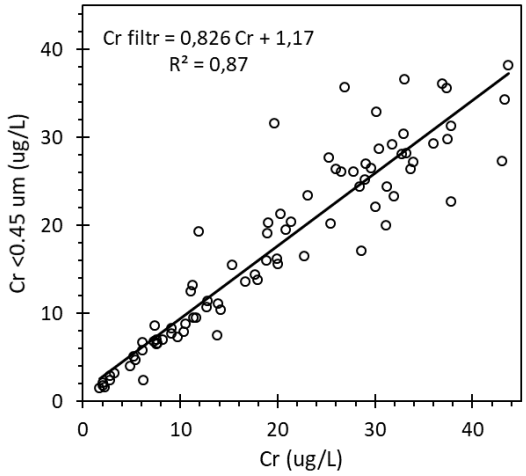

Fig. 1 Comparison of total streamwater Cr and filterable Cr (<0.45 µm) at PLB in 2015-2021.

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I-O11

IMPROVING THE ESTIMATES OF NITRATE CONCENTRATIONS AT THE AGRICULTURAL CATCHMENT SCALE: THE POTENTIAL OF VARIATIONAL DATA ASSIMILATION USING A NEW WATER QUALITY MODEL

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Nowadays, different sources of pollution such as nutrient and pesticides affect the quality of surface water and groundwater. Agricultural nonpoint source pollution coming from the excessive land application of fertilizers is considered by researchers and governments as a concerning and sensitive issue. At the scale of agricultural catchments, modeling nitrate-leaching losses has aroused the interest of several scientists. However, most of developed models require a large number of input data and parameters. Some of them include the complex biogeochemical nitrogen process and can be computationally time-consuming. Moreover, the low frequency of the collected data makes this analysis more difficult.

A new conceptual and tank-based model "Nit-DRAIN" was developed to better access the time-variation of nitrate concentrations [NO3-] at the outlet of subsurface drained catchment (drainage network as hydrological simplification pathway). The model represent a simplified scheme of flow and nitrate transfer processes between the drain and the mid-drain by decomposing this space into a combination of three interconnected compartments. Given the period of nitrate transfer (mainly during winter time), we propose to simplify all biogeochemical transformations of nitrogen and agricultural practices by the remaining pools of nitrate at the beginning of winter season (RNBW). This variable can explain until 80% of the total nitrate flux exported yearly. Hence, Nit-DRAIN model requires only two input variables: the observed discharge and the RNBW. A set of parameters was introduced to regulate nitrate fluxes and discharge transiting through compartments to the drain outlet.

In order to quantify the sensitivity of the model response to its nine input parameters, a global sensitivity analysis based on the adjoint model was implemented. The adjoint model of Nit-DRAIN was generated using TAPENADE automatic differentiation tool. It allows computing the sensitivity of the model response, through its gradient to all parameters values simultaneously. First results indicate that parameters driving the distribution of RNBW and discharge values between the three compartments have the most impact on the model response. Thus, these parameters should be estimated accurately through calibration or data assimilation.

Calibration and validation (C/V) procedures are fundamental to the assessment of the performance and the robustness of water quality models. In this study, the split sample test was carried out on Rampillon (355 ha, data for 3 years) and Chantemerle (36 ha, data for 4 years) datasets. The C/V step was performed using high frequency observations (hourly time-step) of nitrate concentrations and discharge collected by INRAE Research Institute. Both sites, located in the region of Paris in France are subsurface drained. Performance criteria such as KGE (> 0.5) and RMSE (< 5 mgN/l) confirm the very good quality of simulations.

Finally, variational data assimilation method 4D-VAR was implemented to estimate the unknown model inputs. This method, known for its robustness and stability, has been widely used in geophysical sciences. 4D-VAR is based on the minimization of a well-defined cost function using gradient-based minimization methods. It allows to find the best estimate possible of the variables of interest, in this case the RNBW variable, by assimilating observed nitrate concentrations, regardless of the sampling frequency.

I-O12

IMPACT OF FOREST HARVESTING INTENSITY ON THE RELEASE AND BIODEGRADABILITY OF DISSOLVED ORGANIC CARBON IN DRAINED BOREAL PEATLANDS

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Boreal peatlands are vast carbon (C) stores but also major sources of dissolved organic C (DOC) and nutrients (nitrogen (N) and phosphorus (P)) to downstream aquatic ecosystems. Peatland drainage for forestry, as well as forest harvesting, further increases this loading of DOC and nutrients. Partial harvesting, i.e. continuous cover forestry (CCF) is considered to cause fewer adverse environmental effects than conventional even-aged clear-cutting. Yet, the effects of CCF on water quality, the biodegradability of DOC, and consequent CO_2 emissions from inland waters are poorly known. We studied the groundwater DOC and nutrient concentrations in field and column experiments in unharvested, CCF, and clear-cut drained peatland forests in Finland. We also studied the effects of harvesting intensity on DOC quality and the rate of DOC biodegradation to CO_2 with incubation experiments.

Our column experiment did not separate the CCF, clear-cut, and unharvested forests in terms of DOC and nutrient concentrations, DOC quality, or DOC biodegradation rate. However, in the field, we detected the highest groundwater DOC, N, and P concentrations as well as DOC biodegradation in the clear-cut plots, whereas the DOC and nutrient concentrations did not differ in general between the CCFs and the uncut control plots.

The lack of management effect in our column study was likely attributed to controlled abiotic conditions (water table, temperature, lack of trees) between the peat columns from differently managed forests. Thus, it can be interpreted that peat being exposed to long-term drainage is not vulnerable to changes per se, but that forest management alters multiple biotic and abiotic factors that independently and interactively control the production, transport, and decomposition of DOC. Consequently, our results from the field suggest that the partial harvesting used in CCF may cause smaller DOC and nutrient export and therefore lower aquatic CO_2 emissions than the conventional clear-cutting in drained peatland forests.

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I-O13

SOURCES AND SINKS OF GREENHOUSE GASES IN THE LANDSCAPE

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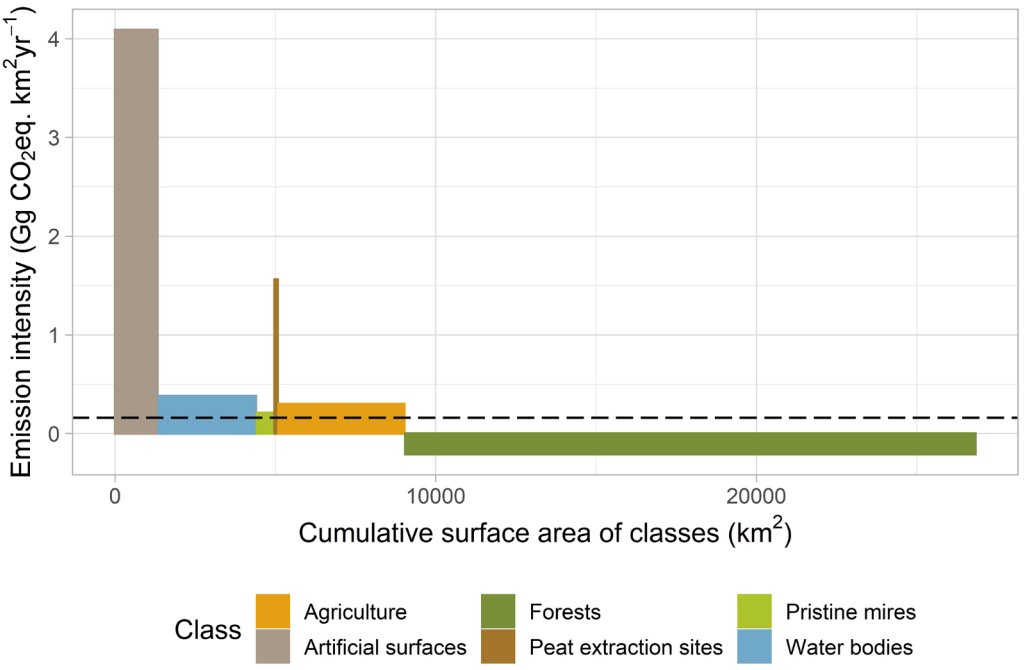
Spatially explicit data on the sources and sinks of greenhouse gases (GHGs) supports planning of ecosystem management actions, and mitigation of anthropogenic emissions. We estimated fluxes of carbon dioxide, methane and nitrous oxide for a river basin in Finland, using simulations with the PREBAS forest growth model and the FRES anthropogenic emissions model, together with area-based emission coefficients reported in literature for water bodies, peatland and agriculture. Emissions from fuel combustion in energy production, heating and road transport made artificial surfaces the most emission intensive land-cover class. Water bodies were as emission intensive as agricultural areas. Forests were abundant, covering 66% of the area, and providing the only significant carbon sink of the region. The forest carbon sink decreased the net emissions by 72%.



Net emission intensities by land cover class (Gg CO_2-eq km^{-2} yr^{-1}). The dashed line gives the average net emission intensity 0.16 Gg CO_2-eq km^{-2} yr^{-1}. For the entire Kokemäenjoki area the net emissions amount to 4.37 ± 1.43 Tg CO_2-eq yr^{-1} (Holmberg et al. 2021).

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I-O14

PARTICULATE ORGANIC MATTER TRANSPORT FROM STREAMS TO LAKES. RELATIONSHIPS TO RESERVOIR GHG EMISSIONS

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Transport of coarse particulate organic matter (CPOM) derived from forest litterfall has been hardly studied in rivers, unlike fine particulate organic matter (FPOM) or dissolved organic matter (DOM). Yet, many rivers are dammed or run into lakes, so that CPOM export from rivers may participate substantially to the greenhouse gas emissions of lakes and reservoirs.

We investigated the transport of CPOM and FPOM by the Leysse River (discharge from 0.2 to 106 m^3 s^{-1}) to Lake Bourget (France) in relation to aerial litter deposition, river network length, and discharge. Over a 19-month study period, the volume-weighted mean CPOM and FPOM concentrations were 1.3 and 7.7 g $m^{-3,}$ respectively. Most CPOM and FPOM transport occurred during major flood events, and there were power relationships between maximum discharge and particulate organic matter (POM) transport during these events. The annual export of CPOM (190 t AFDM) was 85% of the litter accumulation in autumn on permanent sections of the riverbed (224 t AFDM), which suggests that export is a major process compared to breakdown. Export of CPOM was 1.25 t yr^{-1} km^{-2} of the forested catchment area.

The impact of CPOM accumulation on GHG emission was studied in a small hydropower reservoir draining a large and mostly forested watershed. Although the water body was never anoxic, we measured a strong emission of methane, both by diffusion and bubbling. This methane was produced in the litter accumulated in the sediment, especially during water level changes.

The study shows that litter export from streams to lakes and reservoirs contributes substantially to the GHG emission of lakes and reservoirs in forested mountainous landscapes.

I-O15

ECOLOGICAL FLOWS AS INDICATOR OF HEALTHY RIVER ECOSYSTEMS

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According to Water Framework Directive (WFD) 2000/60/EC river hydromorphology is one of parameters to assess ecological quality. About 150 small hydropower plants (HPP) are installed on Latvian rivers and about 30% of all river water bodies are under significant hydrological pressure due to hydropower plants. Natural hydrological regime is one of the most important factors to characterize healthy river environment (Sakaris, 2012) and ecological flows, defined as amount of water required for preservation of life processes in rivers, are one of key mitigation measures in human-affected rivers. The aim of this study was to calculate ecological flows for Rivers Ciecere and Losis and to compare these results with good ecological quality standards.
In this study, the ecological flow rate was calculated for three HPP on the River Ciecere and two HPP on the River Losis. Hydromorphological measurements and fish sampling was done in ice-free period of 2020.-2021. Altogether five river stretches below HPPs on both rivers were surveyed four times under different flow conditions: summer low flow minimum, average, maximum and annual average flow. Each time water depth, flow velocity and channel substrate were measured. Depending on river type and size, length of studied stretches varied from 100 to 300 meters. Meso-scale habitat simulation model MesoHABSIM was used to calculate ecological flows and habitat suitability. This model operates with daily flow data, fish habitat suitability model and river habitat units.
Preliminary results show that ecological flows for all surveyed HPPs are insufficient to achieve good ecological status, which is the main objective of WFD. Most of the actual ecological flows specified in the water use permits are calculated as the average flow of the low flow period, but the results of our study show that ecologically more meaningful ecological flow is closer to the maximum flow of the low water period. Our results show that juvenile and adult fish species have different requirements for the amount of water available, and the term "ecological" should be applied not to a single value of flow, but a cluster of flow values that follow a variation pattern similar to the natural regime. Hence, we have changed the expression "ecological flow" to the "ecological flow regime", which includes natural flow fluctuations. To implement these findings changes in legislation acts are needed. Eutrophication also affects fish species and their response to water level alterations.
This work was supported by the Lat-Lit project TRANSWAT (LLI-533).

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Oral presentation abstracts

II SESSION

Biogeochemistry of lakes, rivers and wetlands

II-O1

LINKS BETWEEN CRITICAL LOAD EXCEEDANCE OF N AND S DEPOSITION AND MEASURED IMPACT INDICATORS AT IM-CATCHMENTS IN EUROPE

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Anthropogenic emissions of N and S compounds and their long-range transport have caused widespread impacts on different ecosystems. The critical loads (CL) approach has provided a direct link between effects-based science and the emission reduction policy process under the Air Convention (CLRTAP) and EU negotiations through an integrated assessment modeling framework (Grennfelt et al., 2020). We have computed CLs for eutrophication and acidification at intensively studied ICP IM forested catchments (n=17), using a large European long-term dataset (Vuorenmaa et al., 2018). ICP IM is an effects assessment programme under the Air Convention (https://www.slu.se/en/Collaborative-Centres-and-Projects/integrated-monitoring/). We have calculated exceedances of CLs in a novel way (Forsius et al., 2021) displaying time-series of measured deposition (e.g., Fig. 1), and assessed the link between the site-specific calculations and time-series of CL exceedance (using both measured and modelled deposition) and measured impact indicators (surface water chemistry).

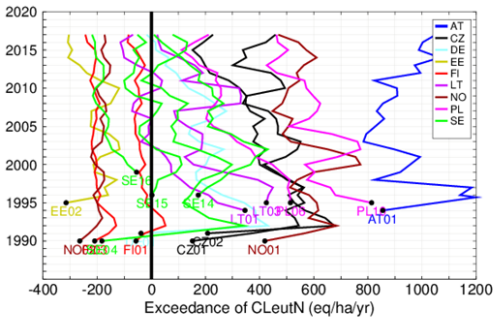

Fig. 1 Exceedance of eutrophication critical loads (CLeutN) over time at the 17 ICP-IM catchments using the total N deposition measurements at the sites. A three-year moving average of depositions has been used to increase clarity. Negative numbers indicate non-exceedance.

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II-O2

ANOXIC AGE AS A NEW TOOL TO PREDICT BIOGEOCHEMICAL CONSEQUENCES OF OXYGEN DEPLETION IN LAKES

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Deoxygenation in aquatic ecosystems, particularly in lakes, threatens ecosystem services delivery and is of growing concerns due to its projected expansion and increased duration. Anoxia consequences include the production or release of nutrients, greenhouse gases and metals from the sediments. Anoxic waters also constitute environments of slow but continuous carbon turnover that possibly harbor unique organic matter (OM) processing routes (Lau and del Giorgio, 2020). Many of these compounds' dynamics cannot be easily predicted thus hindering our capacity to forecast the ecological consequences of global changes on lakes. Here, we present a framework that uses monitoring data from lakes to develop a novel metric termed the "anoxic age" to characterize anoxia in lake hypolimnia.
As a single predictor, anoxic age of hypolimnion samples explained between 44% and 74% of the variation in anaerobic metabolites, including ammonium and soluble reactive phosphorus. We also found that increasing anoxic age gradually alters the chemical, optical and redox properties of dissolved OM. We discuss how the anoxic age framework may be used as a deductive biogeochemical forecast tool and to study lake-scale metabolism and OM processing.

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II-O3

SEDIMENT NITROGEN TRANSFORMATIONS DURING AN ICE-FREE WINTER IN A LARGE, SHALLOW, EUTROPHIC LAKE

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Lake Võrtsjärv is a shallow (2.7 m), large (270 km^2), eutrophic lake in Estonia (EU) subjected to frequent sediment resuspension. The phytoplankton community is dominated by non-nitrogen (N)-fixing cyanobacteria (*Limnothrix* spp.). The lake is typically ice-covered from November into April, but winter 2019/2020 was an extraordinary exception, with brief periods (days) of ice-cover in late November and mid-February, and ice-free conditions for the remainder of the winter. In September and December 2019 and February 2020, we measured sediment oxygen demand, net nutrient fluxes, and N_2 gas production (denitrification/anammox) using intact sediment cores incubated in a continuous-flow system with and without ^{15}N ammonium or nitrate amendments. Differences were observed between a shallow, macrophyte dominated area near the primary river inflow (Väike Emajõgi) and the main lake. Net O_2 consumption was higher near the river inflow and decreased from fall to late winter, but dissimilatory nitrate reduction to ammonium (DNRA) and N fixation were not detected at either location. Anammox may have accounted for up to 4% of total N_2 production. Little or no phosphate was released from sediments, but ammonium and urea were readily released from sediments in the main lake, and from the river-influenced site in fall, even at bottom-water temperatures of 1.2˚C. The two lake areas exhibited opposite responses to isotopic nitrate enrichment. In winter, nitrate enrichment increased N_2 production near the river inflow, but not in the main lake. In fall, N_2 production increased as a result of nitrate amendment in the main lake, but not near the river inflow. Differences in organic matter accumulation and remineralization rates, as well as the degree of coupling between nitrification and denitrification, may help explain these differences, since dissolved organic matter content and molecular weight were higher near the river inflow. Future work will focus on repeating these experiments under-ice during ‘normal’ winter conditions, as well as expanding the sampling regime to spring and summer months.

II-O4

PREDICTING MULTIPLE STRESSOR EFFECT ON ZOOPLANKTON ABUNDANCE, BIOMASS AND COMMUNITY COMPOSITION IN TWO LARGE EUTROPHIC LAKES

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We aimed to investigate the influence of environmental factors on zooplankton biomass and abundance in Lake Peipsi and Lake Võrtsjärv, two large, shallow eutrophic lakes in Estonia. We employed time series of zooplankton and environmental parameters that were measured monthly to build estimates of zooplankton community metrics (biomass, abundance). We used machine learning algorithms (boosted regression trees for Võrtsjärv, random forests for Peipsi) to find the most important predictors of zooplankton abundance and biomass. The analysis of historical time series revealed that temperature was by far the most important variable to explain the change in zooplankton biomass and abundance in both lakes. The second most important variable for zooplankton was pH in Võrtsjärv, whereas water clarity, total nitrogen and the biomass of cyanobacteria are mostly affecting zooplankton community in Peipsi. Models constructed with the best predicting variables explained more than two-thirds of zooplankton biomass variance in Võrtsjärv, but only one third in Peipsi. Most of the predictive variables had opposing or antagonistic interactions. Although temperature and cyanobacteria biomass had individual positive effects on zooplankton biomass, their combined effect was negative. Additionally, three future climate scenarios were developed for Võrtsjärv following different Intergovernmental Panel on Climate Change (IPCC) temperature projections and entered into an empirical model. The scenarios corresponded to a stabilization, moderate increase and strong increase in greenhouse gases emissions. Simulation results showed that only a scenario in which air temperature stabilizes would curb total zooplankton biomass and abundance. Quantitative changes within the zooplankton community are expected: copepods would increase in biomass and abundance, whereas cladocerans would lose in biomass but not in abundance. These changes in the zooplankton community will have important consequences for lake trophic structure and ecosystem functioning. Our findings show that although lake warming alone could be positive for zooplankton, the necessity of reducing interacting stressors that influence harmful cyanobacteria growth, especially nitrogen loads, must be also considered.

II-O5

SEASONAL AND SPATIAL VARIATION OF ALLOCHTHONOUS ORGANIC MATTER CONTRIBUTION IN LAKE FOODWEB

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Lake ecosystems, intimately connected with their catchments, are impacted by terrestrial organic matter flux. It can enter the lake food web by microbial communities, supplying important contribution of carbon and energy sources for consumers, and its loading variation might affect fundamental functions of lake ecosystem. However, it is still not clear how this contribution is significant for the consumer communities. Although previous research indicated that in-lake primary production is the most important source, recent studies found that also allochthonous material represents a significant energy contribution to the food webs of many lakes.
Reflecting the expected importance of terrestrial organic matter to lake food webs and its capacity to affect key functions in lake ecosystems, the main aim of this study was to investigate the role of allochthonous organic matter in the food web of an Estonian eutrophic shallow lake, Lake Võrtsjärv.
Stable isotope analyses of hydrogen (δ^2H), carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) were employed to quantify the contribution of allochthony, represented by inflow of particulate organic matter (POM) and dissolved organic matter (DOM), and autochthony, represented by phytoplankton, for the lake principal consumers macroinvertebrates, profundal chironomids, zooplankton and fish, using two-source mixing model.
Results indicated that the use of hydrogen stable isotopes appeared to be more robust approach to differentiate between terrestrial and aquatic sources of organic matter, if compared to carbon stable isotopes. In general, our findings showed substantial seasonal and spatial variation of allochthonous contribution for the lake consumers. In particular, the allochthony contribution increased from the growing season towards the winter up to 90%, for both profundal chironomids and zooplankton consumers. However, our results indicated high and consistent contribution of autochthony for macroinvertebrates and fish among seasons. Moreover, significant spatial differences in allochthony and autochthony contribution for lake consumers were detected between the North and South parts of the lake. The allochthony contribution was significantly higher for the profundal chironomids in the South part of the lake, whereas it was much lower in the North part, where the contribution of authochtony was more important. Although its spatial and seasonal variation, allochthonous organic matter appeared to be an important source for the consumers of Lake Võrtsjärv, complementing the autochthonous source especially during winter when the latter tended to decrease, particularly for the primary consumers.

I-O6

HIGH GREENHOUSE GAS EMISSIONS AS TRADE-OFF FOR WATER TREATMENT IN CONSTRUCTED WETLANDS TREATING AGRICULTURAL RUN-OFF

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Constructed wetlands (CW) are widespread measures to reduce agricultural diffuse pollution. Systems that are often planted with emergent macrophytes such as *Typha* spp. and *Phragmites* spp. are efficient to reduce nutrients, particularly nitrogen and phosphorus compounds. On the other hand, the dense and intensive vegetation creates ample amount of fresh organic carbon due to the plant litter to sediment layer, providing substrate for microbial processes such as nitrification, denitrification, and methanogenesis. Since constructed wetlands also receive high concentration of nutrients, these systems can become major greenhouse gas (GHG) sources.

The study was conducted on Vända CW in Southern Estonia, which has a catchment area of 2.2 km^2. Approximately 62% of the catchment is under intensive agricultural management. The CW was established in 2015 and consists of two shallow water wetlands (total area ~4500m^2) colonized mainly with cattail (*Typha latifolia*) and common reed (*Phragmites australis*). We measured biweekly N_2O, CH_4 and CO_2 (ecosystem respiration, R_{eco}) fluxes with white closed floating chambers from 12 sampling plots over the wetland (total of 1872 chamber fluxes), collected monthly water samples from wetlands inlet and outlet (total of 450 water samples) and used portable devices to measure water parameters such as oxygen concentration, temperature, pH, flow rate, on site each time along with GHG sampling. Removal efficiency of nutrients (TN, NO_3-N, NO_2-N, TP, PO_4-P) was calculated based on the differences between concentrations in the inlet and outlet of the wetland.

Our results showed that over 90% of CH_4 and N_2O fluxes from the wetland occurred during the warm period (from May to Oct). The average warm half-year period CH_4 emissions were 88 µg C m^{-2} h^{-1} in 2018, 264 µg C m^{-2} h^{-1} in 2019, 812 µg C m^{-2} h^{-1} in 2020, and 2505 µg C m^{-2} h^{-1} in 2021. CH_4 emission increased during the study period probably due to the increase amount of plant litter. Vegetation had spread rapidly, and plant litter accumulated over the years could decompose more intensively due to the higher water level, as it created more suitable conditions for microorganism. The emission of N_2O showed slight decrease over the years. However, almost half of the total wetlands annual N_2O emissions originated from shallow water areas where water table depth was <10cm, although covering only 6% of the total wetland area. Although the GHG emissions were relatively high, the system was also able to reduce up to 85.2% of phosphorus from the agricultural run-off.

Our study showed that in-stream CWs are efficient for nutrient removal but at the same time they are also significant sources of GHG. The study also confirmed that several design criteria and management practices can reduce the GHG emissions, and therefore reduce the impact of these systems to the global warming.

II-O7

SUMMER GREENHOUSE GAS FLUXES IN DIFFERENT TYPES OF HEMIBOREAL LAKES

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Lakes are considered important regulators of atmospheric greenhouse gases (GHG). Taking into account lake typologies based on water chemistry and morphometric features (e.g. as the one established by the European Union Water Framework Directive (WFD)) would allow to improve the assessment of aquatic GHG emissions. We measured open water GHG fluxes and environmental variables in nine hemiboreal lakes in Estonia classified under different lake types according to WFD. We used the WFD typology to further provide an improved estimate of the total GHG emission from all Estonian lakes with a gross surface area of 2204 km^2 representing 45,227 km^2 of hemiboreal landscapes (the territory of Estonia). GHG fluxes were measured with a transparent 31 L floating chamber combined with a portable Fourier transform infrared (FTIR) spectrometer (Rõõm *et al.*, 2014) on one or two occasions at each lake. The studied lakes, representing all the lake types in Estonia and most of the lake types in the whole hemiboreal region, showed a large variety of GHG fluxes. The strongest CO_2 sources were lakes with predominantly allochthonous supplies of either mineral (carbonate rock) or organic (peat) carbon: the alkalitrophic lake with spring water supply (Alk) and the dystrophic lake with high humic substance content (Dark Soft), followed by stratified alkalitrophic and medium alkalinity lakes (StratAlk and StratMedAlk). Three of the nine lake types (Coastal, Light Soft, and Very Large) acted as net CO_2 sinks. CO_2 fluxes correlated strongly with dissolved CO_2 saturation values in surface water. Highest CH_4 emissions were measured from Coastal, followed by Light Soft, StratAlk, and Alk; Coastal, Light Soft, and StratAlk were also emitting CH_4 partly as bubbles. The only emitter of N_2O was Alk. Dark Soft and Coastal binded N_2O, while in all the other studied lake types, N_2O fluxes were too small to be quantified. Contrary to several studies in the boreal biome, Estonian lakes constituted in late summer a net sink of both CO_2 alone and the sum of CO_2 and CH_4. This discrepancy is mainly caused by the predominant climate cooling effect of Lake Peipsi forming ¾ of the total area of lakes and showing negative net emission even after considering the Global Warming Potential (GWP) of CH_4. However, small "chimney" lakes strongly affected the regional balance: Coastal lakes contributed 62% to the the total CH_4 emission while comprising only 1.6 % of total area of lakes. The summer efflux of GHG carbon from all Estonian lakes was 8 T C day^{-1}, and the greenhouse effect of this emission, 2720 T CO_2 equivalents per day, remains positive due to the high GWP of methane. Thus, by converting CH_4 data into CO_2 equivalents, the combined emission of all Estonian lakes is turned strongly positive.

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II-O8

WINTER NITROGEN CYCLING IN SEDIMENTS OF BOREAL LAKES AFFECTED BY BROWNING AND MINING

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Ice-covered period of boreal lakes last almost half a year. This period has contrasting environmental conditions respect to the ice-free, with cold temperatures, absence of light, and no gas exchange between water and atmosphere, overall favoring the growth of prokaryotes respect to eukaryotes. Focusing on the nitrogen (N) cycle, winter seems a suitable period for N-transforming prokaryotes with a high availability of ammonia and nitrate as there is minor assimilation by the light-dependent primary producers. However, there is limited data about winter N cycling rates and the microbes involved on, perhaps due to the wrong idea that N cycle is slowed down due to the dark and cold conditions. Also, there is limited knowledge about the role of organic matter quality on N cycling processes.

We studied two oligotrophic big boreal lakes in North Karelia, Finland, Lake Viinijärvi and Lake Höytiäinen, each lake with clear-water and brown-water sides. Viinijärvi has an additional side affected by mining activities in the catchment showing higher nitrate and sulphate levels in the hypolimnion. During winter of 2021 we sampled two times these five sites, at the beginning (January-February) and at the end (March-April) of the ice-covered period. Using the Isotope Pairing Technique we incubated sediment cores with $^{15}NO_3^-$ and quantified the products of 1) complete denitrification (N_2), 2) truncated denitrification (N_2O), and 3) dissimilatory nitrate reduction to ammonium (DNRA, NH_4^+) to infer the process rates. In addition, to see the role of organic matter, we perform anoxic slurry incubations of the top sediment layer with $^{15}NO_3^-$ and 1) lake water, 2) miliQ water, 3) algal dissolved organic matter (DOM) extract, or 4) peatland DOM extract. We characterized the DOM using FT-ICR MS. We also explore the genetic potential (DNA) of the sediment microbiome by using several sequencing techniques: 1) amplicon (16S rRNA), 2) captured, capturing the main N and CH_4 functional genes, and 3) shotgun. Results show changing nitrate consuming activities and N genetic potentials between the clear-water, the brown-water, and the mining affected sites.

II-O9

EFFECT OF WATER DEPTH ON CARBON AND NUTRIENTS SEQUESTRATION IN FISHPOND LITTORALS

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The objectives of the study was to evaluate carbon, nitrogen and phosphorus sequestration in the fishpond littoral sediment in relation to water depth. The research was carried out within reed stands at two fishponds near Prague during the period 2014-2015. At both fishponds, three sites were selected according to the water depth. Two sites were in the littoral zone with average water depth of about 5 and 40 cm, the third site was above the water level and was never flooded during the period of monitoring. During the study, surface water chemistry and water depth were measured on three-weeks interval while pore water was measured four times a year. At each site two 30 cm soil cores were taken and 2cm increments were analyzed for C, N and P. In each subsample, bulk density was measured as well. At all six sites, aboveground biomass of *Phragmites australis* and C, N and P concentrations in the biomass was measured at the end of August. In addition, decomposition of aboveground *P. australis* biomass was evaluated at all six sites during 2014. The litterbags technique was used and the decomposing biomass was weighed and analyzed for nutrients in three months intervals. The sediment accretion rate in the littoral zones was calculated using the information that sediment in both fishponds was removed all the way to the clay layer in 2004 and 2008. The accretion rate at the sites above water was evaluated using the feldspar method.

The results revealed that the aboveground biomass decreased in the order deep water > shallow water > above water at both fishponds. The decomposition experiments revealed that the decomposition rate was significantly higher at the flooded sites. However, the decomposition in flooded sites is most probably incomplete as the carbon concentration in the flooded sediment was much higher (18-23%) than above water (12-14%) in the top 10 cm layer. The accretion rates were the highest in the deep water (average 2.20 cm/yr), followed by shallow water (average 1.64 cm/yr) and above the water (0.9 cm/yr). The highest carbon accumulation rate was observed for deep water sites (average 548 g C/m^2 yr), followed by shallow sites (403 g C/m^2 yr) and above the water (139 g C/m^2 yr). Nitrogen accumulation rates averaged 18.3, 37.8 and 47.7 g N/m^2 yr) at deep water, shallow water and above water. Phosphorus accumulation rates averaged 0.80, 2.51 and 4.36 g P/m^2 yr) at deep water, shallow water and above water.

The results revealed very high accumulation rates of C, N and P in the reed stands of the monitored fishponds. The results also indicated that accumulation rates of C, N and P were the highest in deep water and the lowest rates were observed above the water. We suspect that the major reason for this phenomenon is the highest aboveground biomass in deep water and incomplete decomposition of the biomass at deep sites.

II-O10

THE EFFECT OF MACROPHYTES AND BIOCHAR ENHANCEMENT ON THE PERFORMANCE OF COLD CLIMATE TREATMENT WETLANDS IN MITIGATION OF PESTICIDE POLLUTION

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Pesticides pollution is a serious threat to aquatic ecosystems, human health and biodiversity. Treatment wetlands have shown promising results in removal of different kind of pesticides from polluted waters (Vymazal and Březinová, 2015). The main objective of our study was to determine the effect of three macrophyte species (*Phragmites australis* subsp. *americanus* (PA), *Scirpus cyperinus* (SC) and *Sporobolus michauxianus* (SM)) and hardwood biochar substrate enhancement on performance of subsurface flow treatment wetland (TW) mesocosms in removal of widely used herbicides glyphosate (GLP) and atrazine (ATZ), and rather new insecticide chlorantraniliprole (CAP).

Three experiments were conducted over three consecutive vegetation periods. All used the same setup with total 14 mesocosms (L×W×H = 1.3×0.8×0.5m): 3 with PA, 3 with SC and 3 with SM; and additional 3 with SC and 15% (by volume) biochar addition; one unplanted control with biochar and one with granite gravel. CAP and GLP removal efficiencies were determined in 2019 and 2020, respectively. In summer 2021, we tested a mixture of three different concentrations of GLP, CAP and ATZ. The first two studies about CAP and GLP removal are already published as Abas et al. (2022) and Boucher-Carrier et al. (2022).

Overall, best mass removal of tested pesticides was reached with biochar addition to the main substrate (granite gravel). Biochar enhancement ensured high CAP and ATZ mass removal (CAP 90-99% and ATZ 95-97%). Plants had only buffering effect in CAP reduction. GLP was efficiently removed both with the help of plants and with biochar in experiments in 2020 and 2021 (average efficiencies from 54-76% with plants and 78-85% with biochar). Additional studies are required to confirm if lower GLP removal in mixture was due to presence of other pesticides or some additional factor or mechanism.

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II-O11

FATE OF TRACE ORGANIC STORMWATER CONTAMINANTS IN A BIORETENTION CELL ASSESSED VIA A FIELD TRACER TEST WITH BENZOTRIAZOLE

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Bioretention cells are urban stormwater control systems known to effectively remove contaminants such as suspended solids, dissolved nutrients and trace metals, though with variable efficiencies. Field research on the fate of trace organic contaminants in bioretention cells is limited. We investigated the performance of a bioretention cell located in Vaughan, ON, Canada, for trace organic contaminant removal. For that, we performed a tracer experiment at the site to obtain in situ field data at a high time-resolution with the goal of investigating the underlying transport, transfer and transformation mechanisms of benzotriazole, a model urban stormwater contaminant. A tracer mixture containing bromide, rhodamine WT, and benzotriazole was injected as a pulse at the inlet of the bioretention cell. Outflow samples were collected at different time points and analyzed to generate tracer breakthrough curves for these compounds. The results showed that the bioretention cell had a short retention time of less than 2 hours and significant dead volumes and/or preferential flow paths. The recovery rates were 81-96% for the water tracer bromide and 71% for benzotriazole. This is consistent with the weak adsorption properties of benzotriazole to soil and showed that limited removal was obtained for this conventionally-designed system. Samples were analyzed by liquid chromatography followed by high-resolution mass spectrometry using an Orbitrap mass spectrometer for both targeted and non-targeted analyses. Benzotriazole transformation products that were signatures of biotransformation and phytotransformation were found. The results suggest potential for microbial transformation between runoff events and fast phytotransformation during the event. However, the results emphasized that the contribution of sorption and transformation processes to the overall fate of benzotriazole remained limited. There is therefore a need to use new design strategies to effectively sorb or transform these contaminants, such as increasing the retention time, incorporating soil amendments, and selecting specific plant species for better treatment performance.

II-O12

COMMERCIAL MANGANESE OXIDES AS AN AMENDMENT FOR NATURE-BASED SYSTEMS TREATING GREYWATER IN COLD WEATHER

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Little attention is drawn to the use of commercial manganese oxides (cMnOx) in nature-based systems (NBS) to remove micropollutants from greywater. Notably, previous studies confirmed MnOx (mostly lab-synthesized materials) effectiveness to deal with some micropollutants (Remucal & Ginder-Vogel, 2014) mainly due to oxidation or sorption. The integration of cMnOx as an amendment in NBS aims not only to be an environmentally-friendly greywater treatment strategy, but also to intensify NBS performance toward persistent micropollutants and selected standard contaminants during cold-weather period. This study aimed to investigate the role of cMnOx in this respect under a cold-weather regime. To target micropollutants removal via cMnOx, a filtering material active mass G-1 (granulation of 0.5-1.2 mm; pyrolusite; purchased from Ecopol, Poland) was employed. Four micropollutants (5-methylbenzotriazole (5MBTR), metoprolol (MTP), bisphenol-S (BPS), and diclofenac (DCF)) were selected due to their occurrence in greywater. Outdoor pot experiment was conducted by applying a combination of four variables i.e., media type (sand or G-1), presence of plants (planted or unplanted), presence of aeration (aerated or unaerated), and ammonium addition in influent (with ammonium or without ammonium). *Iris pseudacorus* was chosen for planted pots as one of the most frequent plants used in NBS. Removal of substances and standard parameters (nitrogen and carbon components, ions, pH, and conductivity) were evaluated over a period of 10 weeks from October to December with an air temperature ranging from -3.4°C to 22.8°C. The experimental system was operated in a batch mode with a retention of 5 days and a 2-day resting period. Synthetic greywater was used in the experiment. The results indicated that G1 provided complete DCF removal, which was significantly higher than in the pots with sand ($p<0.05$). cMnOx also enhanced the removal (median value) of TOC (by max 61.73%) and IC (by max. 105.66%), fluoride (by max. 82.29%), and conductivity (by max. 21.23%). Sand-filled pots provided higher removal efficiency for 5MBTR, MTP, and BPS than G-1 ($p<0.05$) with the highest median value removal of 68.7%, 97.7%, and 78.1%, respectively, as well as standard parameters namely nitrogen components. Higher removal of the substances in the sand pots than in the G-1 pots was presumably attributed to a more diverse and active microbial community related to more favorable conditions. Notably, the enantiomeric fraction of MTP in the treated greywater indicated active biodegradation even under cold conditions in the pots regardless of the filtering material. Additionally, the presence of MTP acid as a transformation product of MTP was detected, and its production was pronounced in the treatment filled with sand and plants ($p<0.05$). Future research is required to adjust cMnOx/sand ratio and to consider plant rhizosphere-media interaction to achieve better removal of a wider range of pollutants.

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BIOGEOMON 2022

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Oral presentation abstracts

III SESSION

Fluxes between atmosphere and ecosystems

III-O1

WHAT DOES IT TAKE TO SEQUESTER CARBON?

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Carbon sequestration in natural ecosystems, especially forests, is promoted as an important climate mitigation tool. However, recent evidence suggests that high productivity may not be the answer to this challenge. Ecosystem carbon balance depends on both the inputs and outputs, and some evidence suggests that these are correlated, that is, fast-growing biomass also tends to decay rapidly, at least in part because of simpler, more easily degradable chemical composition. Greater concentration of complex secondary metabolites are associated with resource limitation, slower growth, competition, and possibly also with mycorrhizal symbionts. On one hand, rhizosymbionts consume both mineral and assimilatory resources, presumably reducing the primary production of vegetation. On the other hand, mycorrhizal fungi may contribute to soil carbon accumulation through a range of mechanisms – greater recalcitrance of fungal compounds, greater recalcitrance of cross-linked root and fungal compounds and decay products, suppression of free-living saprotroph activity through mycorrhizal N mining, and reduced decay capacity of symbiotic fungi themselves due to loss of certain C-mining genes and enzymes. However, the effect of individual mycorrhizal fungi on soil carbon dynamics may be context-dependent, based on broader plant and microbial community, soil mineralogy, and climate. Quantitative understanding of C dynamics in this context remains limited, but qualitatively, it is emerging that belowground carbon allocation depends on (i) the availability of mineral nutrients and water that determine aboveground sink strength, and (ii) the mobility of photoassimilates in the phloem (i.e. the "surplus carbon hypothesis"), whereas the persistence of belowground C depends on (i) the chemical composition of the organic matter, (ii) its chemical and physical protection, and (iii) complex community interactions among plants, microbes and soil mineral surfaces that determine the resource availability to different taxa. The path to maximum carbon sequestration in ecosystems requires not maximum primary production, but maximum carbon stabilization, which is mediated by (i) anabolic biochemistry, (ii) physical and biochemical protection from degrading enzymes, and (iii) the level of such enzymes produced, which are all mediated through soil structural and functional diversity.

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III-O2

EUROPEAN BEECH STEMS SUBSTANTIALLY REDUCE METHANE (CH_4) UPTAKE OF TEMPERATE MONTANE FOREST

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Trees are known as possible sources of atmospheric methane (CH_4), an important greenhouse gas. However, still little is known about the seasonality of the tree stem CH_4 fluxes, particularly for the dormant winter season, and relationships to environmental parameters. These uncertainties prevent correct estimation of net annual tree and forest ecosystem CH_4 fluxes.

We quantified seasonal dynamics of CH_4 exchange of mature European beech stems (*Fagus sylvatica*) and adjacent soil plots in a temperate montane beech forest of White Carpathians, Czech Republic, over a period of one year, using the static chamber methods and gas chromatographic analyses. The forest site is characterized by high spatial heterogeneity in soil water content, and is, therefore, most appropriate to test the hypothesis whether soil water content affects CH_4 emission by trees. We investigated the tree stem fluxes' contribution to forest CH_4 exchange and the impact of important environmental parameters on the gas exchange.

The beech stems were net annual CH_4 sources, whereas the soil was a net CH_4 sink. High tree CH_4 emitters showed substantial seasonality in their stem CH_4 emissions, clearly following their stem CO_2 efflux. The fluxes of CH_4 peaked during the vegetation season, and remained low but significant to the annual totals during winter dormancy. The "winter" stem CH_4 emissions contributed up to 20.6% to the annual totals. At the annual scale, the beech trees substantially offset the soil CH_4 uptake by up to 46.5%.

The detected high spatial variability in stem CH_4 emissions could be explained neither by soil CH_4 exchange, nor by CH_4 concentrations, water content or temperature in soil profiles near each measured tree. We therefore assume a connection of stem CH_4 emissions to CH_4 production and transport within stem tissues.

In Central Europe widely spread beech trees markedly contributed to seasonal dynamics of forest CH_4 exchange and significantly offset the soil CH_4 uptake. We conclude that clarifying their role in CH_4 exchange of typical beech forests is the prerequisite for correct estimations of the ecosystem CH_4 budgets and global greenhouse gas flux inventories.

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III-O3

DIURNAL PATTERNS OF WHITE POPLAR (*POPULUS ALBA*) TREE STEM CH_4 AND CO_2 FLUXES USING HIGH-FREQUENCY MEASUREMENTS IN A TEMPERATE UPLAND WOODLAND

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In recent years, novel studies on tree stem CH_4 emissions have drawn worldwide attention. High temporal variability in stem CH_4 fluxes hampers the accurate estimation of these fluxes in forests, but this can be addressed by using high-frequency measurements (Barba et al., 2021). However, to date, few studies have reported high-frequency measurements of tree stem CH_4 flux using automated chambers in temperate trees. In this study, high-frequency tree stem CH_4 and CO_2 flux measurements (1.5-hourly frequency, n>14,000) of three white poplar (*Populus alba*) were taken at heights of 45, 130 and 200 cm above the soil from mid-June to mid-August 2021(60 days) in a temperate upland woodland. We observed large hour-to-hour variation in stem CH_4 flux with both net CH_4 uptake and net CH_4 emission occurring each day. The average frequency of stem net CH_4 uptake on a daily basis was 50.7% ± 1.8. While there was no marked diurnal pattern, we found three poplar stem CH_4 flux at three heights was significantly higher after midnight (00:00-04:00) than during dawn and afternoon (04:00-16:00) periods, and compared to the evening (20:00-24:00), stem CH_4 flux was significantly lower during the morning (08:00-12:00) ($P<0.05$). Height effect on tree stem CH_4 flux was not observed. All three of the poplar tree stem CO_2 flux exhibited a clear diurnal pattern, with higher CO_2 flux during the night-time (20:00-04:00) than the rest of the day, and lowest CO_2 flux during the morning (08:00-12:00). We did not find any significant correlations between stem CH_4 flux and soil CH_4 flux, soil moisture and initial CH_4 concentration at three different heights, and soils mostly exhibited a net CH_4 sink. Wood incubation experiments further confirmed the capacity of CH_4 production and oxidation from bark, sapwood and heartwood. The results we observed suggest that biologically *in situ* tree stem produced CH_4 is the major source of stem CH_4 emission in temperate upland forests, while stem CO_2 flux is originated from stem and roots respiration. The drivers of the large hour-to-hour variation in stem CH_4 fluxes are still unclear, but it indicates the need for high-frequency measurements of tree stem fluxes to quantify their contribution to overall greenhouse gas budgets in upland forests.

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III-O4

CAN TREE STEM AND SHOOT EMISSIONS CLOSE THE GAP IN THE METHANE BUDGET OF A BOREAL SCOTS PINE FOREST DURING THE SUMMER MONTHS?

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The role of boreal upland forests in the global methane cycle remains poorly constrained. While chamber-based measurements clearly show that the soils of upland forest act as methane sinks, micrometeorological measurements indicate that the same forests are methane-neutral at the ecosystem level. We conducted a measurement campaign covering soil, tree stem, tree shoot, and ecosystem-level flux measurements to test whether upscaled methane fluxes from tree stems and shoots can close the observed gap between the soil and ecosystem fluxes.

The campaign was conducted in a Scots pine dominated upland forest in southern Finland at the SMEAR II Hyytiälä research station between July 1 - Aug 15 2017. It included weekly measurement of methane fluxes at 15 soil locations, 47 stem chambers at the three tree species (*Pinus sylvestris*, *Picea abies*, *Betula* sp.), and 6 shoot chambers, as well as micrometeorological measurement of methane fluxes at 23 m height with two methods, eddy covariance (EC) and true eddy accumulation (TEA). Soil and stem methane fluxes were further upscaled based on a topographical statistical model (Vainio et al., 2021).

Our results show a persistent gap between chamber- and micrometeorological flux measurements. While the soil acted as a moderate methane sink (-1.71 nmol m-2 s-1 ,95% confidence interval -2.03 to -1.39), micrometeorological measurements indicated that the forest was near methane neutral (EC: -0.29±0.24 nmol m-2 s-1; TEA: -0.25±0.16 nmol m-2 s-1). Spatial heterogeneity was a significant factor for soil methane uptake, as the median methane location in the tower footprint showed an approximately 0.5 nmol m-2 s-1 greater uptake than the footprint average. Methane exchange from stems (-0.035 to 0.083 nmol m-2 ground area s-1) and shoots (0.025 to 0.075 nmol m-2 ground area s-1) were at least an order of magnitude smaller than the gap between the soil and ecosystem measurements. While these estimates are associated with significant uncertainties primarily stemming from the upscaling model, it is unlikely that the stem and shoot fluxes act as the missing methane source in this ecosystem.

Overall, our results indicate that the gap between soil and ecosystem fluxes results either from a systematic error in micrometeorological flux measurements or from too high uncertainties related to measured fluxes very close to the detection limit of the EC/TEA system. It is also possible that an unidentified methane source exists in these forests. We were, for example, not able to conduct shoot flux measurements at moist sites within the flux tower footprint. We further note that our campaign was conducted during the peak summer months when stem and soil fluxes are expected to be relatively small due to low soil moisture. Nevertheless, our data suggests that a difference between trace gas fluxes at the soil and ecosystem level are not necessarily indicative of stem or canopy processes, and that such differences need to be interpreted with great care.

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III-O5

EFFECTS OF DROUGHT ON THE METHANE EMISSIONS FROM THE SHOOTS OF YOUNG SCOTS PINE SAPLINGS

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Plants can emit methane (CH_4) produced by an unknown aerobic, non-enzymatic process, driven by plant stressors like UV-radiation, elevated temperatures and wounding. In ambient spring conditions in Finland, CH_4 emissions from the shoots of Scots Pine (*Pinus sylvestris*) correlated with solar radiation independently of temperature (Tenhovirta et al., in revision). The spring-time shoot CH_4 emissions also had a diurnal pattern with the highest emissions during noon. It remains unknown whether these emissions are driven directly by solar radiation or indirectly via its effect on tree physiological processed such as photosynthesis or stomatal conductance. Characterizing the ecophysiology of the CH_4 fluxes of tree canopies is a crucial step in order to understand the role of forests in the global CH_4 cycle.

To test whether shoot CH_4 emissions are driven by tree physiological activity (e.g. stomatal conductance), we conducted a measurement campaign in greenhouse conditions during which Scots pine saplings were exposed to drought. During this 3-month-long campaign, CH_4, carbon dioxide (CO_2) and water vapour (H_2O) fluxes from tree shoots were measured with an automated shoot trace gas flux measurements system (*ShoTGa-FluMS*)(Kohl, Koskinen et al., 2021). This system is capable of replacing the CO_2 assimilated by the shoots, removing transpired water and cooling the chambers to near ambient temperatures. The experimental setup consisted of six 2-3 year old nursery saplings each with a shoot enclosed inside an automated shoot chamber, alternating (a) in closed loop with a Picarro G2301 cavity ring-down spectroscopy (CRDS) greenhouse gas concentration analyser (CH_4 and CO_2 measurements), (b) in a flow-through setup with a Li-cor 850 CO_2-H_2O analyser (photosynthesis and transpiration measurements), or (c) flushed with ambient air. The saplings were exposed to a daily 9-hour photoperiod of ~ 600-800 µmol s^{-1} m^{-2} photosynthetically active radiation (PAR), and irrigated automatically. Drought was induced by stopping the irrigation and continued to the point where net uptake of CO_2 no longer occurred.

Our experiment produced a unique dataset of continuous measurements of shoot-level CH_4, CO_2 and H_2O fluxes over a period of several weeks. Our preliminary results show small but consistent CH_4 emissions from the shoots of Scots Pine during daylight, supporting our earlier findings of the dependency of shoot CH_4 emissions on light. The data furthermore allows to analyse the effects of drought on tree physiological activity and shoot CH_4 fluxes providing much needed process understanding of shoot CH_4 emissions from boreal trees.

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III-O6

METHANE DYNAMICS AND MICROBIAL ACTIONS IN BOREAL SPRUCE PHYLLOSPHERE

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Current knowledge on methane (CH_4) sinks is limited to chemical processes in the atmosphere, and to methanotrophy in forest soils and peatlands. However, recent discoveries have indicated that also tree stems and branches, i.e. phyllosphere, may consume atmospheric CH_4, thus functioning as a novel CH_4 sink, but the mechanism is not yet resolved (Putkinen et al. 2021). Here, we show that leaves and needles of boreal trees had the potential to consume CH_4 in field and laboratory experiments. Test results of inhibitor and sterilization treatments will be discussed. Molecular and stable isotope analyses, can show, which microbes are participated on CH_4 cycling in tree tissues. Microbial-mediated CH_4 dynamics in tree canopies will be discussed. This potentially symbiotic connection between microbes and plant cells can be later on linked into increase carbon capture of boreal trees. Our results indicate that CH_4 dynamics can play a role in boreal trees and can participate ecosystem-scale carbon cycle.

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III-O7

LONG TERM GREENHOUSE GAS BUDGET IN THE MALUDAM SWAMP FOREST IN SARAWAK, MALAYSIA

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Tropical peatlands are carbon (C) rich ecosystems and are important in the global greenhouse gas (GHG) budget. Measurement of GHG fluxes from peat swamp forests (PSF) is important to assess the impact of both land use and climate change and will be valuable for improving the global GHG budget and climate policy development. Here, we present the carbon dioxide (CO_2) and methane (CH_4) fluxes from a PSF measured with different techniques over different periods. The experimental site was in the Maludam National Park, Sarawak, Malaysia. Maludam forest is a unique ecosystem with different forest types, *i.e.,* Mixed peat swamp, Alan Batu, Alan Bunga, and Padang Alan. Our objectives were to quantify the long-term CO_2 and CH_4 fluxes, clarify the seasonality effect on CO_2 and CH_4 fluxes, and determine annual CO_2 and CH_4 emissions. Eight years of measurement of both fluxes at three different forest types using manual chamber technique suggested that both environmental and soil physicochemical properties contribute to the variations in soil C emission from PSF. The interannual variations in soil CO_2 and CH_4 fluxes also confirmed the importance of long-term monitoring under different forest types. When the peat soil from the three-peat forest types was buried at the oil palm plantations, CO_2 and CH_4 fluxes over the three years period were greater in the soils with greater *O*-alkyl C derived mainly from polysaccharides. The mean annual soil CO_2 emissions were 313 g C m^{-2} yr^{-1} while soil CH_4 emission was 0.18 g C m^{-2} y^{-1}, and the annual rate of peat decomposition represented by an exponential decay model was in the range of 0.033 yr^{-1} to 0.066 yr^{-1}. Additionally, measurements with the automated-chamber technique indicated that the annual soil CO_2 emissions were 926 ± 610 and 891 ± 476 g C m^{-2} yr^{-1} for soil and heterotrophic respiration. Daily mean soil CO_2 flux was controlled by the water table at the seasonal and annual scales. The annual soil CH_4 emission was 4.32 ± 3.95 g C m^{-2} y^{-1} which was attributable to the high-water table. On an ecosystem scale, the eddy covariance measurement showed that the forest was a net source of CO_2 to the atmosphere with net ecosystem exchange (NEE) of CO_2 ranging from 183 to 632 g C m^{-2} yr^{-1}. The NEE of CO_2 tended to increase under high vapor pressure deficit (VPD) conditions regardless of photosynthetic photon flux density. Annual NEE of CH_4 was 8.46 g C m^{-2} yr^{-1}, which was much higher than the annual soil CH_4 emissions reported by previous chamber studies from tropical peatlands, suggesting that tropical peat swamp forests can be one of the major natural CH_4 sources in the tropics. A long-term GHG measurement is essential for a better understanding of the peat swamp ecosystems, estimating GHG fluxes, and predicting the future of the peatland under the current state of climate change scenario.

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III-O8

WOOD STRUCTURE IS A MAJOR DRIVER OF METHANE EMISSIONS FROM AMAZONIAN FLOODED FORESTS

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Amazonian wetlands contribute to ~ 30% of the global wetlands CH_4 emissions. Recent studies show differences in regional emissions and strong seasonality across the Amazon basin (Wilson *et al.,* 2021). Regional precipitation, flood duration, landcover type and soil temperature are known to act as major environmental drivers of CH_4 emissions. Tree stems in Amazonian wetlands are responsible for up to half of CH_4 emissions from this region (Pangala *et al.,* 2017). The role of wood morphology and species abundance on local and regional CH_4 emissions, which has never been assessed, was the focus of this study.

Methods

We measured tree stem and soil CH_4 fluxes and their $d^{13}CH_4$ from flooded and non-flooded seasons from 8 of the dominant tree species in white water flooded forests. Following CH_4 flux measurements, we measured internal CH_4 concentrations from three stem heights and extracted wood cores for wood structure and morphology assessment. Additionally, two of the eight species were common across black water, and white water flooded forests with distinct methane emission patterns. We measured and compared fluxes, $d^{13}CH_4$, internal CH_4 concentrations, and wood structure and morphology to assess between ecosystem differences.

Results and Discussion

We found substantial differences in emissions and internal stem CH_4 concentrations in eight tree species analysed within the white water flooded forest plot. As a general trend, species with higher xylem lumen diameter and cell length showed lower internal CH_4 concentration and higher stem fluxes. Species with a smaller volume of conductive elements, a higher number of cell layers, thicker cell walls and oil, resin or high viscosity sap tend to store more internal CH_4 and emit less CH_4 - which could offer higher resistance to radial gas diffusion. We also found one species in which oil production, not wood structure, played a role in limiting gas diffusion. We found no apparent differences in wood morphology analysed with tree stem heights, from stem base to 25% stem height. This corroborates no significant differences in internal CH_4 concentrations or $d^{13}CH_4$ across the analysed stem heights. We found no significant difference in $d^{13}CH_4$ between tree species because of mixing with a much bigger soil-derived CH_4 pool. Our results indicate that local CH_4 emissions are considerably influenced by tree species' wood morphology and the natural abundance of species across Amazonian wetlands.

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III-O9

N_2O AND CO_2 FLUXES MEASURED BY EDDY COVARIANCE TECHNIQUE IN A SHALLOW DRAINED AGRICULTURAL BOREAL PEATLAND OVER TWO CONTRASTING YEARS

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Cultivated organic soils represent only ca. 13% of agricultural fields in Finland but they contribute to 43% and 82% of total N_2O and net CO_2 emissions from agricultural fields (Statistics Finland, 2021). It is well known that cultivated organic soils can be high sources of N_2O and CO_2 but only minor sources or sinks of CH4.

Contrary to CO_2, N_2O emissions do not follow a strong seasonal pattern. Instead, they have high spatial and temporal variability throughout all seasons. Short-term N_2O peak emissions can be observed after various meteorological or soil management events, for example after soil freezing and thawing or fertilization.

Low frequency measurements (e.g. chamber technique) may miss the short term peak events especially during winter, a season which contributes significantly to the annual N_2O budget in boreal regions (Regina et al., 2004). To reduce the uncertainty and increase our understanding of N_2O events, more continuous measurements are needed.

N_2O and CO_2 fluxes were measured continuously for two full years in Ruukki, on a drained agricultural boreal peatland in Northern Finland with a shallow peat layer. Both years had contrasting winters: one was warm (with non-continuous snow cover) while the other was similar to the 1991-2020 long-term average (with continuous snow cover).

To our knowledge, this is the first time that N_2O fluxes are measured continuously from such a site with the Eddy Covariance technique (EC).

We will answer three research questions:

1) Does a warmer winter induce more N_2O emissions than a traditional winter?
2) How does the N_2O and CO_2 annual budget compare to the IPCC EFs?
3) What is the contribution of N_2O versus CO_2 to the sustained global warming potential?

In addition, we will also present the short-term N_2O variation observed in relation to weather and management events in Ruukki.

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III-O10

GREENHOUSE GAS DYNAMICS IN A DRAINED PEATLAND FOREST: ANNUAL CH_4 AND N_2O FLUXES FROM TREE STEMS AND SOIL

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Peatland soils are considered the dominating source of methane (CH_4) and nitrous oxide (N_2O) to the atmosphere. However, there are high spatio-temporal uncertainties regarding the soil greenhouse gas (GHG) fluxes due to complex dynamics between the soil chemical, physical and biological variables. Although GHG fluxes from peatland soils are relatively well studied, tree stem fluxes have received far less attention. Many studies show that stems of different tree species may also emit CH_4 (e.g. Barba *et al*., 2021) and N_2O (e.g. Machacova *et al*., 2019), but most biogeochemical models still neglect tree stems and only consider soil to be exchanging GHGs between ecosystem and the atmosphere. Moreover, simultaneous year-long measurements of soil and tree stem CH_4 and N_2O fluxes in peatland forests are missing, as previous studies have primarily focused on the growing season. We aim to determine the seasonal dynamics of CH_4 and N_2O fluxes in a drained peatland forest, as drainage can lead to release of the large amounts of carbon and nitrogen stored in peat into the atmosphere as GHGs. We measured tree stem and soil GHG fluxes in a drained peatland forest dominated by Downy Birch (*Betula pubescens*) and Norway Spruce (*Picea abies*) trees. During the weekly sampling campaigns (November 2020–December 2021), we used manual static stem chambers to collect gas samples, which were later analysed for CH_4 and N_2O in the laboratory using Shimadzu GC-2014 gas chromatography. Soil CH_4 and N_2O fluxes were measured using an automated dynamic soil chamber system connected to a Picarro G2508 analyser (December 2020–August 2021).

Preliminary results show that on average, birch stem GHG fluxes were greater than spruce stem fluxes. Birch trees were a net annual source of both CH_4 (1.07 ± 0.11 µg C m^{-2} stem area h^{-1}, mean ± SE) and N_2O (3.22 ± 0.45 µg N m^{-2} h^{-1}). Spruce trees were a net source of CH_4 (0.20 ± 0.06 µg C m^{-2} h^{-1}) but a net sink of N_2O (-0.19 ± 0.03 µg N m^{-2} h^{-1}). Temporal dynamics of birch stem fluxes showed relatively small fluxes with fluctuations between emissions and uptake for most of the year, but significant emissions peaks in November and June (CH_4), and November and March (N_2O). Spruce fluxes remained very low throughout the year. Soils were a net sink of CH_4 (-5.65 ± 0.11 µg C m^{-2} ground area h^{-1}) and source of N_2O (44.39 ± 0.67 µg N m^{-2} h^{-1}) during the study period. A substantial increase in CH_4 uptake was observed in the summer, peaking at –49.53 µg C m^{-2} h^{-1} at the end of July, and diminishing towards the end of summer. Hot moments – notably higher daily average emissions compared to the period average – characterised the temporal dynamics of soil N_2O emissions. Further results on soil meteorological and biogeochemical properties will help determine the possible drivers of stem and soil fluxes' dynamics and their origin.

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III-O11

SIMPLE METHOD FOR IDENTIFYING THE (B)VOCS SOURCE CONTRIBUTION AREA USING UNMANNED AERIAL VEHICLE (UAV) AND METEOROLOGICAL DATA

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Biogenic volatile organic compounds (BVOC) play an important role in plant growth, reproduction, defense. The presence of certain compounds in the air indicates plant stress, which could be observed on an ecosystem level. (B)VOCs are an essential part of many chemical processes in the atmosphere and are major precursors of ozone and secondary organic aerosols.
Most of the field (B)VOCs measurements take place only on the ground level. An atmospheric vertical profile can be studied with towers, balloons, aircrafts, and unmanned aerial vehicles (UAVs). UAVs have better flexibility for the local air sampling by hovering over a target area/place and can reach altitudes up to 1000m. This makes them optimal for permanent (B)VOC monitoring where repeated measurements are required in spatio-temporal domain. At the same time, the source contribution area of obtained concentrations is rarely identified potentially resulting in misleading conclusions about the exchange in surface-vegetation-atmosphere volume above the target area.
In this study, we obtained vertical profiles of (B)VOCs at SMEAR Estonia (Station for Measuring Ecosystem Atmosphere Relations) to investigate compounds' composition and distribution in the near surface layer. Vertical samples were collected in 2020-2021 from heights between 0 m and 90 m by commercially available pump with attached cartages filled with adsorbents and mounted on UAV.
To overcome the space-time representativeness issue related to the source signal, the footprint analysis was caried out. Micrometeorological data for four target areas were obtained from three SMEAR Estonia flux towers. We adopted Flux Footprint Prediction model (Kljun et al., 2015) for footprint calculation. Temporal and spatial changes of roughness length (z_0), zero-displacement height (z_d) were derived for each day of measurements using geospatial data of land cover types with an estimated canopy hight. The atmospheric boundary layer height was calculated following Kljun et al. (2015). As due to the presence of surface heterogeneity, z_0 and z_d vary substantially for each wind sector, we run spin-up of the FFP model with updating model parameters input with each step.
We evaluated footprints and their representativeness over the target areas in the space-time domain. We exanimated land-cover composition and vegetation characteristics in the target areas in SMEAR Estonia site for each day of the measurements. The (B)VOC source contribution area could have different size and shape depending on the atmospheric conditions. We propose simple solution for footprint-to-target-area problem.

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III-O12

TERPENE EMISSIONS FROM BOREAL WETLANDS CAN INITIATE STRONGER ATMOSPHERIC NEW PARTICLE FORMATION THAN BOREAL FORESTS

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Aerosols and their interaction with clouds constitute the largest uncertainty in estimating the radiative forcing affecting the climate system. Secondary aerosol formation is responsible for a large fraction of the cloud condensation nuclei in the global atmosphere. Wetlands is an important to the budgets of methane and carbon dioxide, but the potential role of wetlands in aerosol formation has not been investigated.

It has been shown that aerosol formation can be initiated by clustering of sulphuric acid and stabilizing bases (Jokinen et al. 2018), highly oxidized organic vapors (Kirkby et al. 2016) or iodine oxides (Sipilä et al. 2016). Highly oxygenated organic molecules (HOM), with very low volatility, have been shown to originate from the oxidation reaction of VOCs (Ehn et al. 2014).

Here we show observations from Finnish wetland, Siikaneva where is located ICOS (European Integrated Carbon Observation System) station and from SMEAR II station (Station for Measuring Ecosystem-Atmosphere Relations), in Hyytiälä, Finland. We found a previously not recognized climatically relevant process in the atmosphere above wetlands. In addition to CH_4 wetlands also emit VOCs. While the amounts are small, they are enough to initiate new particle formation, cloud formation and thereby, potentially, influencing radiation balance of the planet.

During daytime, the formation rate of 1.5 nm clusters became significantly enhanced as a function of the CH_4 emissions (fluxes). This shows clearly that the CH_4 emissions and new particle formation (NPF) are connected to each other, but it does not mean the CH_4 is chemically involved in NPF. We can assume that the processes in wetlands, such as microbial activity in the peat, produces both CH_4 and terpenes, and therefore CH_4 can be used as a proxy for terpene production. This study demonstrates that, compared with boreal forests, boreal wetlands are even a stronger areal source of atmospheric clusters.

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III-O13

CONDITIONS FOR NANOPARTICLE CONCENTRATION INCREASE IN THE ATMOSPHERE OF HEMIBOREAL FOREST

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Climate change is influenced by many different factors including physical, chemical and biological processes such as New Particle Formation that creates new cloud condensation nuclei affecting the climate through cloud formation (Bonan, 2008; Kerminen *et al.*, 2018).
To study the nanoparticle concentration growth in hemiboreal forest a study was conducted including measurements by Airmodus A11 nCNC system, Neutral cluster and Air Ion Spectrometer, Proton Transfer Reaction Time of Flight Mass Spectrometer (PTR-ToF) and Chemical Ionization Atmospheric-Pressure interface Time-of-Flight Mass Spectrometer with Filter Inlet for Gases and AEROsols (FIGAERO). The measurements took place in a hemiboreal forest at SMEAR Estonia station in south-eastern Estonia (58°16´N, 27°16´E) during April 26th – May 22nd 2018.
We discovered 37 short time periods when monoterpene signal increased considerably above the background level. The peaks were separated into two categories: 1) peaks during which also new particles were formed and 2) peaks without fast nanoparticle concentration rise. The main focus was put on the chemical signal differences between the two categories. For this a two-sided Wilcoxon rank sum test was applied to data from PTR-ToF, FIGAERO gas phase measurements as well as weather conditions and trace gas measurements. The results showed that out of 101 chosen monoterpene oxidation products measured by FIGAERO-CIMS, there were 56 that were statistically different during the two groups of peaks. Two most prominent compounds were $C_{10}H_{16}O_2$ and $C_9H_{14}O_4$ (likely pinonaldehyde and pinic acid) which had at least 1.5 times higher signals during monoterpene signal peaks resulting in fast nanoparticle concentration rise.
These results give insight into chemical dynamics and new particle formation in hemiboreal forest.
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III-O14

EMISSIONS OF BIOGENIC VOLATILE ORGANIC COMPOUNDS FROM A BOREAL FEN AND BOG AS IMPACTED BY VEGETATION AND A PERIOD OF DROUGHT

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Peatland ecosystems emit biogenic volatile organic compounds (BVOC), which have a net cooling impact on the climate. However, the quality and quantity of BVOC emissions, as well as the role of vegetation and peatland type in regulating BVOC emissions remain poorly understood. To bridge these knowledge gaps, we measured BVOC emissions with dynamic enclosures from a boreal fen and bog situated in Siikaneva, southern Finland and assessed the role of vegetation experimentally by removing vascular vegetation only, and vascular vegetation and the moss layer. Our measurements from four campaigns during growing seasons in 2017 and 2018 detected a total of 60 compounds from nine different chemical groups, with isoprene accounting for 81% of BVOC emissions. Isoprene and alkane emissions were higher in the fen than in the bog, and they significantly contributed to the higher overall BVOC emissions in the fen. Total BVOC emissions and the emissions of isoprene, monoterpenoids, sesquiterpenes, homoterpenes and green leaf volatiles were tightly connected to the presence of vascular vegetation. Isoprene and sesquiterpene emissions were associated with sedges, whereas monoterpenoids and homoterpenes were associated with shrubs. Emissions of oxygenated alkanes, organic halides and benzenoids were not impacted by vegetation removal. During an extreme drought event in 2018, emissions of (E)-4,8-dimethyl-1,3,7-nonatriene increased, while organic halide and oxygenated alkane emissions were low or absent. Notably, the emissions of isoprene, the most common compound, were associated mostly with sedges and emissions declined during the drought period. Therefore, we suggest that an increase in shrub cover and increased frequency of extreme weather events may have a negative impact on total BVOC emissions that otherwise are predicted to increase in warmer temperatures. Combined with the related change in the quality of BVOC emissions, this may alter the climate impact of peatlands by affecting atmospheric oxidants and the formation of secondary organic aerosols.

III-O15

SOIL AMMONIA FLUXES FROM MAIZE FIELDS

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Nitrogen (N) fertilizers have contributed significantly to ammonia emissions, leading to secondary inorganic aerosol pollution which causes respiratory, cardiovascular, and other health issues. Maize (*Zea mays* L.) is the most widely produced crop in the world and also uses the most N fertilizers. Thus, changes in agricultural practices used on maize fields can play a prominent role in efforts to address air pollution. One such change is a living mulch (LM) system, a method of reducing traditional fertilizer application that involves maintaining a live cover crop year-round. This study analyzes maize fields in Georgia (USA), Rwanda, and China with LM and conventional fertilizer applications to determine the impact of different agricultural techniques on soil ammonia fluxes. Ammonia fluxes were measured with an acid trap connected to a static chamber in an open system configuration. LM plots in the US and China had 39.8% lower mean fluxes than conventional plots, with 10.2% lower cumulative emissions over all sampling dates. Our results suggest that LM systems have the ability to reduce ammonia fluxes and flux variance significantly compared to conventional fertilizer application and that this impact grows over time due to prolonged N fixation. Future studies will compare the emissions reduction potential of LM systems using different crops and soil types.

III-016

EFFECT OF N-FERTILIZATION AND CUTTING HEIGHT ON GREENHOUSE GAS BALANCE OF GRASSLAND ON MINERAL SOIL IN EASTERN FINLAND

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There is an urgent need to mitigate greenhouse gas emissions in agriculture. IPCC has estimated that agriculture can cause 10-12% of the global greenhouse gas emissions and in Finland approximately 20% of the overall emissions. A major part of these emissions is originating from soils. Northern grasslands on mineral soils are sources of nitrous oxide (N_2O) as a result of N-fertilization but they are mostly sinks for methane (CH_4). Their role as a potential carbon dioxide (CO_2) sink is not well known. Agricultural practices, such as fertilization and harvesting, can strongly affect the greenhouse gas emissions. In CARBO-NURMI and ORMINURMI projects (2019-2022) we are going to show how different N-fertilization rates (0, 150 or 300 kg N $ha^{-1}yr^{-1}$) and varying cutting heights (6 or 12 cm) affect greenhouse gas emissions and crop yield on a grassland site on mineral soil (coarser fine sand) in eastern Finland. The studied grassland is a short-term ley growing a mixture of timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.). N_2O and CH_4 fluxes, gross photosynthesis and ecosystem respiration are measured by chamber methods for calculation of net ecosystem GHG balance. The results from the first full three years (May 2019-April 2022) will be presented and discussed.

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III-O17

CLOSING THE CARBON AND NITROGEN BUDGETS IN A WINTER RAPESEED FIELD

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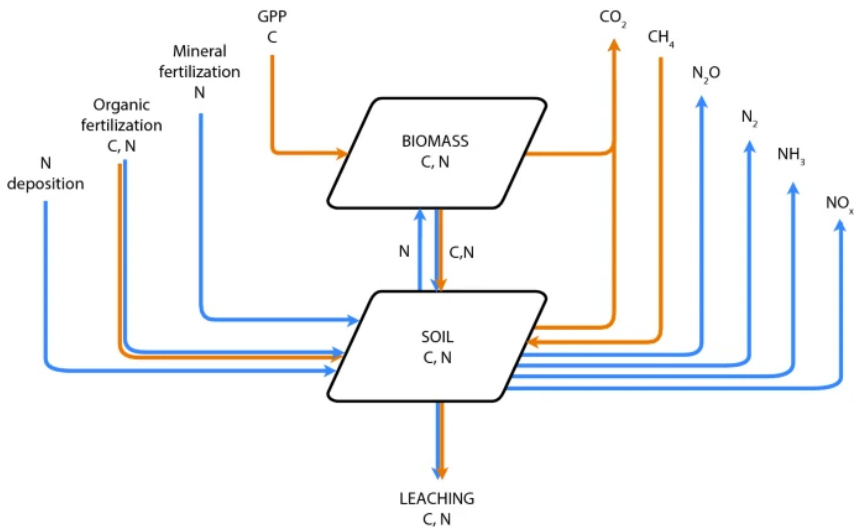
In this work we assembled a collection of methodologies for the carbon (C) and nitrogen (N) budget estimation for a Winter Rapeseed field in Central Estonia.

Greenhouse gas fluxes were measured to calculate the C and N gaseous losses with the CO_2, CH_4 and N_2O fluxes. Soil and leachate analyses were performed to monitor nutrient change in soil as well as nutrient losses through leaching. The nutrient content in the leachate analysis was combined with percolation estimated using the soil water balance, to quantify the total nutrient loss. The inputs with organic and mineral fertilizer were also accounted for. Plant biomass samples were collected and analyzed at the end of the experiment and partitioned into seeds, crop residues and weeds. The main non-measured fluxes, Gross primary production (GPP) and N_2 emissions, were calculated from the mass balance, as the difference between known inputs and outputs. Other fluxes (NH_3, NO_x, N deposition) were estimated or the values from obtained from existing regional estimations.

The field was a net sink of C because of the high C fixation rate through GPP, although a part of the sequestered C would be lost with the mineralization of the remaining crop residues. Estimated N_2 emissions from the mass balance were the highest N flux, surpassing the N removal through seed harvest. Nitrogen losses caused by N_2 and N_2O emissions and leaching resulted in a decrease in the soil N content.

Direct measurement combined with balance calculation and modeling allowed to close the C and N budgets, but also to identify the critical points for closing the budget.



Oral presentation abstracts

IV SESSION

Soil and microbial processes, trace elements and micropollutants, biodiversity issues

IV-O1

TREE SPECIES DRIVE SOIL FERTILITY CHANGE DURING THE 43 YEARS AFTER PLANTATION – A DUAL APPROACH (SOIL SAMPLING AND INPUT-OUTPUT MASS BALANCE) STUDY OF THE BREUIL-CHENUE COMMON GARDEN EXPERIMENT (BURGUNDY, FRANCE)

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A forest ecosystems are generally developed on acidic and nutrient poor soils. In some numerous areas, elevated acid atmospheric deposition (sulphuric and nitric acids) drastically accelerated soil and surface water acidification during the XXth century leading, in many cases, to degraded soil fertility and forest decline. In addition to this context, tree species selection and/or substitution by forest management (to increase biomass production and/or adapt forests to a changing climate and its consequences) may have an important effect on the biogeochemical functioning of soils and ecosystems. Generally, acidification increase under conifers due to: higher atmospheric deposition rates, higher nitrate leaching fluxes, lower soil pH, higher aluminium concentrations in soil solutions and reduced organic matter mineralization rates. In such a context, the sustainability of the fertility of forest soils is at risk and a major concern for the forestry communities. It is therefore essential to understand the biogeochemical functioning of forest ecosystems and deconvolve environmental drivers from tree species effect drivers of forest soil fertility change over time.

Using a very unique dataset acquired over the 20 years of monitoring of the common garden experiment (6 monospecific plots planted in 1976: Norway spruce, Douglas fir, Nordmann fir, Beech, Oak and Laricio pine) at the Breuil-Chenue site in Burgundy, France, the objectives of this study were (i) to quantify the change in plant-available nutrient pools over time (soil resampling and "input-output" mass balance approach) and (ii) determine the drivers (derived from the tree species effect) of soil fertility change.

The soils in the different monospecific plots were sampled in 2001 and in 2019. The comparison of these two sampling dates showed an on-going soil acidification at this site and a marked tree species effect on soil chemical properties and their change over time. Three groups of species were identified: i) Nordmann fir/Norway spruce for which acidolysis and chelation was likely to be the dominant process, resulting in the most pronounced pH decrease in the topsoil, ii) Douglas fir/Laricio pine where soil acidification was most likely caused by elevated nitrification rates, iii) and oak/beech where soil acidification was the least intense compared to all other species. For certain nutrients and species, both the soil resampling and nutrient mass balance approaches were in agreement for instance on the depletion of K exchangeable pools in the beech stand : - 4 kg.ha^{-1}.yr^{-1} and - 6 kg.ha^{-1}.yr^{-1} respectively. In other cases, there were strong discrepancies between approaches: in the Douglas fir stand, exchangeable Ca depletion was predicted by mass balance (-1.5 kg.ha^{-1}.yr^{-1}) whereas soil resampling showed an increase exchangeable Ca pools (+ 3 kg.ha^{-1}.yr^{-1}).

These results show that tree species exert a very strong influence over soil processes and thus over how chemical properties change over time. However our current models and understanding of nutrient biogeochemical cycling are yet incomplete: different fluxes in the ecosystem may be poorly estimated and/or trees may access nutrient sources that are not currently or properly taken into account.

IV-O2

ACCUMULATION, AGEING AND TOXICITY OF COPPER IN EUROPEAN VINEYARDS IN A CONTEXT OF REGULATORY CHANGE

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Studies of the ecotoxicological impact of copper (Cu) in vineyard soils are generally based on the effect of the addition of a specific dose of Cu. However, soil properties and the dynamics of Cu accumulation in the soil must also be taken into account to determine, at the vineyard and the region level, the ecotoxicity thresholds that should not be exceeded in order to maintain a good biological quality of the soil. In particular, the transformation and mobility of Cu in soil depend on ageing, involving its chemical and physical distribution among soil fractions over time (Meite et al., 2022). Although the threshold of 200 kg Cu/ha may be conservative on an annual scale (Karimi et al., 2021), the sole consideration of an annual dose may be insufficient to guarantee the integrity of soil fertility and biodiversity. Indeed, the pre-existing Cu stock in the soil and its availability before the addition of a new Cu dose can vary greatly at the vineyard level and between vineyards depending on the physico-chemical properties of the soil, the vegetation and the different forms of Cu in soil. This calls into question the notion that Cu can be used safely at a specific dose, even if it is lower than the doses used historically. Using an average of 4 kgCu/ha/year, in accordance with recent European regulations, pushes back the deadline by which some European vineyards will have reached a threshold of Cu toxicity for soil organisms. Nevertheless, the ecotoxicological threshold for the biological quality of the soil of 200 kg Cu/ha (applied Cu) could be reached within a few decades in several European vineyards. The Cu content measured in European vineyard soils is on average 30% higher than non-agricultural Cu (Droz et al., 2021). We estimate that the threshold of 100 mg Cu/kg soil (measured), or about 150-250 kg Cu/ha in the top 10-15 cm soil layer (estimated stock), is already exceeded for >50% of the wine-growing areas in Central and Western Europe. Improving the quality and sustainability of wine production and vineyards in Europe requires appropriate local use and a more specific assessment of the impact of Cu, also taking into account the trajectory of Cu accumulation, availability and ageing in soil.

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IV-O3

UNDERSTANDING N_2O PRODUCTION AND CONSUMPTION PROCESSES IN PEAT SOIL WITH THE HELP OF ISOTOPIC AND MICROBIAL ANALYSIS

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Peatlands are one of the sources for N_2O emissions globally. Nitrous oxide is produced in soil via many microbial transformation processes and these processes act simultaneously with each other. To plan mitigation strategies and calculate annual nitrous oxide budgets, it is important to distinguish between N_2O production and consumption mechanisms.^{15}N tracer and stable isotope techniques have been used to associate N_2O fluxes to different microbial processes (Yu et al., 2020). Studies on pure microbial cultures have also supported evidence in similar direction but still further developments are needed in the field of isotope mass spectrometry and microbial ecology to make more precise estimates of processes responsible for N_2O fluxes (Sutka et al 2004). During our laboratory experiment on nitrate-rich floodplain fen peat, we found that site preference and $\delta^{18}O$ values fell within the previously observed range indicating multiple simultaneous processes, with bacterial denitrification as the dominant process both in the flooded and intermediately moist peat. This was followed by nitrification via comammox *amoA*. High archaeal *amoA* and bacterial *amoA* gene copy numbers and N_2O emissions from the intermediate and flooded peats indicated that ammonia oxidation was also an important source for N_2O.
As a full-scale follow-up, we studied N_2O source processes in a drained nitrogen-rich peatland forest. We observed high N_2O emissions from nitrification via AOB ammonia oxidation. Denitrification via *nir*S was a secondary source. Site preference values ranged from +5‰ to +17‰ and *amo*A and *nir*S genes dominated under this treatment. From the flooded treatment we observed negligible N_2O fluxes from bacterial denitrification. This was supported by the site preference range (+8‰ to +20‰) and the dominance of denitrifier (*nir* and *nos* genes) genes under this treatment. Hence, a combined approach of isotopic and microbial analysis provides a clear insight into nitrous oxide production and consumption mechanisms.

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IV-O4

A DECISION SUPPORT TOOL TO OPTIMIZE THE SELECTION OF ^{15}N ANALYSIS METHODS OF AMMONIUM AND NITRATE IN ENVIRONMENTAL RESEARCH

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The stable nitrogen isotope (^{15}N) analysis of ammonium (NH_4^+) and nitrate (NO_3^-) is widely used in ecological research, providing insights into N cycling and its underlying regulating mechanisms in both aquatic and terrestrial ecosystems. To date, a large number of methods have been developed for the preparation and measurement of ^{15}N abundance of NH_4^+ and NO_3^- in liquid environmental samples at either natural abundance or enriched levels. However, these methods are all subjected to certain specific advantages and limitations, and ecologists might be looking for an efficient way to select the most suitable methods in face of shifting sampling and analytical conditions.

Based on our extensive review of these ^{15}N analysis methods we developed a decision support tool (DST) to provide quick and proper guidance for environmental researchers in finding the optimal method for preparing their liquid samples for ^{15}N analysis in NH_4^+ or NO_3^-. The DST is a decision tree based on several key criteria that users need take into account when choosing the preferred sample preparation method for their samples. The criteria concern: the sample matrix, the ^{15}N abundance and the concentration of the target N species, the contamination by other N-containing chemicals, the isotopic fractionation, the availability of equipment, concerns about toxicity of reagents, and the preparation time. This work links field-scale experiments and laboratory ^{15}N analysis. Potential applications of our decision trees include ^{15}N studies ranging from natural abundance to tracer level in a wide range of terrestrial, freshwater and marine ecosystems.

IV-O5

TEMPORAL VARIABILITY OF PESTICIDE REMOVAL FROM ARTIFICIAL WETLAND RECEIVING AGRICULTURAL DRAINED WATER

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To reduce agricultural pollutants in agricultural drained watershed, artificial wetland showed a real potential as a management practice for pesticide removal. Several publications carried out such experimentations for short period but few are dealing with long term efficiency. This study, included in the framework of PESTIPOND project (www.cnrs.pestipond.fr) aims to fill the gaps in our knowledge in this field.
An off-stream artificial wetland (5270 m², 0.1 to 1 m deep), designed to abate pesticide pollution, intercepts drainage water from a 355 ha watershed in Rampillon, France (03°03'37.3'' E, 48°32'16.7'' N). Farms are conventional and the crop rotations include mainly winter crops (winter wheat, barley), corn, sugar beet and rape. A sluice gate at the inlet of artificial wetland controls the INLET drained flow during peak events specially during winter season The flow entering the wetland fluctuates from 0 to 120 L s-1. The wetland is partially covered by sedges, reed, cattails and algae. Since 2012, an automatic water quality monitoring system measures water discharge, temperature, in both inlet and outlet. Weekly flow weigh samples help to assess pesticide flux removal between INLET and OUTLET artificial wetland, receiving agricultural drained flows. Water samples were then sent to chemical analysis sub-contractor to evaluate about 500 different pesticides, with a detection limit lower than 0.005µg/L.
Agricultural practices survey showed that among the 100 applied pesticides corresponding to 1.7 kg/ha of active molecules, about 40 were exported for a very stable inter-annual amount about 1.5g/ha per year. The 8 years monitoring INLET/OUTLET (2012-2020) showed 1) an average removal of 30% depending on seasonal hydrological response; 2) a mitigation efficiency according pesticides: from 100% for fungicide pesticides like tebuconazol, epoxyconazol to 0% for pesticides playing as water tracers (mesotrione, imazamox). To go deeper in the removal efficiency, we performed statistical analysis based on pesticides properties, temperature, application period and transfer, hydrological response and hydraulic residential time. The main results showed that temperature and HRT controlled global efficiency in which Koc and a new dissipation factor (far away from the classical DT50), helped to forecast removal efficiency.

IV-O6

ANNUAL CO_2 BALANCE OF A BARLEY GROWING ON CLAY SOIL - COMPARISON OF DIRECT AND INDIRECT MEASUREMENTS

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Agricultural soils have been recognized as a potential sink of carbon (C), which could contribute greatly to global climate change mitigation efforts (Paustian et al. 2016). Sequestration of carbon in soil can be enhanced through various management and cultivation practices, such as use of cover crops, reduced tillage, rotational grazing, use of legumes, etc. In order to improve soil C sequestration, we need reliable methods to quantify and verify the rate of C transfer into the soil. Verification methods, including multiple sources of field-based and remote sensing data, ecosystem, soil and vegetation models, and platforms capable of assimilating data are currently being developed (Nevalainen et al. 2022). An essential feature of such ”monitoring, verifying, reporting” systems to produce an estimate of the field C sequestrations is to use direct greenhouse gas flux measurements which can provide the CO_2 budget of a grass- or cropland ecosystem in hourly, daily, monthly or annual basis. Such measurements are typically done either by using the eddy covariance (EC) or chamber methods. While the former is a non-intruding and area-integrating method, it is expensive and quite challenging to deploy. The latter method, on the other hand, is typically cheaper and can provide useful information about the spatial variation, however, it disturbs the ecosystem and provides non-continuous data if non-automatic measurements are used.

Here we present one year of data from a clay field growing barley, located in southern Finland, in Haltiala area in Helsinki. The eddy covariance tower (60°16,259'N, 24°56,637 E) was built there in May 2021 and has operated now about one year, providing data on the CO_2 and energy exchange. During the growing season of 2021, we also measured total ecosystem respiration (TER) and CH_4 and N_2O fluxes biweekly using a portable combination of chamber and Li-Cor 850 and LGR N2OM1-919analyzers. Respiration data from 48 collars, the continuous air and soil temperature data and green leaf area information were used to reconstruct a continuous time series of TER. This information was combined with the estimate of satellite-based (Sentinel-2) gross primary production (GPP) to obtain an alternative estimate of growing season NEE.

In this presentation we will show the comparison of the methods in estimating the NEE and discuss the carbon balance of the clay soil growing barley during 2021, including a warm and dry summer. We also discuss the possibilities of deploying the indirect “low-cost method” presented here for wider use, such as estimating farm-level field C budgets with as small amount of field measurements as possible.

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IV-O7

STABLE ISOTOPES ELUCIDATE MORE AND MORE FACETS OF FUNGUS-TO-PLANT CARBON FLUXES IN SHARED MYCORRHIZAL NETWORKS

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Mycorrhiza is a wide-spread symbiosis between plants and fungi. More than 95% of all terrestrial plant species form in their roots morphologically distinguished mycorrhizae with a wide range of fungal partners. The most prominent types of mycorrhiza are the arbuscular mycorrhiza (AM), ectomycorrhiza (ECM), ericoid mycorrhiza (ErM) and orchid mycorrhiza (OrM). Mycorrhiza is usually considered as a mutually beneficial interaction, in which plants exchange carbon (C) compounds from photosynthesis for mineral nutrients acquired by a network of fungal hyphae in the soil. Up to 30% of C gained through photosynthesis is transferred by this way into soils. This mutualistic arrangement, however, has repeatedly been subverted by plants. The most prominent examples are plants producing dust seeds and relying completely on fungal hosts for C supply in the seedling development stage. All orchids follow this initially mycoheterotrophic (MH) mode of nutrition. A few hundreds of initially MH plant species are known to remain achlorophyllous as adults and to continue relying on fungal C throughout their entire life cycle. Such fully MH plants can be found among plants forming AM, ErM and OrM. Interestingly, even saprotrophic wood- and litter-decomposing fungi – usually not involved in any type of mycorrhiza – serve occasionally as hosts of fully MH plants. Due to the fact that the so far investigated fungi are mostly enriched in heavy stable isotopes of the elements C, nitrogen (N) and hydrogen (H) in comparison to accompanying plants, initially and fully MH plants become also enriched in heavy C, N and H isotopes. Due to an isotopic positioning between autotrophic and fully MH plants, a steadily increasing number of adult chlorophyllous plants has been identified since the first discovery in 2003 as gaining C simultaneously from two sources, own photosynthesis and fungal hosts. This nutritional mode is now known as partial MH and has until recently exclusively been found among orchids and Ericaceae mycorrhizal with fungi simultaneously forming ECM with forest trees. By adding H isotopes to C and N isotopes further partially MH plant species have recently been identified. These species include orchids from open-land habitats mycorrhizal with fungi of the ubiquitary ‘rhizoctonia’ group (Gebauer et al., 2016) and plants forming AM of the so called *Paris*-morphotype (Giesemann et al., 2021). Thus, fungus-to-plant C fluxes and MH nutrition are obviously much wider distributed among plants than previously thought.
In analogy to the tripartite network between autotrophic trees, ECM fungi and fully or partially MH orchids or Ericaceae we also postulate for the more recently as partially MH identified plant species tripartite networks between autotrophic and partially MH plants with shared mycorrhizal fungi as mediators. The consequences of these fungus-to-plant C fluxes for the C cycle on ecosystem level are discussed.

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IV-O8

CONTRASTING DIVERSITY AND SPECIALIZATION PATTERNS OF ARBUSCULAR MYCORRHIZAL FUNGAL COMMUNITIES ALONG A STEEP ELEVATIONAL GRADIENT

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Climate change effects on high elevation plant communities are influenced by the diversity, distribution and ecology of their symbiotic fungi. Root associated arbuscular mycorrhizal (AM) fungi can be beneficial for plants under environmental stress, hence affecting the way plants are able to adapt to warmer climates. However, very little is known about the ecology and diversity of these fungi in high elevations with the highest warming rates. We report findings of AM fungal diversity and community patterns from distinct habitat types in the NW Himalayas that spans across some of the longest elevational gradients examined (1941-6150 m a.s.l), reaching the altitudinal limit of known plant life. Using DNA metabarcoding, we found that although taxonomic richness and diversity of AM fungal taxa declined with elevation, their phylogenetic diversity, as well as phylogenetic dissimilarity increased. AM fungal communities in low-elevation sites were generally more closely related than expected by chance, whereas high-elevation communities were relatively more distantly related. In addition, the realized niche volume of the AM fungal communities decreased, and the proportion of putatively non-ruderal AM fungal taxa increased with elevation. In general, taxa from the *Glomeraceae* family dominated in all elevations and habitat types, however, higher elevations were associated with increased presence of *Claroideoglomeraceae*, *Ambisporaceae* and *Paraglomeraceae* families. Our results suggest that plants in lower to mid-elevations harbour AM fungal communities which albeit taxonomically diverse, are phylogenetically clustered and dominated by generalist ruderal taxa. In contrast, high elevation AM fungal communities, despite being taxonomically less diverse, are phylogenetically divergent and more specialized. These results imply that climate change induced shifts in habitat conditions may facilitate more diverse AM fungal communities in higher elevations, but could also steer the AM fungal communities towards higher ruderality. Further research should focus on the underlying biotic and abiotic mechanisms structuring AM fungal communities along altitudinal gradients, also assessing their functional role in these extreme environments.

IV-O9

NITROGEN BUT NOT PHOSPHORUS ADDITION AFFECTS SYMBIOTIC N_2 FIXATION IN GRASSLANDS LOCATED ON FOUR CONTINENTS

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The amount of nitrogen (N) derived from symbiotic N_2 fixation by legumes in grasslands might be affected by anthropogenic N and phosphorus (P) inputs, but the underlying mechanisms are not known. We evaluated symbiotic N_2 fixation in 17 natural and semi-natural grasslands on four continents that are subjected to the same full-factorial N and P addition experiment, using the ^{15}N natural abundance method.
Nitrogen, as well as combined N and P (NP) addition, reduced aboveground legume biomass by 65% and 45%, respectively, compared to the control, whereas P addition had no significant impact. Addition of N and/or P had no significant effect on the symbiotic N_2 fixation per unit legume biomass. Consequently, the amount of N fixed annually per grassland area was less than half in the N addition treatments (1.39 and 2.13 kg N ha^{-1} $\mathbf{yr^{-1}}$ in N and NP, respectively) compared to control and P addition (3.50 and 3.71 kg N ha^{-1} $\mathbf{yr^{-1}}$, respectively), irrespective of whether the dominant legumes were annuals or perennials. Our results reveal that N addition mainly impacts symbiotic N_2 fixation via reduced biomass of legumes rather than changes in N_2 fixation per unit legume biomass. Further, the unique global design of this study allowed us to derive an equation to correct for the effect of elevation on the isotope signature of N in grasses and non-fixing forbs (used as reference plants), which will be useful in future studies.
The results show that soil N enrichment by anthropogenic activities significantly reduces N_2 fixation in grasslands, and these effects cannot be reversed by additional P amendment. This reduction in symbiotic N_2 fixation per area increases the dependence of grassland productivity on fertilization and can ultimately change the ecological functioning of grasslands, affecting their net primary productivity as well as their above and belowground biodiversity, forage quality and provision of ecosystem services.

IV-O10

FOREST GROWTH RESPONDS MORE TO AIR POLLUTION THAN ACIDIFICATION

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The forests of central Europe have undergone remarkable transitions in the past 40 years as air quality has improved dramatically. Retrospective analysis of Norway spruce (*Picea abies*) tree rings in the Czech Republic shows that air pollution (e.g. SO_2 concentrations, high acidic deposition to the forest canopy) plays a dominant role in driving forest health. Extensive soil acidification occurred in the highly polluted "Black Triangle" in Central Europe, and upper mineral soils are still acidified. In contrast, acidic atmospheric deposition declined by 80% and atmospheric SO_2 concentration by 90% between the late 1980s and 2010s.

In this study we observed that annual tree ring width (TRW) declined in the 1970s and subsequently recovered in the 1990s, tracking SO_2 concentrations closely. Furthermore, recovery of TRW was similar in unlimed and limed stands. Despite large increases in soil base saturation, as well as soil pH, as a result of repeated liming starting in 1981, TRW growth was similar in limed and unlimed plots. TRW recovery was interrupted in 1996 when highly acidic rime (originating from more pronounced decline of alkaline dust than SO_2 from local power plants) injured the spruce canopy, but recovered soon to the pre-episode growth. Across the long-term site history, changes in soil chemistry (pH, base saturation, Bc/Al soil solution ratio) cannot explain observed changes in TRW at the two study sites where we tracked soil chemistry. Instead, statistically significant recovery in TRW is linked to the trajectory of annual SO_2 concentrations or sulfur deposition at all three stands.

IV-O11

QUARTER OF CENTURY LITTERFALL RECORD IN NORWAY SPRUCE STANDS HIGHLY IMPACTED BY ACID RAIN (ORE MOUNTAINS, CZECH REPUBLIC)

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Recent works have provided evidence that litterfall is the dominant way for Hg deposition from atmosphere to the forest ecosystems. We evaluated 25-years long trend (1994–2019) in mercury (Hg) concentrations and fluxes in five litterfall components needles, bark, twigs, cones, and a mixture of unidentified fragments at a research plots situated in mountain forest Norway spruce stand. The study site Načetín is in the Ore Mountains (Erzgebirge) near the Czech-German border in an area known as the Black Triangle due to extensive damage by acid precipitation in the second half of the 20th century. The litterfall Hg deposition averaged 50 ± 17 $\mu g.m^{-2}.yr^{-1}$, while the bulk precipitation and throughfall Hg deposition determined in 2019 were an order of magnitude lower (2.2 and 7.0 $\mu g.m^{-2}.yr^{-1}$). Hg concentrations in the individual litter components averaged 256, 234, 119, 95 and 44 µg/kg in bark, unidentified fragments, twigs, needles and cones, respectively. Due to decreasing Czech, German and overall European Hg emissions, Hg concentrations in litter decreased from 1994–2019. Despite that, the litter-associated Hg flux to forest floor increased from 44 to 71 $\mu g.m^{-2}.yr^{-1}$ during 1994–2019 due to increase of the litterfall mass fluxes from 407 to 678 $g.m^{-2}.yr^{-1}$. Using the three soil sampling campaigns in years 1994, 2004 and 2018 we evaluated the effect of the changes in litterfall composition and deposition onto the O horizon soil layers. Mercury concentrations in the Oi horizons decreased significantly from 354, through 295 to 202 $\mu g.kg^{-1}$ in years 1994, 2004 and 2018. In contrast, Hg concentrations in more decomposed Oa horizons increased from 453, across 489 to 593 $\mu g.kg^{-1}$. Lumped O horizon soil Hg pool decreased from 7.6 to 5.5 $mg.m^{-2}.yr^{-1}$ but without statistical significance. We further investigated on the interplay between changes in litterfall chemical composition e.g. Hg/C, Hg/N and Hg/S ratios and its reprint into the soil.

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IV-O12

NATURAL ATTENUATION OF DICHLORONITROBENZENES AND DICHLOROANILINES IN CONSTRUCTED WETLANDS REVEALED BY COMPOUND SPECIFIC ISOTOPE ANALYSIS

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Compound specific isotope analysis (CSIA) is an established tool for evaluating *in situ* transformation of selected organic contaminants in groundwater. To date, CSIA has never been applied to understand the fate of (di)chloronitrobenzenes and (di)chloroanilines in constructed wetlands. We investigated the fate of these compounds in a pilot constructed wetland system receiving industrial effluents. Concentrations and stable isotope analysis of selected compounds suggested their transformation in the constructed wetland system. Using a controlled-laboratory experiment, we determined, for the first time, negligible carbon and hydrogen isotope fractionation, and a significant inverse nitrogen isotope effect during aerobic biotransformation of 2,3-dichloroaniline using a mixed microbial culture from the site. The bulk nitrogen enrichment factor, ranging from +6.2±0.3 to +7.9±0.4‰ was applied to estimate the extent of 2,3-dichloroaniline *in situ* biotransformation. The field-obtained carbon and nitrogen isotope signatures suggested up to 80 to 90% aerobic biotransformation of 2,3-dichloroaniline by native microorganisms. This study proposes multi-element CSIA of (di)chloroanilines and (di)chloronitrobenzenes as a novel application to study their natural attenuation in constructed wetlands.

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IV-O13

HIGH-FREQUENCY MONITORING AT THE LYSINA CATCHMENT

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Long-term monitoring of stream water chemistry aids our understanding of ecosystem processes highlighting impacts, changes over time, and recovery. However, how frequent samples are taken can make a difference in what can be said or interpreted. Sampling frequency can play a key role in deciphering biogeochemical processes, particularly if those are dependent or influenced by flow conditions. Here we examined the differences between regular weekly and high-frequency monitoring at the Lysina stream, Slavkov Forest, Czechia (Hruška et al., 2002). Regular monitoring at Lysina has been conducted for 32 years and these measurements have been important in tracking changes over time and stream water recovery from acidification. In recent years, a multi-probe sonde was installed at Lysina to measure in-situ pH, conductivity, fluorescent dissolved organic matter (fDOM), and temperature at a 10-minute interval frequency. We compared the difference for these parameters along with discharge for both sampling approaches (regular and high-frequency) for the water years of 2020 and 2021. Changes in flow conditions, notably exert control on the concentration of solutes and parameter dynamics. Our data show enrichment of dissolved organic carbon, as well as increases in conductivity and H^+ when flow conditions increase. However, when compared to our high-frequency parameters, it is well highlighted that often our grab samples miss important events during regular sampling (Fig. 1), which can translate in overall misinterpretation of processes. Therefore, having in-situ measurements allows to compliment and aid our understanding of the signals that are often not picked up by regular sampling, which has implications for calculation of element fluxes, and conditions for biota.

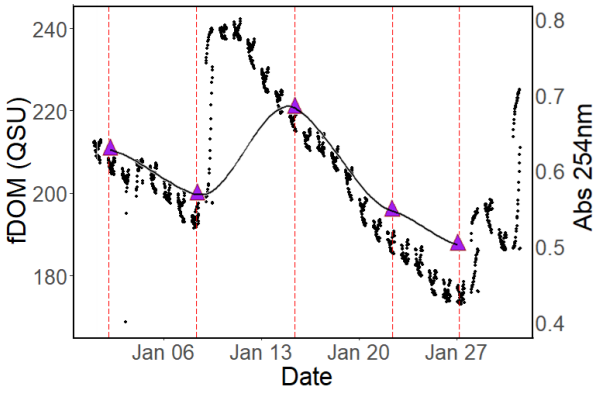

Fig. 1 Comparison between high-frequency (fDOM) and regular sampling (Abs 254) at Lysina. Vertical dash-red lines show days when grab samples were collected. Black data points are fDOM measurements from in-situ sensor, and purple triangles data points for absorbance (Abs 254).

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IV-O14

LONG-TERM INSIGHT INTO THE CHANGES OF THE VEGETATION OF PEATLAND ECOSYSTEMS IN ARCTIC ALASKA

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Peatland ecosystems located in high-latitude regions play an important role for soil organic carbon and as habitats for unique plants and animals. Arctic regions, such as Alaska, experience rising temperatures that cause permafrost thaw and vegetation changes. However, most of the results on the response of at high latitude plant communities (species, biomass, phenology) to recent warming come from observational and experimental studies, with comparatively limited data concerning centennial to millennial temporal scales. It is unclear how peatland plant populations responded to previous climate changes over the last 3000 years and how they will respond to a sustained rise in temperature in the 21st century. Detailed long-term palaeoecological studies of peatlands from high latitudes are important for understanding the relationships between climate, hydrology, fire, and vegetation, especially moss populations to climate warming.

We conduct a multiproxy, detailed high-resolution palaeoecological analysis: plant macrofossils, pollen, non-pollen palinomorphs, micro and macrocharcoal, testate amoebae, and elemental analysis and stoichiometry, supported by radiocarbon and lead dating on eight peat cores taken in various types of peatlands (rich fens, poor fens, string fens) along a N-S gradient ranging from the northern slope of Brooks Mts to Prudhoe Bay, northern Alaska. Our data cover the peatlands development over the past 3000 years. The aims of our studies are to: i) reconstruct local and regional vegetation changes, moisture conditions, and fire activity during the late Holocene; ii) evaluate the impact of climate changes, fire, and dust deposition on development of arctic plant communities. We address the following hypotheses: i) the expansion of the northern distribution of mosses typical of dry peatland habitats and shrubs (e.g. *Betula nana*) into Arctic areas following past warm climatic periods; ii) the responses of the herbaceous and moss populations to temperature and hydrological changes vary between types of peatlands; iii) some of plant populations might have been resistant to past climate change and will be resistant to future temperature rise due to their wider ecological tolerance to moisture changes and pH.

Based on our results we draw the following conclusions: i) plant populations composed of *Carex* spp. and mosses (e.g. *Scorpidium scorpioides* and *Drepanocladus trifarius*) demonstrated resistance to climate changes in the late Holocene; ii) we noticed an increased abundance of macrofossils and pollen of shrubs and dwarf shrubs, e.g. Ericaceae, *Betula nana*, *Salix* sp. in peat cores linked to warming stages of climate and this pattern was repeatedly observed; iii) we documented the appearance of *Sphagnum* species (usually growing in dry habitat) and brown mosses during the last decades on some of our sampling sites; iv) we noticed a negligible fire activity over the study period, that that did not impact local plant succession; v) we think that autogenous plant succession at Arctic peatland ecosystems that developed towards ombrotrophic status may also have been an important factor for plant populations shifts.

IV-O15

MORPHOLOGICAL AND BIOGEOCHEMICAL CHARACTERISTICS OF BIOLOGICAL SOIL CRUSTS FROM A DRY, HIGH-ALTITUDE GLACIER FORELAND IN THE NE PAMIR (TAJIKISTAN) IN THE CONTEXT OF NUTRIENT ACCUMULATION

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Under demanding climatic conditions that limit development of vascular vegetation, biological soil crusts (BSCs) drive the processes of soil formation and nutrient sequestration. Though BSCs were examined in glacier forelands across the world, the high-altitude areas with combination of glaciation/deglaciation and arid/hyperarid climate remain almost unstudied in this respect. Therefore, we provide the first description of the occurrence, morphological diversity, and cover of BSCs from a dry, high-altitude foreland of the Uisu Glacier, located in NE Pamir. Given the extreme environmental conditions in the investigated area, we expected that BSCs of different developmental stages comprise the dominant part of the biologically active soil cover and that the microbial biomass and total nutrient retention patterns in BSCs are positively related to their developmental stage. Additionally, we hypothesized that there is noticeable increase in microbial biomass (assessed using content of PLFAs and ergosterol) and, consequently, C, N and P accumulation in BSCs and sub-crust soils relative to non-crusted bare soils. Subsequently, to assess the potential importance of BSCs for nutrient accumulation/mobilization processes in soils of the Uisu Glacier foreland, we compared the C, N, and P enrichment, and the origin and transformation degree of organic matter (assessed using content and ratios of n-alkanes) in soils under the BSCs with the same parameters in soils under vascular plants.

Our study showed that poorly developed BSCs (no lichens, no bryophytes) dominated in the foreland (mean coverage of 14%). In comparison to advanced crusts (mean coverage 1.1%), they accumulated less total C, N and available P in their biomass. Yet, they were still the main biological soil-forming factor (next to the plants) in our study site, given that stones and non-crusted bare soils covered most of the area (joint mean coverage over 80%). In non-crusted soils the biomass of free-living microorganisms, especially fungi, was negligible. Therefore, during the investigated season, BSCs and plant root zones were the hotspots of microbial occurrence and probably activity. Soil-forming properties of both poorly developed and advanced crusts were confirmed by the observed enrichment of their sub-crust soils in total C, N and available P in comparison to non-crusted bare soils (on average, there was ~1.5 times more nutrients in soils under poorly developed crusts and ~2.5 more nutrients in soils under advanced crusts than in non-crusted bare soils). Moreover, average enrichment observed for soils under advanced crusts was similar to the results obtained for soils under vascular plants (~2.5 times more than in non-crusted bare soils), thus emphasizing the potential importance of BSCs in such extreme environments as the one investigated by us. As the further aridification is projected for the Pamir, leading to limitation of ecological niches available for vascular plants, BSCs could potentially become the most important, or even the sole player in accumulation of soil nutrients in many areas.

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IV-O16

EFFECT OF PEAT ORGANIC MATTER ON SULFIDE WEATHERING AND THALLIUM MOBILITY

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The purpose of this study was to better understand the geochemical stability, dissolution kinetics, alteration products and the associated release and mobility of anthropogenic Tl from sulphides in organic environments. We also present the effect of industrial acid rainwater on sulfide degradation and Tl migration in naturally acidic peat. A commercial pollutant-free peat was used throughout the experiment and Tl-rich sulphide concentrate was obtained by the flotation of Zn-Pb ores from a hydrothermal/MVT deposit at Olkusz, Poland. The peat was treated with deionized water or synthetic rainwater (SRW). Peat pore solutions were collected after 1, 2, 3, 4, 6, 8 and 12 weeks; at the end of the trail, the individual bags were extracted, weighed and analyzed. A combination of X-ray diffraction analysis (XRD), scanning electron microscopy (SEM), electron probe microanalysis (EPMA), energy dispersion spectrometer (EDS), basic physicochemical and chemical analysis (eg. pH, CEC, total carbon, total elemental concentrations) were used to analyze the sulphide concentrates, peat samples and pore water.

Our results showed that element monitoring in the peat solutions showed a gradual/time-dependent increase in Tl concentrations. This trend is related to Tl leaching from sphalerite (ZnS) and to a limited degree from less abundant galena (PbS) and pyrite (FeS2). Sphalerite (ZnS) was much less stable in peat when compared to other Tl-containing sulfides, making it a major phase responsible for Tl mobilization. Samples subjected to acid rain watering proved to elevate Tl leaching from the ZnS, with elevated Tl concentrations being recorded in the peat (≤0.4 mg Tl/kg) and peat solutions (≤5 μg Tl/L). The element with the highest enrichment and mobility in the peat samples and peat solutions was Zn. The results of Pb in the peat samples prove the conservative nature of Pb, which displayed very little mobility within the peat profile. While Tl and Pb are relatively similar in their behaviours, in the case of Tl, its mobility is slightly higher than Pb. The trail conducted in this paper with both SRW and H_2O has shown that peat pH can control the degradation of specific sulphides (mainly ZnS), with the SRW promoting sulphide degradation and enhanced Tl and Zn leaching. The long-term implications that industrial acid precipitations can have on contaminated peatlands could be severe, as it compromises the stability of ZnS (and possibly other Tl-bearing minerals) even in acidic peat, which in turn can enhance weathering and Tl release.

IV-O17

CO-COMPOSTING ROSE WASTE, ASSESSING THE POTENTIAL AS SUSTAINABLE WASTE MANAGEMENT STRATEGY

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The limited usage of rose waste makes rose farming far from a sustainable circular industry. The re-use of horticultural waste is currently limited due to unfavorable properties such as high lignin content of stems and high polyphenol levels in both flowers & leaves which hamper an effective composting process.

The aim of our study was to investigate the potential of co-composting rose waste with other green wastes (tomato and kalanchoe) or mature rose compost to obtain compost with high fertilizing capacity. We closely monitored the evolution of five mixtures in a small-scale drum composting system and assessed in-vivo disease suppression. All mixtures resulted in stable and mature compost after six months of composting containing sufficient nutrients, a C/N below 10, strong decrease in polyphenols of ≥70% and good fertilizing capacity with increase of CEC ≥70%. Mixtures with mature compost added reacted faster but less pronounced in terms of final physicochemical parameter values. For the first time, a high disease suppressive capacity against several common rose pathogens was shown for mature rose compost.

The results from our study showed that the ligneous character of rose wastes is not preventing an effective composting process to take place, but an increased maturation phase might be favored for optimal results. Our study showed the potential of co-composting rose waste to improve the circular economy waste-based objectives of the horticultural sector.

IV-O18

DECLINE OF AVAILABLE PHOSPHORUS CONTENT IN MOUNTAIN FOREST SOILS OF THE CZECH REPUBLIC

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Mountainous forest soils particularly in northern parts of the Czech Republic were strongly impacted by acid deposition in the second half of the 20th century. Strong acidity, high sulphur accumulation in soils, continuing nitrogen deposition and consequent unbalanced tree nutrition are reasons for very slow forest soils recovery. One of the critical nutrients is phosphorus (P). The changes in the content of available P were studied in forest floor and surface mineral horizons of Czech forest soils using a large database compiled from several soil surveys carried in the last 20 years. A clear and strong decline was found for soils of the Northern mountainous regions of the Czech Republic. In many soils, the content is under deficiency level for forest vegetation already. This decline was reflected already in the low P content in spruce needles that was correlated with the soil content (Novotny et al. 2018). In consequence, the lack of available P coupled with unbalanced plant nutrition can lead to damage of forest trees. However, the total P content did not show a similar decline. Therefore, sharp decline of available P forms has to be caused by changes in soil conditions after termination of sulphur deposition in 1990s and consequent tendency of labile aluminum forms to decrease. These changes could lead to an increase of precipitation and/or binding of phosphorus. Changes in soil microbial activity, soil organic matter decomposition (Tahovska et al. 2018) and mycorrhizal efficiency could also have an effect. The influence of various factors and relationship with other soil characteristics, including soil organic matter content, content of other available nutrients (Ca, Mg, K), nitrogen content, pH, exchangeable Al and Fe, etc., were analyzed. Effect of liming in some regions was also taken into account. Stoichiometric ratios (C/P, N/P, Ca/P etc.) were considered. The methods used for the determination of the available P content were questioned, too. Possible mechanisms and processes that could lead to the current state of available P content in forest soils of these regions are discussed. The mechanisms can be different under different forest types and also between the organic and mineral horizons. To conclude, it appears that the available P decline is not caused by just one simple process. It is rather result of a complex mutual effect of various factors and processes. Further research is needed in this field.

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Oral presentation abstracts

V SESSION

Ecosystem restoration and rehabilitation, peatland processes

V-O1

PLANT COMMUNITY RESPONSES TO EXPERIMENTAL CLIMATE MANIPULATION IN A WELSH BOG AND THEIR PALAEOENVIRONMENTAL CONTEXT

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We test whether the vegetation community composition resulting from a 10-year climate manipulation experiment (warming, episodic drought, combined) on a Welsh peat bog resembles vegetation communities during periods of corresponding climate change inferred from a peat core taken from the bog. Experimentally warmed (ca 0.5°C air temperature) and combined treatments drove significant increases in the abundance of ericaceous shrubs; in the palaeoecological record, *Calluna vulgaris* seeds also increased during warmer periods. There was no significant change in *Sphagnum* abundance under any experimental treatment, and there was no effect on vegetation of the experimental short-term droughts (four 4-week droughts of ca 15 cm below controls).
Vegetation changes due to climate inferred from the palaeo record differ from those observed in the experiments, possibly relating to differences in the importance of drivers over different timescales. Whereas temperature is the dominant driver of plant community change in the experiments, sustained changes in water table appear to be more important in the long-term record. Our experiment suggests that vegetation community composition in ombrotrophic bogs is resilient to moderate increases in drought intensity. Since the core analyses do not identify individual drought events but rather periods of long-term water table drawdown, this finding could not be corroborated by the palaeoecological record. We find evidence that anthropogenic stressors (e.g. drainage, short- and long-range air pollution) may promote the development of novel plant communities without analogues in the fossil record. These communities may respond differently to future climate change than those that predate human activity.
Our study suggests that the c. 0.5°C warming expected over the next 70 years for this region may not exceed a critical threshold for *Sphagnum* decline. However, it does not rule out a change in *Sphagnum* abundance, either in direct response to a sustained temperature/water table change, or indirectly through a community shift driven by the influx of shrubs. We also suggest that responses in peatland vegetation community composition to climate change inferred from the palaeoecological record may need to be viewed with caution as an analogue for future change because many peatlands, even apparently 'pristine' ones, have been influenced by anthropogenic drivers.

V-O2

IMPORTANCE OF SOIL WATER CONTENT FOR GHG EXCHANGE IN GLOBAL PEATLANDS

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Climate warming is a growing concern for the scientific community and the global population. The latest policy reports suggest that global surface temperature will rise 1.5 to 4.4 °C by the century. Thus, it is expected to see increases in soil temperature and reductions in soil moisture leading to changes in the length of the growing season. Peat plays a crucial role in Earth's climate by regulating global greenhouse gas (GHG) exchange. Peat stores more carbon than all the vegetation on the land surface combined but, in its natural wet state, emits methane (CH_4). Scarcity and uncertainty about importance of environmental factors, such as soil water content, on the three major GHGs (CO_2, CH_4, and N_2O) remain a challenge. In this study, we explain GHG exchange as a function of SWC using a generalized additive model (GAM). Our results suggest that GHG exchange follows a unimodal curve (R^2_{adj} = 0.32, p-value = 0.0000059) with peak emission at the intermediate SWC levels. Net ecosystem exchange (NEE) of carbon (C) dominated the GHG budget. Nevertheless, due to the low share of CH_4 in the GHG exchange, the ~62% uncertainty in the relationship between SWC and CH_4 (R^2_{adj} = 0.38, p-value = 0.0000015) did not transfer into uncertainty in the overall GHG exchange. A piecewise regression model) of the modified normalized difference in water index (MNDWI) extracted from the Landsat satellites with cubic splines, explained variances in SWC (R^2_{adj} = 0.39, p-value = 0.000076). The function followed a linear relationship and saturated beyond 0.5 MNDWI. This paves the way for exploring the spatial distribution of GHG fluxes in peatlands and the global peatland GHG budget.

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V-O3

COMPLEX TOOLS TO TACKLE COMPLEX DRAINED PEATLAND FOREST DYNAMICS

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Boreal peatlands are a large terrestrial source of water, nutrients and dissolved organic carbon (DOC) to watercourses. In Finland, nearly half of the original peatland area (~10 mil. ha) was drained for forestry prior to the 1990s, which further increase the nutrient and DOC export from peatlands to watercourses causing brownification. The drainage lowers groundwater table that promotes faster aerobic decomposition and forest growth – the former being an undesired and the latter being a desired outcome. Large portion of the drained peatland forests are becoming to the age of final harvest. Thus, there is an interest to find an optimal water table that supports multiple desired ecosystem services including water protection, carbon sequestration/neutrality and wood production. Ecosystem modelling can be used to simulate the complex interlinked peatland dynamics, and it provides a practical tool for the use of wide range of stakeholders.

An existing ecosystem model - Peatland Simulator (SUSI) - captures the drained peatland forest dynamics and their feedbacks by simulating peat decomposition, release of nutrients, net primary production, forest growth, and the ecosystem net C balance (soil and biomass) as well as the effects of ditch depth on the water table and related processes. We further developed the model to assess the whole peatland C balance including DOC production, biodegradation, and lateral transport for the first time. In the revised model, the DOC production is controlled by litter and logging residue mass and quality, availability of oxygen and soil temperature. The DOC pools are divided into labile and recalcitrant DOC fractions, which formation are temperature dependent, and biodegradation of DOC described using first-order kinetics based on known half-times. The transport of DOC can be approached in two ways: 1) using a simplified model based on mean annual residence times or 2) through advection based on solution of full 2-dimensional Richard's equation.

We use the revised model to simulate different management schemes (ditch depth, harvesting intensity) to demonstrate the model functions and to discuss the management effects on DOC processes. Overall, the revised model allows a holistic evaluation of the peatland forestry including the stand biometrics, the nutrient and DOC export as well as peatland C balance.

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V-O4

EFFECTS OF THE WATER TABLE LEVEL AND GLUCOSE ADDITION ON THE RELEASE AND BIODEGRADABILITY OF DISSOLVED ORGANIC CARBON IN A BOREAL PEAT COLUMN EXPERIMENT

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Boreal peatlands are among the greatest terrestrial carbon sinks, due to their characteristic waterlogged, anoxic conditions slowing organic matter decomposition and promoting its accumulation as peat. However, they are also major sources of dissolved organic carbon (DOC) and nutrients (nitrogen (N) and phosphorous (P)) to surrounding water bodies. This can be amplified by climate change and various disruptive forms of land use, such as farming and forestry. Continuous cover forestry has been proposed to cause less adverse effects on the environment than conventional clear-cutting practices, but information regarding its benefits to the runoff water quality is still lacking. We conducted a common garden experiment using peat cores, followed by a laboratory incubation experiment, to study how forest management, groundwater table and availability of easily decomposable carbon (^{13}C-labelled glucose) and nitrogen (glycine) affect the decomposition rate of DOC.

The forest clear-cut and continuous cover forestry did not change the DOC and nutrient concentrations, or DOC biodegradability compared to an uncut control forest. However, the DOC and DON (Dissolved organic nitrogen) concentrations increased significantly after the first month of the experiment, but this increase was significantly less with glucose addition. A variance component analysis found more CO_2 production in samples with high water table level and glucose addition, which was also supported by the ^{13}C- signal being stronger in the incubation results from the high water table samples.

These findings indicate that lowering of the groundwater table stimulated the biodegradation of soil organic matter in the peat, resulting in a higher decomposition rate of DOC when easily decomposable carbon in the form of glucose was added. This points toward a priming effect in the peat. The results also reinforce the idea that the forest management effect is shown indirectly through various abiotic factors such as the temperature and water table, explaining the lack of direct changes between forest types that we have observed in the field.

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V-O5

CARBON EXCHANGE RESPONSE OF *SPHAGNUM* DOMINATED PEATLAND TO MULTIPLE ASPECTS OF GLOBAL CHANGE

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Global change is expected to have adverse effects on the carbon (C) storage function of *Sphagnum* peat bogs. The aim of this study is to examine how interactions between rising air temperatures, declining groundwater levels (WL) and nitrogen eutrophication affect C exchange of both natural and degraded *Sphagnum* bog ecosystems.
A greenhouse experiment with *Sphagnum papillosum* planted on packed bog peat columns has been carried out from July 2021 to March 2022. Three different mean annual air temperature and WL treatments (ambient, + 1 °C, + 3 °C and 0 cm, 7 cm, 15 cm below peat surface, respectively), three different amounts of nitrogen (N) input (5, 25 and 50 kg N/(ha*a)) and two different types of peat substrate (slightly and highly decomposed) were combined in a fully factorial design. Five measurement campaigns with manual chambers were conducted over the course of the experiment to quantify CO_2 and CH_4 fluxes for each treatment combination. Soil temperature was measured continuously as explanatory variable. During each campaign, at least three flux measurements using opaque chambers were conducted per soil column to assess the variation of ecosystem respiration (R_{eco}) and CH_4 exchange over the range of soil temperatures occurring during each campaign. To quantify the impact of the imposed environmental conditions on moss C-uptake capacity (GPP_{sat}), one measurement at an irradiation close to moss light saturation was conducted per column using an illuminated chamber. Linear flux calculation was applied to the data and models describing the relationship between soil temperature and R_{eco} and CH_4 fluxes were fitted.
Preliminary results indicate that GPP_{sat} was affected negatively by higher air temperatures in summer, but positively in cooler seasons. A negative response to a drop in WL was observed only after several weeks and only for highly decomposed peat. After nine months, a decreased GPP_{sat} could be detected in the columns with the lowest nitrogen input. This seemed to be related to mosses growing less compact under these conditions than in both high nitrogen treatments and thus drying more strongly when temperatures were rising again after winter. R_{eco} increased in columns with lower WL and at higher temperatures and showed a fast response to treatment variation (< two weeks). The effect of the lowered WL seemed to increase at higher temperatures. As expected, WL strongly affected CH_4 fluxes with highest emissions observed in high WL treatments. CH_4 emissions increased with increasing soil temperatures in the high WL treatment, but no strong relationship of the two variables could be found in columns with lower WL.
The results of the study will provide insights into the effects of projected future environmental changes on *Sphagnum* bog peatlands. The findings can be used to optimize the management of natural, rewetted or commercially used *Sphagnum* peatlands with regard to the reduction of greenhouse gas emissions and to improve physically-based models.

V-O6

DOES NITROGEN DEPOSITION LEAD TO A WEAKER OR STRONGER CARBON SINK IN NUTRIENT-POOR PEATLANDS?

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In nutrient limited peatland ecosystems, atmospheric nitrogen (N) deposition has been found to increase vascular plant growth, but to decrease *Sphagnum* growth. Higher vascular plant abundance and higher nutrient content alter decomposability of plant litter. These changes may affect net imbalance of production and decomposition and thus, carbon (C) accumulation in peatlands, which store about a third of global soil C. We studied whether the vegetation feedbacks of N deposition lead to stronger or weaker C sink in nutrient-poor peatlands. We investigated vegetation and ecosystem CO_2 exchange at two of the longest-running nutrient addition experiments on peatlands, Mer Bleue Bog, Canada and Degerö Stormyr poor fen, Sweden that have been fertilized with NH_4NO_3 (2-15 times ambient annual wet deposition) for 12-23 years. Gross photosynthesis, ecosystem respiration and net CO_2 exchange were measured weekly during June-August using chambers. To examine vegetation changes with increasing N influx, we determined the peak growing season aboveground biomass and coverage of vascular plants using the point intercept method. After 12-23 years of nutrient addition, the two sites revealed contrasting patterns: At Mer Bleue the highest nutrient additions were associated with up to 3-fold net CO_2 uptake potential than in the control, whereas N addition treatments at Degerö Stormyr with only 0.3-fold net CO_2 uptake potential, compared to the control. The stronger C sink potential at Mer Bleue was mainly due to up to 50% increase in the gross photosynthesis and a diminished C sink potential at Degerö Stormyr due to down to 40 % lower gross photosynthesis. Ecosystem respiration showed similar trends at both peatlands: the rates were unaltered or increased to a lesser extent under N load. The contrasting C sink responses to long term N load may be explained by the type of vegetation and the water table depth. Shrubs were strong competitors at the dry Mer Bleue Bog while sedges had gained in abundance under N load at the wetter Degerö Stormyr. Our study emphasizes the value of the long-term experiments in examining whether the key feedback mechanisms to ecosystem C sink potential differ in two main types of peatlands.

V-O7

THE UNEXPECTED LONG PERIOD OF EXTREME CH_4 EMISSIONS FROM AN INUNDATED FEN MEADOW ENDED ONLY WITH CATTAIL

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When drained for e.g. agricultural use, natural peatlands turn from a net C sink to a net C source. It is therefore suggested that restoration of peatlands, despite of increasing CH_4 emissions, holds the potential to mitigate climate change by reducing their overall global warming potential. The time span required for this transition, however, is fairly unknown. Moreover, greenhouse gas emission measurements from peatlands are often limited to a couple of years only. This is problematic in so far, as most peatland ecosystem are in transitional stage due to restoration related disturbances (e.g. enhanced water table) and global climate change. This might affect GHG emissions in one way or another which emphasizes the necessity of longer-term observations to avoid misinterpretations and premature conclusions.

Exemplary for that, we present 14 consecutive years of CH_4 flux measurements following restoration at a formerly long-term drained fen grassland within the Peene river catchment (near the town of Zarnekow: 53.52^0N, 12.52^0E). Restoration of peatland was done by simply opening the dike. Thus, no water table management was established and water table was strongly fluctuating. CH_4 flux measurements were conducted at two sites (inundated vs. non-inundated) using non-flow-through non-steady-state (NFT-NSS) opaque chambers.

Throughout the 14 years study period, distinct stages of an ecosystems transition, differing in their impact on measured CH_4 emissions, were observed. During the first two years of the measurement period directly following restoration in autumn 2004, an eutrophic shallow lake was formed. This development was accompanied by a fast vegetation shift from dying off cultivated grasses to submerged hydrophytes and helophytes and evidenced substantially increased CH_4 emissions. Since 2008, helophytes have gradually spread from the shore line into the established shallow lake especially during drying years. This process was only periodically delayed by exceptional inundation, such as in 2011, 2012 and 2015, and finally resulted in coverage of the measurement site in 2016 and 2017. While, especially the period between 2009 and 2015 showed exceptionally high CH_4 emissions, these decreased significantly after helophytes were established at the measurement site. Hence, CH_4 emissions only decreased after ten years transition following restoration and potentially reaching a new steady state.

V-O8

EXPERIMENTAL NITROGEN ADDITION ALTERS STRUCTURE AND FUNCTION OF A BOREAL BOG: CRITICAL LOAD AND THRESHOLDS REVEALED

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Bogs and fens cover 6% and 21%, respectively, of the 140,329 km^2 Oil Sands Administrative Area in northern Alberta. Development of the oil sands has led to increasing atmospheric N deposition, with values as high as 17 kg N $ha^{-1}yr^{-1}$; regional background deposition is <2kgN $ha^{-1}yr^{-1}$. Bogs, being ombrotrophic, may be especially susceptible to increasing N deposition. To examine responses to N deposition, over five years, we experimentally applied N (as NH_4NO_3) to a bog near Mariana Lake, Alberta, unaffected by oil sands activities, at rates of 0, 5, 10, 15, 20, and 25 kg Nha1yr1, plus controls (no water or N addition). Increasing N addition: (1) stimulated N_2-fixation at deposition <3.1 kg N $ha^{-1}yr^{-1}$, and progressively inhibited N_2-fixation as N deposition increased above this level; (2) had no effect on *Sphagnum fuscum* net primary production (NPP) in years 1, 2, and 4, but inhibited *S. fuscum* NPP in years 3 and 5; (3) stimulated dominant shrub and *Picea mariana* NPP; (4) led to increased root biomass and production; (5) changed Sphagnum species relative abundance(decrease in *S. fuscum*, increase in *S. magellanicum*, no effect on S. angustifolium); (6) led to increasing abundance of *Rhododendron groenlandicum* and *Andromeda polifolia*, and to vascu-lar plants in general; (7) led to increasing shrub leaf N concentrations in *Andromeda polifolia*, *Chamaedaphne calyculata*, *Vaccinium oxycoccos*, *V. vitis-idaea*, and Picea *mariana*; (8) stimulated cellulose decomposition, with no effect on *S. fuscum* peat or mixed vascular plant litter decomposition; (9) had no effect on net N mineralization rates or on porewater NH4+-N,NO3-N, or DON concentrations; and (10) had minimal effects on peat microbial community composition. Increasing experimental N addition led to a switch from new N being taken up primarily by *Sphagnum* to being taken up primarily by shrubs. As shrub growth and cover increase, *Sphagnum* abundance and NPP decrease. Because inhibition of N_2-fixation by increasing N deposition plays a key role in bog structural and functional responses, we recommend a N deposition critical load of 3 kg N $ha^{-1}yr^{-1}$ for northern Alberta bogs.

V-O9

SPECIES-SPECIFIC RESPONSES TO CONTROLS REGULATE PLANT-MEDIATED METHANE EMISSIONS IN A NORTHERN BOREAL FEN

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Plant-mediated CH_4 transport is an important mechanism that influences CH_4 emissions from peatlands, yet its magnitude, seasonal variations, and the factors affecting it remain unclear. Moreover, the impact of reindeer herding, a major land-use form in subarctic fens, on plant-mediated CH_4 transport has rarely been investigated.

We measured CH_4 fluxes through *Carex rostrata*, *Menyanthes trifoliata*, *Betula nana*, and *Salix lapponum* throughout growing seasons in 2020 and 2021 *in situ* and in a climate-controlled cabinet, and through *Equisetum fluviatile* and *Comarum palustre* in high summer 2021 *in situ* only. Abiotic factors such as porewater CH_4 concentration, potential CH_4 production and oxidation rate, peat temperature, water table level (*in situ* only), PAR and simulated grazing (in cabinet only) were measured simultaneously.

In high summer, CH_4 transport rate (the amount of CH_4 transported per unit of plant surface area or plant dry biomass) and efficiency (CH_4 transport rate per unit of rhizospheric porewater CH_4 concentration) were the highest for *C. rostrata*. *M. trifoliata* showed a high transport rate, but its efficiency was low. Low transport rates and efficiency were detected for the remaining species. Moreover, *C. rostrata* showed the greatest seasonality in the CH_4 transport rate *in situ* and in efficiency in the cabinet measurements, controlled primarily by plant seasonal development (phenology), with rhizospheric temperature and porewater CH_4 concentration being of secondary importance. In the early summer, *S. lapponum* and *B. nana* actually absorbed CH_4 both *in situ* and in the cabinet measurements. In high summer, *S. lapponum* emitted CH_4 *in situ* but absorbed CH_4 in the cabinet, while *B. nana* switched to a clear emitter. The high-summer transport rate of *B. nana* was sensitive to the rhizospheric CH_4 concentration and PAR in cabinet. Very limited fluxes through the shrubs were detected in leafless early autumn in both measurements, suggesting that leaves might offer dwelling places for methanotrophic microbes and/or the importance of plant physiology in controlling the transport. Furthermore, we observed that simulated grazing negatively affected plant-mediated CH_4 transport in general, indicating that reindeer grazing is unlikely to increase CH_4 emissions from peatlands.

Plant species differ significantly in the transport capacity, seasonality, and responses to controls, which should be considered in the current models when estimating the role of plant-mediated CH_4 transport at the ecosystem-scale.

V-O10

SIMPLE EMPIRICAL MODELS BASED ON SOIL, WATER AND VEGETATION PARAMETERS DESCRIBE GREENHOUSE GAS FLUXES ALONG DRAINAGE GRADIENT IN PEATLANDS

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The majority of studies associate greenhouse gas (GHG) fluxes with water table changes in peatlands, which on the other hand has large spatial and temporal fluctuations over the season. A one-time measurement of water table could under- or overestimate the mean value at a specific location, whereas vegetation, being good predictor of mean water level, is more easily identified and mapped than the fluctuating hydrological regime. The main objective of this study was to analyse the relationships between GHG emissions and environmental factors determining their fluxes in drainage affected raised and transitional bogs in order to select the most indicative and easily detectable parameters for further proxy estimations of potential GHG fluxes.
Sampling plots were founded on transects following the water regime changes gradient in 17 peatlands in Estonia. Closed-chamber-based GHG sampling lasted from July 2012 to August 2016, measurements were carried out on a monthly basis. In total 7310 samples of each gas, CO_2, N_2O and CH_4 were collected and the GHG concentration was determined in the laboratory. During each sampling session, groundwater table depth, temperature, O_2 content, pH, conductivity, redox potential, soil temperature were measured and water samples for determining carbon and nitrogen content collected. Both, the water and soil samples were analysed for total nitrogen (N), NH_4-N, NO_3-N, available P, K, Ca and Mg content in the laboratory. The contents of soil dry matter, ash and total-C were determined. Botanical and dendrochronological analyses were conducted.
As expected, the fluxes of three GHG-s had a distinctive pattern regarding the distance from the drainage ditch. Both in drained bogs and drained transitional bogs the median ecosystem respiration (CO_2-C) and the emission of N_2O-N were highest closer to the ditch, 78.4 mg C m^{-2} h^{-1} and 1.5 µg N m^{-2} h^{-1} in bogs and 105.0 mg C m^{-2} h^{-1} and 10.3 µg N m^{-2} h^{-1} in transitional bogs respectively. The median emissions of methane, on the other hand, increased with the distance from the drain, from 45.5 and 53.8 µg C m^{-2} h^{-1} in bogs and transitional bogs, to 2714.6 and 5168.3 µg C m^{-2} h^{-1} in the pristine parts accordingly. By the results of the multiple regression analyses, in raised bogs the flux of CO_2-C was best predicted by the function of log value of distance, cover of shrub layer species and the height of tree layer ($R^2_{adjusted}$ = 0.47), in transitional bogs the combination of minimum water level, log value of distance and the height of tree layer was the most powerful ($R^2_{adjusted}$ = 0.58) predictor of the respiration. The emission of CH_4 in bogs was best modelled with the function of cover of *Sphagnum* mosses, temperature at 40 cm depth and minimum water level ($R^2_{adjusted}$ = 0.66), in transitional bogs the combination of minimum water level and the tree canopy cover were good predictors ($R^2_{adjusted}$ = 0.64). Simple parameters alone tend to have insufficient explanatory power for predicting N_2O fluxes. In raised bogs, the flux was explained by the cover of *Sphagnum* mosses, soil NO_3-N and soil organic matter content (SOM; $R^2_{adjusted}$ = 0.37), in transitional bogs the N_2O was best predicted by the function of the cover of *Sphagnum* mosses, minimum water level and SOM ($R^2_{adjusted}$ = 0.52). The results of this study simplify the estimation of GHG-s in drained bogs and drained transitional bogs.

V-O11

ELECTRON ACCEPTING CAPACITIES OF PEAT MATERIALS FROM AROUND THE GLOBE

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In peat soils the availability of terminal electron acceptors (TEAs), both inorganic and organic, largely determines the ratio of CO_2 to CH_4 formation in organic soils under anoxic conditions (Gao et al. 2019; Yu et al. 2016). While still typically only inorganic electron acceptors are considered, the importance of electron accepting capacities (EAC) or organic matter is increasingly acknowledged (Walpen et al. 2018). EAC of organic matter may represent >95 % or total EAC in peat soils (Gao et al. 2019). Nevertheless, the redox properties of peat organic matter and their relationship with anoxic carbon mineralization are yet only investigated for a limited amount of peat and reference materials. To address this knowledge gap, we incubated 60 peat samples from four different depths of 15 sites located in five major peatland regions distributed around the globe covering a variety of both bog and fen type samples and characterized their EAC for anaerobic CO_2 formation.

To identify microbially available ranges of EAC, we quantified CO_2 and CH_4 formation, as well as changes in the available EAC over the course of 56 days in controlled laboratory anoxic incubations. On the time scale of our experiment, on average 36.5 % of CO_2 could be attributed to CH_4 formation, and of the remaining CO_2 formation we could on average explain 70.8 % by consumption of measured EAC, assuming a CO_2/CH_4 ratio in methanogenesis of 1:1. Our results thus indicate that CO_2 not stemming from methanogenesis can largely be explained by available EAC. When the initial EAC was high, CO_2 formation from apparent consumption of EAC was also high and by far outweighed CO_2 formation from methanogenesis. A rapid depletion of available EAC resulted in a high share of CO_2 from CH_4 formation and was especially relevant for more reactive peat with low molar ratios of carbon to nitrogen (C/N), nitrogen to phosphorus (N/P) and carbon to sulfur (C/S).

Our study demonstrates that EAC of peat organic matter provides the most important redox buffer for competitive suppression of CH_4 formation in a wide range of peat materials. Moreover, we could show that electron budgets including EAC of organic matter could largely explain anaerobic CO_2 production of most peatlands.

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V-O12

COMPOSITION OF N_2O-GOVERNING MICROBIAL COMMUNITIES IN PRISTINE AND MANAGED TROPICAL PEATLANDS

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Peatlands are changing worldwide (Bahram *et al.*, 2022), and tropical peatlands have been under intensive anthropogenic pressure for the last fifty years because of expanding agriculture, forestry, and human settlement. Therefore, both the carbon and nitrogen cycle are passing drastic changes in these areas, and sustainable management is critical for economic, ecological, and environmental reasons. However, the lack of knowledge regarding microbial communities governing nitrous oxide (N_2O) emissions hinders estimation of the tropical peatlands' climate-change impact. This study aimed to discover the key players of soil microbial communities governing N_2O emissions under different land uses in tropical peatlands.

The peat sampling from topsoil was carried out from 2013 to 2020 at natural and managed peatland sites of eight tropical regions (Myanmar, Borneo, Taiwan, Uganda, Florida, Pantanal, Peru, and French Guiana). Metagenomics sequencing of over sixty samples was done to assess the microbial communities' structure and function of the peat soil. The bacterial and archaeal community and its size from 230 samples were evaluated respectively by metabarcoding and quantitative PCR (qPCR). qPCR was also applied to quantify the abundance of different functional genes of nitrogen cycle processes. Genetic potential of nitrogen transformation processes was evaluated by targeting the following functional genes: *nirS*, *nirK*, *nosZ* clade I and *nosZ* clade II (denitrification); *nifH* (N_2 fixation); *nrfA* (dissimilatory nitrate reduction to ammonium, DNRA); bacterial, archaeal and COMAMMOX (complete ammonia oxidation) *amoA* (nitrification); and ANAMMOX-specific 16S rRNA genes (anaerobic ammonium oxidation). Besides, in situ N_2O emissions and physicochemical parameters were measured.

Based on the balanced weighted phylogenetic diversity index, we found that denitrification (*nirK* and *nosZ*) and N-fixation (*nifH*) gene phylogenetic diversities were significantly smaller in managed sites compared to natural ones. The reduction in denitrifiers' and nitrifiers' phylogenetic diversity increased gaseous emissions in both studied land uses: i) composition of archaeal *amoA*-type nitrifiers were negatively correlated with N_2O emissions in managed sites; ii) composition of *nirK*- and *nosZ*-type denitrifiers were negatively associated with N_2O emission in natural sites. Conversion of N_2O to N_2 was mainly controlled by microbes possessing *nosZI* genes in the wet sites and microbes possessing *nosZII* genes in the managed sites. Denitrification taxa are relatively diverse in both sites. *amoA*-harbouring archaea from genus *Nitrosoarchaeum* were dominant at the natural sites and from genus *Nitrososphaera* at the managed sites. *nrfA* gene-possessing microbes (DNRA, dissimilatory nitrate reduction to ammonium) influenced the N_2O emissions. DNRA process is governed in managed sites by *Anaeromyxobacter* and *Myxococcus*, but in natural sites by *Carboxydothermus* and *Slackia*.

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V-O13

DERIVING TEMPORAL CHANGES IN WATER TABLE DEPTH POSITION IN NORTHERN PEATLANDS WITH OPTICAL SATELLITE DATA

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The Optical TRApezoid Model (OPTRAM) is a promising approach for monitoring temporal changes in moisture conditions. OPTRAM utilizes moisture (transformed SWIR-band) and vegetation (NDVI) information derived from optical remote sensing data. Previously, we have tested OPTRAM performance over intact northern peatlands. In this research, we evaluated OPTRAM performance over peatlands that differ by management type (intact, restored and drained), vegetation cover (treed and open), and fertility (from eutrophic to ombrotrophic through oligotrophic). Additionally, we tested the effect of applying different vegetation indices on OPTRAM performance. For this, we utilized vegetation information from kNDVI, EVI and RENDVI, instead of NDVI, for OPTRAM calculation. OPTRAM was calculated based on Sentinel-2 MSI images for the snow-free period (April-September) from 2018 through 2021. The workflow was implemented in Google Earth Engine. We provide a unique overview of OPTRAM's potential and limitations for diverse types of peatlands with this work.

V-O14

THE TEMPORAL COMPLEXITY OF CARBONATE DEPOSITION AT PUSZCZA ROMINCKA CUPOLA ALKALINE FEN (NE POLAND) DURING THE HOLOCENE

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Carbonate precipitating alkaline fens are highly valued for hosting many rare and protected calciphilous species with low nutrient demands, sedge-moss communities in particular, accompanied with characteristic molluscs assemblages. Factors controlling $CaCO_3$ precipitation at alkaline fens are complex and include: changes in temperature; variations of groundwater water supply at the fen driven by natural causes changes in tree cover that controls shadowing of the fen surface; rate of Ca^{2+} supply controlled by chemical denudation of carbonate deposits in the aquifer and depletion of this Ca^{2+} source. Whenever $CaCO_3$ precipitation is disturbed peat is deposited on the fen surface and specific interbedding peat and tufa sediments form.

The present study concentrates on the sedimentary history of the exceptionally well developed and according to our knowledge, the only cupola alkaline fen located in the young glacial region of Puszcza Romincka, north-eastern Poland. Time frames and conditions of tufa deposition, and palaeoenvironmental history of the fen, are reconstructed using plant macrofossil, mollusc and geochemical, including loss on ignition and $\delta^{13}C$ and $\delta^{18}O$, analyses of two sediment sequences taken from the top and slope of the fen cupola. The fen studied holds exceptional in young-glacial area continuous Holocene-long history of $CaCO_3$ precipitation. Shallow groundwater circulation and intensive chemical denudation of glacial deposits warranted the early start of $CaCO_3$ precipitation, ca. 11650 cal yr BP, and occurrence of brown mosses, e.g. *Tomentypnum nites*, indicators of alkaline fens. The locally elevated heat flow density controlled by deep geological sources of energy could result in early permafrost thawing and activation of the deep water circulation. Despite being disturbed by immigration of trees at the fen, and repeated flooding events, responsible for bringing nutrients and *Urtica dioica* fruits at the fen surface, sedimentation of peat-tufa intercalations continued until ca. 4700 cal yr BP. During the late Holocene water did not reach the top of fen surface, but $CaCO_3$ precipitation continued in the scattered form within the upper peat layer. Slopes of the fen were supplied with artesian waters until ca. 2200 cal yr BP. $CaCO_3$ precipitation stopped about 100 years ago in reaction to groundwater level decrease after melioration of the surrounding area. Sensitive response of the fen to environmental changes allowed to recognize among other things development of dense vegetation in the catchment during the early Holocene and increased human impacts recorded by the abundant charcoals after 4700 cal yr BP. Although affected by flooding and immigration of trees, both unfavourable for development of proper ecosystem of the alkaline fen, the fen contains clear climate signal. The predominately intensive $CaCO_3$ precipitation assured by continuous supply of alkaline artesian waters was weakened by colder and/or dryer episodes, mainly of supra-regional significance.

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BIOGEOMON 2022

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Poster presentation abstracts

I SESSION

Nutrient and carbon fluxes at catchment/landscape level,
remote sensing of biogeochemical fluxes

I-P1

IRON STOCKS AND ISOTOPY IN THE WÜSTEBACH FORESTED HEADWATER CATCHMENT

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Iron (Fe) is a growth factor with multiple interaction mechanisms in the cycles of all three major nutrients (carbon (C), nitrogen (N) and phosphorus (P). It couples to the C cycle through fixation of organic C on Fe oxide surfaces and formation of soluble organo-Fe complexes, some of which enhance microbial and plant uptake of Fe. Simple iron concentration determination though cannot reveal the origin of a specific Fe pool, especially in streams which can be fed by different sources (e.g., detrital particles, organically-complexed colloids, oxyhydroxide particulates). Over the past decades the determination of stable isotope ratios of Fe (δ^{56}Fe or δ^{57}Fe) has been increasingly applied to identify soil formation processes, to pinpoint soil Fe translocation processes, to determine the geologic Fe sources and to identify stream Fe sources (see review Wu et al., 2019).
The Wüstebach catchment is a small forested subcatchment (~38.5 ha) located within the German National Park Eifel. It is part of the TERENO Eifel/Lower Rhine Valley Observatory (Bogena et al., 2018) which aims at monitoring the long-term impacts of environmental change at a regional scale. This catchment has two distinct hydrological regimes in summer and winter (Bogena et al., 2018) we therefore hypothesized that the main source of riverine Fe will also change with seasons. We determined Fe content and isotopic composition in the catchment to (i) determine Fe pool sizes and (ii) identify the main seasonal sources of the riverine Fe. To this aim, we sampled top- and subsoil (down to 1m) of the two main soil types and the vegetation (root, stem, branches and needles), as well as stream water at different locations and at times of the season.
The total stock (0-30 cm) was estimated to be approx. 2770t. The plant available Fe (Gottselig et al., 2014) revealed a stock of 33.6 t (0-30 cm of soil). The vegetation (mainly *Norway Spruce*) contained approx. 1.6 t of Fe stock. Monitoring of the Fe concentration in the stream water over 5 years revealed that, depending on hydrological conditions, the catchment losses between 18 and 57 kg dissolved Fe per year. First Fe isotope measurements of environmental samples (stream water, soil horizons, spruce needles and beech leaves) were in a range of δ^{56}Fe values from -1.82 to 0.92 ‰ (relative to IRMM-014). Vegetation samples are the lightest reservoir -1.82 to -0.61 ‰). Mineral soil samples ranged from -0.20 to 0.25 ‰. Stream water samples were found to vary between -0.53 to 0.32‰ in the dry summer regime to -0.32 to 0.92‰ in the wet winter regime.
Overall, we conclude that our results indicate a stronger contribution of topsoil/litter-borne Fe in summer, while the winter regime shows a larger mixing range of different sources.

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I-P2

CARBON SEQUESTRATION ESTIMATION USING SATELLITE IMAGERY WITH MACHINE LEARNING ALGORITHMS: A CASE STUDY OF THE CEDAR FOREST OF AZROU, MOROCCO

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In order to assess the degree to which it has met its commitments under the Paris Agreement, Morocco is called upon to carry out carbon assessments and transparent evaluations. With respect to the forestry sector, the absence of growth models for all species and for all growth conditions limits the Tier assessment approach adopted. The present study makes use of satellite imagery (Sentinel1, Alos palsar2, Sentinel2) combined with Stepwise regression SWR, Random Forest RF, and Extreme Gradient Boost XGBoost algorithms in order to assess the carbon balance through Aboveground biomass AGB at the level of Azrou cedar forest during the period 2016-2021. The results of this study are as follow: i- The combination of several data sources significantly improved the quality of AGB prediction, this is revealed through the linear regression analysis which shows that the combination of SAR and Sentinel-2 induces a reduction in RMSE of about 5.88 $t.ha^{-1}$ compared to SAR alone. ii- Machine learning algorithms had the advantage on AGB estimation and provided the best results (RMSE equal to 55.75 and 56.40 $t.ha^{-1}$ respectively for RF and XGBoost) iii- According to the predictions made by both RF and XGBoost models, the carbon balance of Azrou cedar forest during the study period is negative; the XGBoost model predicts a decline in aboveground carbomass of 3.34 tC/ha/yr, while the RF model estimates it at 4.36 tC/ha/yr. These results suggest that the combination of multi-source data and the use of machine learning algorithms could be an interesting prospect for improving the accuracy of greenhouse gas inventories. It would also be advisable to prospect images of very high spatial and temporal resolution in order to target better results (Berninger et al., 2018).

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I-P3

NITRATE VULNERABILITY OF CARBONATE AQUIFERS IN THE BALTIC REGION INFERRED FROM A CASE STUDY OF PETRIFYING SPRINGS IN THE KAZU LEJA, LATVIA

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Carbonate aquifers often are affected by development of karst processes, making them vulnerable to surface pollution, for example, nitrate from diffuse agricultural sources. We have elaborated a map predicting where particularly vulnerable zones could be found along the distribution margin dolomite karst aquifer of the upper Devonian Pļaviņas formation (D3pl) in Latvia (Kalvāns et al., 2022). It is likely that similar conditions can be found along distribution margins of other carbonate and, perhaps, terrigenous bedrock aquifers in the region.

The vulnerability map was based on a recent case study where we found nitrate concertation of up to 51 mg/l in spring water emerging from a D_3pl aquifer at Kazu Leja, Latvia. It was concluded that the D_3pl aquifer was particularly vulnerable to the nitrate pollution due to its geological setting. It is covered by a up to some 10 m thick layer of glacial till, that supported development of fertile soils used for intensive agricultural production. The impermeable clay-rich base of the D_3pl aquifer is well above the floor of adjacent valleys. As a result, numerous petrifying springs have formed along valley slopes. Apparently, groundwater table remains within karst aquifer, supporting oxidizing conditions in the aquifer favorable for preservation of any nitrate leaked from the overlying farmland. Similar geological conditions like in Kazu Leja are widespread in the Baltic region as it has experienced little tectonic disturbances in the geological past. Below a relatively thin cover of mostly glaciogenic Quaternary sediments a sub-horizontal layering of Paleozoic and Mesozoic sedimentary rocks is found. At locations where the bedrock is exposed in valley springs are often found.

No clear evidence of negative effects due to elevated nitrate concentration on the spring ecosystem using biotic indicators was found in Kazu Leja. In addition, during the summer seasons, nitrate load appeared to be significantly attenuated by the downstream wetland ecosystem that itself has been heavily disturbed by peat and freshwater tufa extraction. However, during the cold season, when the spring discharges were highest most of the nitrate pollution was exported to the downstream recipients – River Gauja and Baltic Sea. The fate of possible nitrate pollution in other similar locations presumably varies from case to case and needs to be investigated further.

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I-P4

THE MID-TERM IMPACT OF STUMP REMOVAL ON SOIL, WATER AND PROPERTIES OF NEXT ROTATION YOUNG STAND IN OXALIDOSA AND HYLOCOMIOSA SITE TYPES IN LATVIA

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Forests and forestry have been identified as part of solution to several global challenges, including provision of locally sourced renewable resources. Harvest residues, such as branches, tree-tops and stumps, are an important source of bioenergy in Nordic and Baltic countries. Stump wood is used to produce electricity and heat. Furthermore, from stump- and slash-sourced biomass biochar may be produced on a larger scale for further use in agriculture and forestry as fertilizer, to limit nutrient leaching to waterbodies and to stabilize soil moisture. Stump removal is also an effective way to control root diseases for the next rotation trees thus preserving high stand productivity in production forests.

On the contrary, critical views are present due to impact on ecosystems and environmental consequences. Forest Strategy for 2030 of the European Union states to avoid stump and root extraction. In occasions where such site treatment is appropriate positive effects and environmental risks must be carefully assessed. Most existing research on the topic is conducted in Nordic countries, especially Finland, but the knowledge cannot be directly adapted and implemented in practice in Latvian conditions due to different geological, biological and climatic conditions. Major concerns of stump harvesting are nutrient leaching to watercourses and decline in next rotation stand productivity.

To evaluate short-term and mid-term effects on soil, soil water quality, nutrient status and stand productivity (incl. nutrient status in needles) in Latvia five sites were established in 2011 in locally typical mesotrophic forest site types. Two sites are located in *Oxalidosa* and three in *Hylocomiosa* forest site types with Norway spruce (*Picea abies L.* (Karst.)) and black alder (*Alnus glutinosa L.* (Gaertn.)) as dominant tree species. Study sites were divided in two treatment plots: whole-tree harvesting (WTH), where all above-ground biomass was harvested and whole-tree harvesting combined with stump biomass extraction (WTH+SB).

Soil TN and organic C stocks remained similar to pre-felling levels, but a slight trend of higher concentrations were observed in WTH+SB plots especially in deeper soil layers. No acidification of soil was observed after both treatments. Nutrient concentrations in soil solution generally illustrated site specific conditions and varied between study sites and treatment plots. Peaks of some soil solution parameters (for instance, TN, P-PO_4^{3-}) were observed after fellings as well as after four-five years that coincides with the more intense decomposing of remaining logging residues. A decline in the pH of soil solution was also observed four years after felling, possibly related to mineralization of more coarse logging residues in both treatment plots. N and C concentrations in needles did not differ significantly between treatment plots. Nutrient concentrations were in typical range of similar forest site types in Latvia indicating a sufficient nutrient uptake. The most notable differences between treatments were observed regarding stand productivity. Significantly higher mean tree height was observed in WTH plots of sites where single tree species were planted (Norway spruce or black alder) while no significant differences between the treatments were observed in site with mixed stand (Norway spruce + black alder).

I-P5

NITROGEN AND PHOSPHORUS CONCENTRATIONS IN PÄRNU BAY WITH SENTINEL-3 DATA DURING 2016–2021

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The eutrophication caused by nutrient loading to coastal waters is a major issue around the world and especially in the Baltic Sea. Managing the eutrophication process in the coastal waters requires monitoring the concentrations of the nutrients. In the current study we used Sentinel-3 OLCI data to derive total nitrogen (TN) and total phosphorus (TP) in Pärnu Bay (Estonia) during 6-year period. We had 97 TP and 87 TN *in situ* measurements which were collected at the same day with Sentinel-3 OLCI cloud free image acquisitions.

We tested over 25,000 different 2 or 3 band ratio options in retrieving nutrient concentrations. The best performing algorithms for estimating TN showed relatively good results, $R^2 = 0.74$, and $R^2 = 0.60$ for TP, with mean absolute percentage error 18.6% and 15.3%, respectively. The best algorithms for spring (April to June) and summer (July to September) were using reflectances on the bands from 443 nm to 620, 674 nm, and from 779 to 885 nm.

To study the spatial variability of the TN and TP in Pärnu Bay we used the best algorithms and produced TN and TP maps for 2016-2021 period. The maps demonstrate large variability in the Pärnu Bay and significant TN and TP input from the Pärnu River. TN concentrations are higher in springs and lower in summers, while TP is showing the opposite trend (being in lower in spring and higher in summers).

The seasonal medians derived from in situ measurements are based averagely on 17 measurements, while remote sensing is giving averagely 2400 datapoints per season. The median TN trend in Pärnu Bay shows clear decrease from 2016 to 2021 and agrees very well with the *in situ* results ($R^2 = 0.66$). Although, the *in situ* median TP trend shows a decrease, while estimations from remote sensing shows no decrease, the seasonal medians over the bay are in good relationship ($R^2 = 0.59$) with *in situ* data, which is very similar with the determination coefficient of the algorithm development.

I-P6

RESPONSE OF SOIL MICROBES TO LONG-TERM NITROGEN INPUT IN SPRUCE FOREST: RESULTS FROM GÅRDSJON WHOLE-CATCHMENT N-ADDITION EXPERIMENT

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Chronic nitrogen input disrupts plant-microbe interactions in originally N-poor systems, based on a symbiosis of plants with ectomycorrhizal (ECM) fungi. ECM fungi that are capable of efficient nutrient mining from complex organics and their long-distance transport play a major role in controlling soil N mineralization and immobilization, and eventual nitrate leaching. The functioning of N-poor and N-overloaded (N-saturated) forests is well understood, while the transient stages are much less explored. Therefore, we focused on the spruce-forest dominated catchment at Gårdsjön (Sweden) that received N addition of 40 kg N $ha^{-1}yr^{-1}$ over 24 years at the time of our study (a cumulative N input of >1,200 kg N ha^{-1}) but still lost via runoff only <20% of annual N input (deposition + addition) as NO_3^-. We found that, compared to the control, the N-addition catchment had a much larger soil microbial biomass. The N addition did not change the fungi/bacteria ratio, but a larger share of the bacterial community was made up of copiotrophs. Fungal community composition shifted to more nitrophilic ECM fungi (contact and short exploration type ECM species) and saprotrophs. Such a restructured community has been more active, possessed a higher specific respiration rate, enhanced organic P and C mining through enzymatic production and provided faster net N mineralization and nitrification. These may be early indications of alleviation of N limitation of the system. We observed no signs of soil acidification related to N additions. These results suggest that a microbial community can contribute to effective soil N retention despite the partial relative retreat (20–30%) of nitrophobic ECM fungi with large external mycelia, provided the fungal biomass remains high because of replacement by other ECM and saprotrophic fungi. We conclude that microbial biomass and its metabolic activity is not necessarily threatened by a large cumulative N dose, provided N is added at a moderate rate, does not cause acidification and the persistent soil microbial community has time to adapt through structural and functional changes. This is likely one of the explanations for low nitrate leaching that have stabilized in the last decade.

I-P7

ESTIMATION OF THE BIOGEOCHEMICAL PROPERTIES IN LAKES BASED ON REMOTE SENSING, METEOROLOGICAL FACTORS, AND CATCHMENT CHARACTERISTICS

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Lakes play a crucial role in the global biogeochemical (BGC) cycles through the transport, storage, and transformation of different BGC compounds. Furthermore, their regulatory service appears to be disproportionately important relative to their small areal extent. The global temperatures are expected to increase further over the coming decades, and economic development is driving significant land-use changes in many regions. Therefore, the need for improved understanding of the interactions between lake BGC properties and catchment characteristics, as well as innovative approaches and techniques to get required high-quality information for large scale has never been greater. Unfortunately, only a tiny fraction of lakes on Earth are observed regularly and data are typically collected at a single point and provide just a snapshot in time. Using remote sensing is one of the options to mitigate these spatial and temporal limitations. Until very recently, there have been no suitable satellites to perform lake studies on a global scale. The technical issues that were hampering remote sensing of lakes for a long time have been partly solved by the European Space Agency with the launch of Sentinel-2A in 2015 and Sentinel-2B in 2017 (S2). Firstly, we aim to estimate BGC variables of optically different lakes from the S2 data with the help of machine learning model (e.g., Genetic Algorithm Extreme Gradient Boosting). Secondly, we aim to study the interactions between lakes BGC properties (e.g. total nitrogen, total phosphorus, chemical oxygen demand, pH etc.), land cover (ESA Worldcover, 10 m resolution; identified land cover classes: forest, shrubland, grassland, cropland, built-up, bare/sparse vegetation, herbaceous wetland; Zanaga et al., 2021), meteorological factors (ERA5-Land monthly averaged data from Copernicus Climate Change Service; temperature, precipitation and surface solar radiation were extracted), topography indicators (elevation and slope; from the LiDAR based 5m resolution DEM; from Estonian Land Board) and soil parameters (EstSoil dataset; sand, clay, and soil organic carbon content; Kmoch et al., 2021). To investigate the predictive capabilities of the selected environmental variables, machine learning models (e.g., Random Forest) for each BGC water quality parameters will be built. The expected results will improve our understanding of the role of lakes in the global BGC cycles and have a strong applied impact allowing to make reliable recommendations for decision-makers and lake managers for different ecological, water quality, and climate applications.

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I-P8

LONG TERM TRENDS IN NUTRIENT AND DOC CONCENTRATIONS AND UNDERSTOREY VEGETATION IN TWO CATCHMENTS IN BOREAL FOREST

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Long term observations are crucial for ecosystem monitoring especially in forested ecosystems, because such systems have high capacities to store atmospheric inputs and their feedback loops may be slow. Tree layer is an effective receptor of airborne substances delivered in both wet and dry forms because of the reactivity and large surface area of the canopy. The forest floor also retains deposition inputs effectively. Furthermore, understorey vegetation, which holds a remarkable part of the total biodiversity of boreal forests, has a great indicative value when impacts of atmospheric deposition and other environmental changes such as climate change are studied. We studied long-term trends (1990-2018) of nitrogen (N), sulphate (SO_4S), base cations and dissolved organic carbon (DOC) in deposition, foliage and soil in boreal forest catchments at Valkea-Kotinen and Hietajärvi (Vuorenmaa et al. 2020a,b). In addition, changes in understorey vegetation and surface water were studied during the same period (Vuorenmaa et al. 2020a,b). Precipitation was strongly modified before it entered from the terrestrial part of the monitored catchments to the surface water. When precipitation passed through the canopy to the soil, inorganic N concentration decreased due to the uptake of tree canopy, while base cation concentrations increased due to leaching and wash-off nutrients from the canopy. The observed decrease in SO_4S deposition was reflected as similar changes in different parts of the forest ecosystem. In contrast, an increase in DOC concentration, observed in surface waters throughout Europe and North America, was not noticeable in the forests of the studied catchments. DOC concentration increased significantly only in throughfall in Valkea-Kotinen and in soil water at depth of 20 cm (mineral soil) in Hietajärvi. We noticed slight changes also in understorey plant species cover. For example, the cover of cowberry (*Vaccinium vitis-idaea*) showed increasing trends at Hietajärvi and cover of bilberry (*Vaccinium myrtillus*) at Valkea-Kotinen. Despite decreased N deposition, N concentration was still high in bryophyte layer at Valkea-Kotinen, which may have an effect on the species composition of bryophytes communities, even though deposition is lower than the critical load of N deposition (5 kg/ha).
Results showed the value and importance of long-term monitoring on evaluating the effects of air pollution, climate change and their interactions.
Various funding sources and projects have supported study, for example, Freshabit LIFE IP. The sites belong to ICP IM, ICP Forests and National Emission reduction Commitments directive (NECD) networks.

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I-P9

POTENTIAL USE OF THE LOCAL *SALIX* SPP. FOUND NEXT TO THE DITCHES FOR THE DEVELOPMENT OF VEGETATED BUFFER ZONE IN THE HEMI-BOREAL CLIMATE

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Excessive soil conditioning and the use of plant protection products in agricultural areas lead to their leaching to the melioration systems and have a negative impact on the aquatic ecosystem. Establishing vegetated buffer zones at the edge of the ditches results in significantly reduced and even prevented water pollution (de Snoo and de Wit, 1998). Willows (*Salix* spp.) are widely found in vegetation next to the ditches in the hemi-boreal zone. In addition, willows have a high accumulation rate for macro and micronutrients, therefore, they are suitable species for phytoremediation (Pertu and Kowalik, 1997). The use of willow for buffer zones does not only gain ecological benefit but also increases the economic value of this area since willow is short rotation trees and can produce large amounts of biomass in a short time. In Latvia, there are dozens of willow species, subspecies, and varieties with varying morphological differences in the context of growing and biomass accumulation rate and height or tree crown width.
This study aimed to assess the morphological parameters of the various willow species collected next the ditches in order to develop methodology for their suitability for the establishment of vegetated buffer zones in different environmental conditions. For total 12 different Salix genus species, subspecies, and varieties was collected from 38 locations- *Salix aurita* L., *Salix aurita* L. x *Salix myrsinifolia* Salisb., *Salix cinerea* L., *Salix cinerea* L. x *Salix myrsinifolia* Salisb., *Salix cinerea* L. x *Salix aurita* L., *Salix fragilis* L., *Salix myrsinifolia* Salisb., *Salix pomeranica* Willd., *Salix purpurea* L., *Salix purpurea* L. x *Salix viminalis* L., *Salix triandra* L., *Salix viminalis* L. They were planted in field from cuttings in spring of 2011 and was harvested in 2022 before vegetation season. Fresh and dry mass was measured in three different stem heights (lower, middle, upper), as well as shoot height, shrub width and total accumulated biomass. The amount of dry biomass accumulated differed depending on the part of the shoot, *S. cinerea* x *S. aurita*, compared to *S. pomeranica* had accumulated more dry biomass in the upper and middle parts of the offspring. *S. viminalis*, *S. purpurea* and *S. pomeranica* showed high values for the height of the shoot, the width of the shrub, and the accumulated biomass, so if the combination of these parameters is considered, these would be the most potential willows for a buffer zone.

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Poster presentation abstracts

II SESSION

Biogeochemistry of lakes, rivers and wetlands

II-P1

THE ROLE OF PONDS IN PESTICIDE DISSIPATION AT THE AGRICULTURAL CATCHMENT SCALE

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Ponds in agricultural areas are ubiquitous water retention systems acting as reactive biogeochemical hotspots controlling pesticide dissipation and transfer at the catchment scale. Several issues need to be addressed in order to understand, follow-up and predict the role of ponds in limiting pesticide transfer at the catchment scale. Here, we present a critical overview of functional processes underpinning pesticide dissipation in ponds. We highlight the need to distinguish degradative and non-degradative processes and to understand the role of the sediment-water interface in pesticide dissipation. To illustrate this aspect, we combined polar organic chemical integrative samplers (POCIS) with compound-specific isotope analysis (CSIA) to investigate pesticide degradation in ponds connected to agricultural catchment. Contrary to concentration analysis, CSIA may help tracing of in situ degradative processes of pesticides. The POCIS-CSIA method enabled to ascertain whether *S*-metolachlor and dimethomorph were degrading in agricultural soil or in the ponds. Yet it is not well-established how pesticide dissipation in ponds governs the pesticide transfer at the catchment scale under varying hydro-climatic conditions and agricultural operation practices. To illustrate the multi-scale and dynamic aspects of this issue, we sketch a modelling framework integrating the role of ponds at the catchment scale. Such an integrated framework can improve the spatial prediction of pesticide transfer and risk assessment across the catchment-ponds-river continuum to facilitate management rules and operations.

References

Imfeld G., Payraudeau S., Tournebize J. et al. 2021. The Role of Ponds in Pesticide Dissipation at the Agricultural Catchment Scale: A Critical Review. Water 13(9), 1202.

II-P2

DISTINCT STAGES ON THE BACTERIAL COMMUNITY IN HOST PROTECTED ENVIRONMENTS AFTER DISTURBANCE

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Environmental disturbances influence bacterial community structure and functioning. To investigate the effect of environmental disturbance depicted by changes in salinity on host protected bacterial communities, we analyzed the microbiome within the digestive tract of *Radix balthica* at different salinities. *R. balthica* is a benthic invertebrate typically found in freshwater and mesohaline waters. Whereas the total energy pool of *R. balthica* was unaffected by increase of salinity to 3, a strong deterioration of its physiological status was detected after the shift from freshwater to salinity 6. The increase to salinity 6 also caused a significant change in the gastrointestinal bacterial community composition. In contrast to this, was the bacterial community composition at salinity 3 either related to the freshwater or salinity 6 gastrointestinal bacterial community, indicating an ambivalent nature of this salinity. Moreover were the changes in the intestinal microbiome uncoupled from changes in the water bacterial community. Hence, environmental disturbance, depicted as salinity, acts also on the host protected microbiome. However, changes in the host protected environment are independent from the water bacterial community and assume distinct states suggesting the host's control of its intestinal microbiome. In the light of the sea level rise, this indicates that near-shore freshwater areas that become more saline, will also cause changes in organisms' intestinal microbiome if critical thresholds are exceeded.

II-P3

ASSESSMENT OF ECOSYSTEM HEALTH IN LATVIAN-LITHUANIAN TRANSBOUNDARY LAKES

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Catchment approach is one of the EU WFD's requirements for management of water bodies. The aim of the EU WFD is to achieve at least a good ecological status in all water bodies to protect communities of aquatic organisms and habitats (EC, 2020). In water bodies where ecological quality is not sufficient measures should be taken to reduce anthropogenic pressures from the whole lake or river basin, including catchments of upstream water bodies. In the case of Latvia, transboundary pressures are important. Currently, most of the lakes (with the lake area >0.5 km^2) located on the Latvian and Lithuanian state border are recognized as water bodies only in Latvia. As a result, monitoring, assessment of status and pressures, and finally, application of measures are carried out only in the territory of Latvia. Water cannot be divided by human drawn boundaries such as country borders, thus the management of shared water bodies must be a joint effort. The aim of this study was the estimation of ecological status of five transboundary lakes located on the Latvian-Lithuanian borderline in order to establish a harmonised monitoring program and prepare a joint programme of measures.

Sampling of phytoplankton, benthic invertebrates and aquatic chemistry, and surveys of macrophytes and fish were carried out in lakes Ilzu (Garais), Lielais Kumpinišku, Skirnas, Galiņu and Laucesas in 2021 to assess the ecological quality of these lakes. Fish sampling was done by experts from both Latvia and Lithuania, thus allowing comparability of the assessment. Additionally, sampling of zooplankton and lake sediments was done.

Preliminary results suggest that ecological status of lakes Lakes Lielais Kumpinišku, Galiņu and Skirnas is at least good. However, ecological status of lakes Ilzu (Garais) and Laucesas is moderate or worse. Lake Ilzu (Garais) can be considered a turbid lake with low transparency and therefore limited growth of macrophytes. Number of fish species and sensitive taxa of benthic invertebrates is low. That implies joint measures for improvement of ecological status in Lakes Ilzu (Garais) and Laucesas are needed in both countries.

This work was supported by the Lat-Lit project TRANSWAT (LLI-533).

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II-P4

RESPONSES OF RIVER WATER QUALITY TO LONG-TERM NITROGEN AND PHOSPHORUS PATTERNS IN ESTONIA

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We analysed long-term (1992-2020) changes in fertiliser use, wastewater treatment, and river water nutrient status in Estonia in the context of changing socio-economic situations and legislation. After Estonia joined the EU in 2004, adoption of EU legislation on water use and protection created a good basis for further improvement of river water quality. Success was achieved in reducing point source pollution from large farms and municipalities. Point source nutrient loading reductions explained most of the observed decline in riverine nitrogen and phosphorus concentrations, whereas application of mineral fertilisers has increased, hindering efforts to reach water quality and nutrient load targets set by the EU Water Framework Directive and the Baltic Sea Action Plan. Highest nitrogen concentrations and strongest increasing trends were found in rivers within the Nitrate Vulnerable Zone, indicating violation of the EU Nitrates Directive. These results indicate that the rules set by the EU Nitrates Directive to protect surface and groundwater quality in karst areas have been insufficient to reduce nutrient concentrations in surface waters within these watersheds.

This study was funded by the Estonian Research Council grants PRG709 and PRG1167, by the European Regional Development Fund through the Estonian University of Life Sciences ASTRA project “Value-chain based bio-economy”, and by the European Union H2020 WIDESPREAD grant 951963 (TREICLAKE). The Estonian Ministry of Environment and the Estonian Environment Agency supported data collection in the national monitoring program.

II-P5

CARBOWET: CARBON BALANCE OF ARTIFICIAL WETLAND RECEIVING AGRICULTURAL DRAINED WATER

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Wetlands offer vital services to mankind including water quality improvement, flood mitigation, coastal protection, and wildlife protection. It is estimated that a quarter of Earth's soil carbon is stored in wetlands, although they comprise only about 5–8% of the terrestrial land surface. Wetlands sequester the organic carbon produced from atmospheric carbon dioxide in photosynthesis and the dissolved organic carbon received with surface water flow. Simultaneously though, wetlands emit a quarter of global methane emissions. Methane is a greenhouse gas 28 times more potent than carbon dioxide. Much is unknown about the effects of wetland management on the carbon fluxes. A combination of high-frequency runoff monitoring, catchment hydrological modelling, chamber measurements and the eddy covariance method has rarely been fully used to calculate and compare carbon balances, including methane exchange, of wetlands under different hydrology, nutrient status and management. The objective of CarboWet is to understand the carbon balance of experimental artificial wetland in Rampillon (France), receiving agricultural water from a 400ha subsurface drained catchment upstream.
The carbon balance is explored in two steps. The first step will be identification of carbon pools and fluxes. We consider both abiotic (soil and sediment pools of organic carbon of various quality, and water and gas transported fluxes) and biotic (photosynthesis, fine roots, rhizosphere, microbial abundances) stocks and processes. To achieve this task, the chemical composition and volume of sediment, soil, vegetation and streamflow (spectro-UV devices based on light adsorption at an hourly time step) were associated to the net ecosystem exchange of carbon analysed by the chamber and eddy covariance methods.
At final results for the first monitored year, the CO_2 emitted by microorganisms'respiration constituted the main part of the carbon balance, interpreted as the young evolution of artificial wetland, lacking time to become a carbon sink.

II-P6

APPLICATION OF MICROCOSMS TO INVESTIGATE THE TOXICITY OF LA AND GD ON THE PRIMARY AQUATIC CONSUMER LEVEL

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Microcosms are experimental systems that simulate ecosystems that have been simplified to research the effects of contaminants and stressors under controlled conditions. This makes microcosms highly suitable for our objective to investigate the impact of sediment resuspension on the transfer of lanthanum (La) and gadolinium (Gd) from benthic layer to the pelagic layer on the first consumer level. La and Gd are part of a group of 17 chemical elements known as Rare Earth Elements (REE). The demand for REE has been increasing since the 1990's due to global demand for sustainable modern technology (USCG, 2022). Benthic organisms are likely to be exposed to REE due to the high adsorption of REE to sediment particles and fine organic matter. Exchange processes between the benthic layer and the overlying water body might cause exposure of pelagic species. Therefore the impact of REE, which are now considered to be emergent pollutants, on aquatic biological communities needs to be studied. The microcosms used in this study will contain five aquatic grown laboratory species; water fleas (*Daphnia magna*), microalgae (*Raphidocelis subcapitata*), roundworms (*Caenorhabditis elegans*), bacteria (*Escherichia coli*), and seed shrimp (*Heterocypris incongruens*). A series of microcosm experiments in a controlled environment will be undertaken in three steps; 1) cups with daphnia and algae running separately from the cups with the nematodes and the bacteria, 2) combine these two experiments into one and introduce the ostracod population, 3) Introduce sediment re-suspension. Studies will consider parameters such as death rate, reproduction rate, and population count, according to the guidelines of the single-species tests. The microcosms are analysed over a course of 14 days using a sacrificial method. The experiment will be reproduced at least 3 times. The microcosms will be spiked with the (nominal) environmentally and anthropogenic relevant concentrations of La or Gd (1, 10, 100 and 1000 µg/L). La and Gd concentrations will be measured by laser ablation ICP-MS. Preliminary results from a first study with *D. magna* and *R. subcapitata* indicated that neither La or Gd are acute toxic for either species, causing no toxicity at the exposed concentrations. However, it appears that *D. magna* is more sensitive in regards to reproduction towards both REE, with Gd being more toxic than La. On average is the number of neonates found in the control 229, with 16 neonates on average per adult. La was 197 with an average of 15 neonates per adult, while Gd had 146 at most with an average of 11 neonates per adult. We will further elaborate on this study and present preliminary results in the poster.

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BIOGEOMON 2022

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Poster presentation abstracts

III SESSION

Fluxes between atmosphere and ecosystems

BIOGEOMON 2022

10th International Symposium on Ecosystem Behavior

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III-P1

TREES IN AGRICULTURAL LAND: OVERVIEW OF FAST-GROWING TREE RESEARCH IN LATVIA

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The latest international policy, strategies and plans underline that the role of trees in agricultural land and other lands outside the forests will increase mostly to contribute environmental and climate change mitigation purposes as tree introduction in agricultural and other lands outside forest land may contribute significantly to atmospheric carbon dioxide (CO_2) removals. Additional benefit of tree introduction in agricultural land, especially in territories around drainage systems and natural streams, is reduction of surplus nutrient leaching currently presenting one of the main surface water quality issues in the Baltic Sea Region. For instance, new EU forest strategy for 2030 states that "research and innovation on agroforestry systems and other trees outside the forests will be reinforced". The Common Agricultural Policy (CAP) 2023-2027 Strategic plan regulation points out that "the framework definition for 'arable land' should be laid down in a way that allows Member States to cover different production forms, including system such as agroforestry and arable areas with shrubs and trees". In Latvia, agroforestry systems were not defined in national legislation and opportunities to grow trees on agricultural land without land use change were limited, so far. Agroforestry systems as land use management practice are for the first time mentioned in Latvia's CAP Strategic plan for 2023-2027. Thus, in addition to scientific interest, the interest of landowners and managers in tree introduction in agricultural lands and other lands outside the forests is expected to increase.

Latvian State Forest Research institute "Silava" has initiated the implementation of several research projects aimed to evaluate the impact of tree introduction in agricultural land with both marginal mineral soil and drained organic soil and in other lands, such as buffer zones around drainage systems and territories surrounding the protective belts of natural streams. The main studied processes are carbon cycling at ecosystem level and greenhouse gas (GHG) fluxes from soil. Studies also include evaluation of factors affecting GHG emissions reduction potential and elaboration of new technologies and methods for land management. The overall aim of studies is to identify the most efficient climate change mitigation measures and to develop recommendations, and to quantitatively evaluate their potential impact.

Acknowledgement

European Regional Development Fund's Post-doctoral research projects "Evaluation of climate change mitigation potential of agroforestry systems with mineral and organic soils" (No. 1.1.1.2/VIAA/4/20/684) and "Economic and environmental assessment of biomass production in buffer zones around drainage systems and territories surrounding the protective belts of natural water streams" (No. 1.1.1.2/VIAA/3/19/437).

European Regional Development Fund's projects "Elaboration of innovative White Willow – perennial grass agroforestry systems on marginal mineral soils improved by wood ash and less demanded peat fractions amendments" (No. 1.1.1.1/19/A/112), "Climate change mitigation potential of trees in shelter belts of drainage ditches in cropland and grassland" (No. 1.1.1.1/21/A/030), and "Evaluation of factors affecting greenhouse gas (GHG) emissions reduction potential in cropland and grassland with organic soils" (No. 1.1.1.1/21/A/031).

European Innovation Partnership programme project "Wild cherry (*Cerasus avium* Moench. syn. *Prunus avium* L.) propagation technology development and selection of perspective clones for the establishment of productive roundwood plantations under the climatic conditions of Latvia" (No. 19-00-A01620-000088).

III-P2

SHORT-TERM EFFECT OF PRE-COMMERCIAL THINNING ON THE CARBON CYCLING IN FERTILE BIRCH (*BETULA* SP.) STANDS IN HEMIBOREAL ESTONIA

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Pre-commercial thinning (PCT) is a very common silvicultural practice, used for directing the development of a young stand. However, its impact on stands' carbon (C) cycling is still poorly studied. In order to estimate how PCT intensity impacts C cycling, three treatments were established in young fertile birch stands growing on mineral (Site 1, 8-years-old) and drained organic soil (Site 2, 12-years-old): control, moderate thinning (MT; 2,500 trees remaining) and heavy thinning (HT; 1,500 trees remaining). The C budget for each treatment was compiled using data collected during the vegetation period following the PCT.

The remaining trees' C stock and aboveground biomass production decreased in both sites as the thinning intensity increased. In Site 1, the PCT was less intense, therefore the recovery of the C stock of trees will probably arrive in few years. In Site 2, the thinning was almost twice as intense, which means the C stock recovery will also take longer.

The two stands reacted inversely to the PCT: in Site 1, all the treatments were C sinks, whereas the net ecosystem production was lowest in the control (1.3 t C ha^{-1} yr^{-1}) and highest in MT (2 t C ha^{-1} yr^{-1}). In Site 2 only the control plot acted as C sink (2.8 t C ha^{-1} yr^{-1}), MT and HT plots were C emitters (-2.5 and -3.3 t C ha^{-1} yr^{-1}), as a result of lower stem productivity and higher heterotrophic soil respiration (Rh). In both sites and all treatments, Rh was the largest C flux in the budget. Despite a trend of Rh increasing with thinning intensity, no statistically significant difference in the annual Rh flux occurred between the treatments in either site. In both sites the productivity of aboveground part of trees decreased and of aboveground productivity of herbaceous understorey and stump sprouts increased with thinning intensity. In addition, the productivity of fine roots of trees and belowground biomass of herbaceous understorey contributed considerably into stands net primary production in both sites.

III-P3

IMMEDIATE AND CARRY-OVER EFFECTS OF DROUGHT AND LATE SPRING FROST ON FOREST GPP CAPACITY IN THE NORTHERN HEMISPHERE

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Forests are vulnerable to increasingly global warming-induced extreme events. However, the immediate and carry-over effects of extreme events on forests are still poorly understood. Using eddy covariance data from 35 forest sites in the northern hemisphere, we analyzed the immediate and carry-over effects of growing season drought and late spring frost (LSF) on ecosystem gross primary productivity under light saturation (GPPcap_2000). Here, drought events were characterized by Standard Precipitation-Evapotranspiration Index (SPEI), LSF events were determined by daily minimum temperature during the start of the growing season and mid-July with a threshold of -2.2 °C. Results showed that GPPcap_2000 in needle-leaf forest (NF) was more negatively sensitive to drought than broad-leaf forest (BF). LSF showed an obvious negative effect on GPPcap_2000 both in NF and BF. The compound effects of drought and LSF have no significant influence on GPPcap_2000 both in NF and BF, meanwhile, the drought effects were masked by the LSF effect in NF. We also found that the different response of GPPcap_2000 to drought was mainly due to the varied sensitivity to canopy stomata conductance (Gc) rather than the varied ecosystem functional stability (EFS) between NF and BF. Our results highlight that LSF had a more severe and long-lasting impact on forests compared to drought. These results could enrich our understanding of the mechanisms of forest response to extreme events across forest types. Further studies should use observed phenological information and richness information to pinpoint impacts of extreme events on productivity across different types of forest.

III-P4

TOPOGRAPHY LEADS TO A SHIFT IN METHANE (CH_4) AND NITROUS OXIDE (N_2O) FLUXES FROM TREE STEMS AND SURROUNDING SOILS IN A TROPICAL FOREST

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Tropical forests are major sources of terrestrial nitrous oxide (N_2O) and major sinks of methane (CH_4) but not all areas within these forests have been measured and accounted for. Wetland and upland forests can either be sources and sinks for CH_4 and N_2O but compared to soils, it is only recently that stems have shown to be significant contributors to CH_4 and N_2O exchanges.

We conducted our study during the short wet season 2020 along a natural topographic transect characterized by a soil water content gradient, with one end located in a wetland area ("seasonally flooded"), the other one in an upland area ("terra firme") and a transitional area in the slope, in a tropical forest, French Guiana. Fluxes of CH_4 and N_2O were measured from 56 individual tree stems and from soils beneath the same trees with manual static chambers.

In the three habitats, Terra firme (TF), Slope (SL) and Seasonally flooded (SF), tree stems and soils, which were not always acting in the same direction, were sources or sinks of CH_4 and N_2O depending on the habitats. Fluxes of CH_4 in tree stems and soils were higher and mainly negative from seasonally flooded to terra firme areas. For N_2O, however, only soils in the terra firme areas were sinks whereas tree stems were high and occasionally sinks in the slope and terra firme areas, respectively. Also contrasted results between habitats, we only found a significant correlation between soil CH_4 fluxes and soil water content.

Our study demonstrates that spatial heterogeneity exists for fluxes of CH_4 and N_2O at the soil and tree level in tropical forest. Seasonally flooded areas of our study site are major sources of the three gases whereas, in the slopes and terra firme areas, soils or tree stems can either act as sources or sinks for CH_4 and N_2O in particular. Our results also indicate that tree stems represent overlooked sources of CH_4 and N_2O in forested habitats, which has to be further study to better understand controls of theses fluxes and to refine carbon budgets.

III-P5

PERFORMANCE ASSESSMENT OF THE MOBILE G4301 CAVITY RING-DOWN SPECTROSCOPY ANALYZER FOR ATMOSPHERIC CO_2, CH_4 AND H_2O MEASUREMENTS

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Carbon dioxide (CO_2) and methane (CH_4) are the most important greenhouse gases, and there is an increasing need to measure these greenhouse gases with mobile measurement devices. Picarro's G4301 Cavity Ring-Down Spectroscopy (CRDS) analyzer is a high-performance, light-weight, portable, battery-powered gas concentration analyzer that has enabled real-time measurements of CO_2 and CH_4 in challenging environments in the field of ecosystem (Matthes et al. 2018, Kohl et al. 2019, Jeffrey et al. 2019), soil science (Chai et al. 2020), glaciology (Christiansen and Jørgensen 2018), limnology (Villa et al. 2020) and indoor air quality (Merrin and Francisco 2019). Here we evaluate the performance of this portable greenhouse gas analyzer for atmospheric measurements, and discuss data obtained with this analyzer during balloon flights.
The performance of the G4301 analyzer was assessed at the Metrology Laboratory (MLab) that is part of the Atmospheric Thematic Center of ICOS. The MLab regularly tests greenhouse gas analyzers that are used within the European monitoring network ICOS (Integrated Carbon Observation System). We will present CO_2 and CH_4 performance data on the continuous measurement repeatability (CMR), the short-term repeatability (STR), the long-term repeatability (LTR), the ambient temperature sensitivity, the inlet pressure sensitivity, and the built-in water vapor correction. We will discuss these findings considering measurement requirements for different applications.
To assess the performance of the analyzer in mobile field measurements, the G4301 was deployed at several balloon flights over Paris.

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III-P6

TOWARDS ENVIRONMENTAL AND FOREST DATA SCIENCE

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Large-scale measurement stations like the SMEAR stations in Estonia and Finland allow to assess many environmental parameters at once. Building upon comprehensive long-term data of atmospheric, ecosystem, meteorological, micrometeorological, hydrological and forestal data allows for new ways in data analysis. Modern data driven models and algorithms enter the domain of the formerly classical mechanistical or parameterized models.

III-P7

NITROBIOME -PROJECT: MICROBIAL MECHANISMS REGULATING N_2O METABOLISM IN ABOVE-GROUND VEGETATION – SIGNIFICANT NORTHERN SINK?

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Nitrous oxide (N_2O), strong greenhouse gas (GHG), sink strength of boreal and arctic peatlands and forests in warming climate is a key question for climate change mitigation and climate policy. There are indications, and our own findings, that above ground vegetation and cryptogams can increase N_2O sink strength in northern areas. Current vegetation, climate change assessment and GHG flux models, are lacking information on microbiological mechanisms consuming atmospheric N_2O within above-ground vegetation. To improve management of N_2O sink and climate policy, this proposal brings new knowledge about the role of above ground vegetation of peatlands and forests, and their microbiomes as a part of N_2O dynamics of northern ecosystems. We utilize existing infrastructure for manual and automated GHG flux measurements, collect samples across transect from temperate to Arctic region and study functioning of N_2O consuming microbes with novel methods in molecular microbiology and isotope-labelled-metabolomics. The main aim of this project is to identify N_2O uptake in above ground vegetation in Boreal coniferous forests, and peatlands and forests in different climatic zones to make comparison, and via that, to understand the importance of plant-microbe interactions and their contribution on N_2O metabolism. More specifically, we will characterize (1) N_2O consuming microbiome of different above ground vegetation;(2) the microbial functions metabolizing N_2O in vegetation; and (3) their dynamics associated with spatially and seasonally variable environmental conditions. Diversities and community structures of N_2O consuming microbes will be analyzed by through searches of public gene-bank databases, using functional gene targeted PCR and novel targeted metagenomics for microbial nitrogen (N) cycling genes from plant and soil samples collected from the study sites across the transect from temperate to arctic region and along the growing seasons. The N_2O fluxes, microbial activity and diversity data of vegetation will be compared with the soil chemical, metabolic functions and plant community composition and coverage data, to make regional estimations of N_2O consumption in vegetation and it's impact on overall N_2O budget of the ecosystem.

III-P8

HEMIBOREAL FORESTS' CO_2 FLUXES RESPONSE TO THE EUROPEAN 2018 HEATWAVE

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In summer 2018, a heatwave over the Europe influenced the forest carbon cycle. We assessed the elevated temperature impact on the carbon exchange of three forest stands and a clear-cut area located in the geographical vicinity within a hemiboreal zone. Eddy-covariance technique was utilized to obtain ecosystem scale carbon fluxes of all four sites.
Spring 2018 was characterized by higher air temperatures, while soil water content (SWC) was still moderately elevated. The rainfall reduction and anomaly high temperatures (temperature anomaly) in end of July resulted in drought conditions. Several warmer days were also recorded in autumn 2018.
Coniferous (pine and spruce) forest carbon uptake decreased during the temperature anomaly as a result of gross primary production (GPP) reduction being higher than the decrease in ecosystem respiration (ER). The carbon exchange was not affected by the warm spring, while both ER and GPP increased in autumn. Consequently, annual ER was higher and the net ecosystem exchange (NEE) was smaller (weaker net carbon sink) in 2018, compared to 2017. The coniferous forest was most resistant to the heatwave, most probably because of its adaption to low soil water content.
The NEE of a riparian alder forest was similar to the previous year over the temperature anomaly period due to the reduction of both GPP and ER of the same magnitude. The GPP offset was observed as a result of warm days in spring and autumn, and the cumulative net carbon uptake increased.
Contrary to our expectations, the heatwave influence on a mixed conifer-broadleaved forest (pine, spruce, birch, clear-cuts) carbon exchange was more pronounced than on that of a pine-dominated one. Over the vegetation season 2018, the mixed forest was net carbon source while being a net carbon sink during the same period of 2017. On the annual scale, almost three times higher amount of carbon was released in 2018 as a result of GPP reduction.
The carbon exchange of the clear-cut area was the most affected by the heatwave out of all study sites. While it was a weaker source of CO_2 during the temperature anomaly, it resulted from a drastic decrease of both, ER and GPP, with a more prominent reduction of the latter. Warm spring and autumn days not offset the temperature anomaly impact, as was observed for the forested ecosystems.

III-P9

SOIL RESPIRATION IN NORWAY SPRUCE AND SCOTS PINE CHRONOSEQUENCE

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Soil respiration (Rs) can form a remarkable part of forest ecosystem respiration and as forests play an important role in the global carbon (C) cycle it is highly actual to quantify soil CO_2 effluxes. Quantification of the soil heterotrophic (Rh) flux is essential for a better understanding of the dynamics of belowground C and Rh is of particular importance for C budgeting. Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) are a widespread and economically very important conifer tree species in Northern Europe, however, soil properties, soil C pool, understory biomass and soil microclimate can differ between spruce and pine forests (Kriiska et al. 2019; Olsson et al. 2012). The main aim was to estimate the effect of forest age and tree species on soil CO_2 effluxes. Soil CO_2 effluxes were measured monthly from April to November in 10 Norway spruce (10-125 years old) and 10 Scots pine (6-109 years old) forests using the closed dynamic chamber method (PP Systems SRC-1 chamber with the gas analyser Ciras-2). Soil temperature and volumetric soil moisture was measured simultaneously with respiration and continuously at every hour at a depth of 5 cm. All forests grew on fertile sites. All stands of both tree species were divided into five groups based on developmental stages of specific tree species: young, pole, middle-aged, premature and mature.
Soil CO_2 effluxes were generally higher for spruce than for pine: annual mean Rs across all stands 9.4 vs 7.6 t C ha^{-1} and Rh 5.9 vs 4.7 t C ha^{-1}, respectively. In general, soil was warmer and drier for spruce than for pine. Heterotrophic respiration was quite stable flux in both chronosequences and dominated total soil respiration in both, spruce and pine, forests. Mean Rh:Rs ratio varied between 0.54 and 0.76 irrespective of stand age. Soil temperature was the main driver of seasonal variation of soil respiration and soil moisture had rather site-specific effect on respiration.

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III-P10

NEW FLUX MEASUREMENT SITES TO STUDY MITIGATION OF GHG FLUXES IN DRAINED PEATLANDS

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Drained peatlands are known to be considerable sources of greenhouse gases (GHG), particularly of CO_2 and N_2O (Maljanen et al. 2010), and nutrient leaching. In countries with large areas of peatlands drained for agriculture or forestry use, like Finland, high GHG emissions may pose a major risk to the society's carbon neutrality goals. As part of the new "Catch the carbon" initiative, funded by the Finnish Ministry of Agriculture and Forestry, the "TURNEE" project (2021-2023) aims to find ways towards carbon neutrality by mitigating the GHG emissions through restoration of fertile forestry-drained and abandoned cutover peatlands and afforestation of cutover peatlands. The project includes measurements of GHG fluxes, energy exchange, and water quality, modelling and scenarios, and societal interaction and outreach.

In August 2021, we have started eddy covariance (EC) measurements of CO_2 and energy exchange at the Naarasneva mire, an abandoned cutover peatland in Ostrobothnia, Finland (62.9°N, 24.1°E). To determine the full climate impact of afforestation, we also measure the net radiation and its components as well as new particle formation (Kulmala et al. 2020). The peat production has ceased in the area in 2020. The ditches at the site are located at 20 m intervals and the depth of the leftover peat in the area is approx. 1 m. There is hardly any vegetation growing nearby the 2.5 m high EC tower, only some grasses and willows around some of the ditches. In addition, we determine soil CH_4 and N_2O fluxes with the chamber method during the growing seasons. The site will be afforested with pine seedlings in June 2022. To improve the growth of the seedlings the site was fertilized with wood ash (7,000 kg ha^{-1}) in January 2022.

Moreover, we are currently building another EC measurement site "Rottasniitunsuo" in Tammela, in southern Finland. The site is a fertile forestry-drained peatland, drained in 1960-70's, with a mixture of approx. 10-20 m tall pine-spruce-birch stand and ditches located at 40 m intervals. We plan to rewet the site in late 2023 after measuring the GHG exchange for two growing seasons. The measurements will cover CO_2 and CH_4 fluxes with the EC technique and CH_4, CO_2, and N_2O fluxes of the forest floor with opaque chambers.

In this presentation, we will show the first year's data from the cutover peatland and discuss the hydrology-related and future scenario aspects, studied in the project.

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III-P11

LONG-TERM CO_2, CH_4 AND N_2O FLUXES FROM SOIL, TREE STEMS, AND ECOSYSTEM IN A RIPARIAN ALDER FOREST

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Riparian forests are important hot spots of greenhouse gas (GHG) fluxes in landscapes. Grey alder (*Alnus incana*) forests are typical in riparian areas and widespread across the Northern Hemisphere. Here we analyse results from a 2.5-year (September 2017-December 2019) continuous high-frequent study of soil emissions (automated chambers, Picarro G2508) and ecosystem (eddy-covariance (EC); LiCor 7200 and Aerodyne QCLAS) fluxes of CO_2, CH_4 and N_2O in a riparian grey alder forest in Estonia. In addition, we analyse tree stem fluxes measured by manual chambers.

Based on EC data of all three gases, the forest is a significant sink of CO_2 (-7,893 kg CO_2 ha^{-1} y^{-1}), almost neutral regarding CH_4 fluxes CH_4 (-0.24 kg CH_4-C ha^{-1} y^{-1} or -9.0 kg CO_2eq ha^{-1} y^{-1}), and slight emitter of N_2O (0.26 kg N_2O-N ha^{-1} y^{-1} or 120 kg CO_2eq ha^{-1} y^{-1}). At the ecosystem level we could not define any extreme emission events (further referred to as hot moments; HM) for all GHGs, whereas for N_2O three remarkable HM for soil fluxes (wet period is autumn, beginning of dry period in spring and freeze-thaw period in winter) were observed. Regarding N_2O, HMs lasted a quarter of the whole study but contributed >50% of soil fluxes. For CH_4 a remarkable HM was the wet period when 83% of CH_4 was emitted from the tree stems. In the dry period, CH_4 was substantially consumed in the soil whereas stem emissions were very low.

The forest floor (soil+plants within the chambers) and tree stems emitted 534 and 341 kg CO_2 ha^{-1} y^{-1}, respectively, and 10% of their sum was assimilated within the canopy. The rest, we assume, was accumulated in biomass. Throughout the whole study, canopy decreased about 80 % of soil+stem fluxes of N_2O whereas during the HMs the difference was the largest. The horizontal advective fluxes and decoupling of gas fluxes between the layers, UV-induced photodissociation, and potential N_2O dissolution in the canopy airspace are the possible mechanisms for this discrepancy. A significant difference between the EC CH_4 fluxes and the sum of soil and stem CH_4 fluxes during the dry HM is most likely caused by chemically induced CH_4 emissions from the canopy. In conclusion, the riparian alder forest is a major GHG sink mostly owing to CO_2-C assimilation in trees whereas the canopy airspace mitigates the soil N_2O fluxes.

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III-P12

ECOSYSTEM N_2O AND CH_4 FLUXES OF A BOREAL FOREST PRIOR TO CLEAR-CUTTING

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Measurements of energy and CO_2 fluxes have been carried out in Norunda, Sweden, since 1994. In autumn 2018 the station was approved as a class 2 ICOS Ecosystem station. The forest is a mixed pine-spruce forest of 30 m height. Since many of stands close to the tower are older than 100 years, it was decided to clear cut the forest in a radius of 300 m from the tower. The clear-cutting will start in 2022. Fluxes of N_2O and CH_4 from an upland forest stand are known to be very small. However, very little is known how these fluxes change when a forest ecosystem turns into a clear-cut. Changes in the soil and surface properties may change the magnitude of the fluxes and even their sign.

To determine the N_2O and CH_4 fluxes prior to clear-cutting, eddy-covariance measurements started in June 2019 as part of the CORE project. A Metek Omni ultrasonic anemometer and an air intake are placed at 35 m height. The gas analyser, an Aerodyne TILDAS FD (N_2O, CO_2, CH_4 and H_2O, since Dec. 2020), is placed at ground level. Air is transported down along a 57 m long tube at a flow rate of 11 L min^{-1}. Data are recorded at 10 Hz.

Time synchronization of anemometer and analyser signals is crucial for determining fluxes. Lag time is best determined using the CO_2 measurement because its signal is the strongest. As a quality check, CO_2 fluxes from Aerodyne are compared to fluxes from another system consisting of a Metek USA-1 anemometer and a LI-COR LI-7000 gas analyser with short tube length. This comparison also allows correcting for dampening of N_2O and CH_4 fluxes resulting from the long tubes.

According to the review of Nicolini et al. (2013), the typical forest N_2O fluxes are 0.09 to 0.42 nmol m^{-2} s^{-1} and CH_4 fluxes are 1.33 to 5.45 nmol m^{-2} s^{-1}. Both fluxes are usually emissions, but CH_4 flux could also be uptake. Sundqvist et al. (2014) used soil chambers to estimate an uptake of CH_4 between -2.8 and -1.4 nmol m^{-2} s^{-1} in the Norunda forest. Our preliminary results show small emission of N_2O (5-day averages up to 0.2 nmol m^{-2} s^{-1}). The CH_4 flux, however, shows both small emissions and uptakes up to 2 nmol m^{-2} s^{-1}.

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III-P13

GREENHOUSE GAS EMISSIONS FROM DRAINED HEMIBOREAL PEATLAND FOREST SOILS IN ESTONIA

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In the terrestrial biosphere, peatlands constitute the most important long-term carbon store. Peat covers only 3% of the land surface but retains roughly 30% of all carbon. The degradation of peatlands is a major and growing source of nutrient discharge; any changes in the ecology and hydrology can affect peatland biogeochemistry, resulting in significant GHG flux variations. Drainage for agriculture, forestry, and other purposes increases the aerobic decomposition of organic matter, turning the wetland from a carbon sink into an emitter of carbon dioxide. Lower water levels and soil water content in drained histosols lead to reduced CH_4 emissions. In contrast, N_2O emissions can increase due to increased mineralization and more favorable conditions for nitrification.

However, GHG fluxes in peatlands have a spatial and temporal (interannual, seasonal, diurnal) variability, and detailed information on drained nutrient-rich organic soils in the hemiboreal zone is still scarce. We conducted a two-year-long study with different tree species (Scots pine, Norway spruce, Downy birch and Black alder) in drained peatland and a natural wetland (fen) as a reference site in Estonia. In this presentation, the first-year results will be presented.

The GHG fluxes were measured twice per month using the manual static (CH_4 and N_2O) and dynamic (heterotrophic respiration (CO_2)) closed chamber method from Jan 2021 to Dec 2021. Additionally, groundwater level, soil temperature, and moisture were measured hourly with automatic loggers to determine soil conditions.

Our preliminary results show that all peatland soils were high emitters of CO_2 (heterotrophic respiration) during the vegetative season (716 ± 47.9 mg m^{-2} h^{-1}; mean ± SE). Soil CO_2 fluxes were highest during summer, and the temporal variability was associated with soil water content within the sites. Overall, drained forest soils were annual methane sinks (−58.6 ± 2.5 µg m^{-2} h^{-1}), while the studied reference fen has the lowest uptake potential of –11.9 ± 4.3 µg m^{-2} h^{-1}. The birch forest with poor drainage soil consumed less CH_4 than heavily drained birch. Methane flux had a statistically significant correlation with water level and soil temperature. Most of the sites were annual emitters of N_2O; forest sites were stronger emitters (48.5 ± 7 µg m^{-2} h^{-1}) than fen soils (27.4 ± 8.2 µg m-2 h^{-1}). Higher N_2O emissions and temporal variability were associated with sites where the water level had high seasonal fluctuations. N_2O flux was controlled by soil temperature and soil moisture content, with higher emissions in the warmer season.

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III-P14

REGENERATION FELLING EFFECT ON SOIL RESPIRATION OF SCOTS PINE STANDS IN SOUTHEAST ESTONIA

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Soil respiration (Rs) comprises a large part of the carbon (C) fluxes of a forest ecosystem. Different forest management strategies can potentially affect Rs through impacting soil microclimate, vegetation and root dynamics. Alternative regeneration fellings are sought to avoid drastic changes in ecosystem C cycling induced by traditional forestry e.g. clear-cutting. As one of the alternatives, shelterwood cutting is recommended for the possibility of maintaining active C sequestering throughout the ecosystem life cycle by allowing for a new forest generation to form before the overstorey is removed completely. Soil heterotrophic respiration (Rh) is the main C efflux in forest ecosystems and a key factor affecting C balance in managed forests. This study focuses on Scots pine (*Pinus sylvestris* L.) stands as they have the most potential for alternative regeneration felling. We aimed to quantify the effect of shelterwood cutting on Rs and Rh in comparison to unmanaged and clear-cut forests.

The study was carried out in three pine stands in southeast Estonia near Lake Palojärv. Two sites were divided into two experimental plots: shelterwood cutting and clear-cutting. Third site was a control plot with no management action. The trenching method was used to distinguish Rh from Rs. Monthly measurements were taken from May to October, using the manual closed dynamic chamber method. In addition, soil temperature and volumetric soil moisture were measured both discretely with the Rs, Rh measurements and continuously with data loggers on each treatment.

The seasonal dynamics of Rs, Rh and soil microclimate showed a similar pattern in all treatments. Both soil temperature and soil moisture were important drivers of the seasonal variation of soil respiration rates. Different management strategies had a significant effect on Rs and Rh rates ($P<0.05$) showing the highest values for the unmanaged treatment (5.45 ± 0.42 and 2.52 ± 0.15 µmol CO_2 m^{-2} s^{-1}, respectively) and the lowest values for the clear-cut treatment (3.11 ± 0.17 and 1.81 ± 0.11 µmol CO_2 m^{-2} s^{-1}, respectively). The results show that contrary to general assumption the CO_2 efflux from soil can decrease after felling in forest ecosystems.

III-P15

LONG-TERM SOIL METHANE UPTAKE TREND IN A CONIFEROUS BOREAL FOREST: VEGETATION VS NON-VEGETATION PERIOD

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Terrestrial ecosystems play an important role in regulating the atmospheric concentration of greenhouse gases. For example, forest ecosystems covering a large part of the biosphere are significant global methane (CH_4) sources and sinks (Dutaur and Verchot, 2007). The atmospheric concentration of this trace gas has increased rapidly at the present rate, highlighting the importance of understanding its sources and sinks to help forecast and manage the effects of CH_4 on the global climate system. However, the processes influencing the balance in soil CH_4 fluxes, the competing interactions between CH_4 production and oxidation by the microbes, are highly variable in space and time, forming substantial uncertainty in the CH_4 fluxes from terrestrial landscapes to the atmosphere. Furthermore, long-term studies on the impact of main environmental drivers are scarce.

We conducted a long-term study (from 2013 to 2021) in a 60-230-year-old coniferous upland forest of Scots pine (Pinus sylvestris) with the second layer of Norway spruce grown on loose sandy soil in the Soontaga Research Station (58°01'N 26°04'E) in Estonia. The soil CH_4 samples were collected biweekly using manual static soil chambers ($n = 6$) and analyzed using gas chromatography. In addition, the environmental parameters such as air temperature and humidity, precipitation, and soil moisture and temperature (10 cm depth) were measured, and the correlation with soil CH_4 flux was calculated.

The mean hourly CH_4 uptake varied from −158.95 to −5.66 ug m^{-2} h^{-1} over the whole study period. The highest CH_4 uptake was observed in July 2021, the warmest and driest month of the year. The variation of annual uptake between the investigated years was low; on average, the forest soil was a net annual sink of CH_4: −7.56 ± 0.88 kg ha^{-1} y^{-1} (mean + SE). CH_4 uptake correlated positively with soil temperature ($r^2 = 0.60$, $p < 0.01$) being significantly higher during the vegetation (Apr-Sept; −4.52 ± 0.41 kg m^{-2} h^{-1}) than during the non-vegetative seasons (Oct-Mar; −3.04 ± 0.56 kg ha^{-2} y^{-1}). As the soil moisture variation was small, the correlation with CH_4 uptake was weak ($r^2 = 0.20$, $p < 0.05$). However, the CH_4 flux was affected by precipitation. This indicates that in cold and wet conditions in winter, the CH_4 uptake decreased with increasing precipitation. In contrast, in dryer conditions in summer, an increase was observed.

III-P16

DEVELOPMENT OF CHEMICAL-KINETIC MODEL OF SMALL ATMOSPHERIC IONS

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Factors like composition and concentrations of trace gases and the level of high energy particles from space play a role in determining the composition and concentrations of atmospheric small or cluster ions. (Luts and Parts, 2002). The motivation for this work is to develop a user friendly model that could predict and simulate the atmospheric ion composition and concentrations change in time.

We gathered 306 reactants and 605 reactions for our model. By gathering as many reactions and reactants as possible we minimized the effect that every single reaction has on a whole system. The model works by first calculating the time series of each individual ion and then, by using the last step from time series calculation, it calculates the steady state. The resulting steady state of ion composition can be compared with the ion composition measured in the ambient air or in laboratory experiment (e.g., in the CLOUD chamber) (Luts and Salm, 1994).

We compared the model results with measurement collected with atmospheric pressure interface time of flight mass spectrometer (API-TOF-MS) in SMEAR Estonia on 29.09.2018 from 06:00 - 06:00. To improve the signal-to-noise ratio of API-TOF spectrum we applied averaging and noise removal algorithms using software package tofTools (Junninen et al. 2010). We created API-TOF peak list that contains 703 peaks in the spectrum. The peak list was created by conducting a peak search which parameters were defined by numerical estimation on the peak shape; mass calibration which determinates the mass accuracy of API-TOF by comparing the known peaks with measured peaks; the resolution function which determinates the relation between peak height and width then we also added known peaks from literature and peaks from model. After we divided the peaks into groups and compared each individual group percentage of total signal. Then we compared the group percentages of model to the group percentages of measurement data to evaluate quality of our model.

Each group list of ions included in current version of model is still imperfect. From comparison to atmospheric ion measurements we conclude that the model is missing reactions including iodine, ammonia, dicarboxylic acids and organics like highly oxygenated organic molecules. Inclusion of these missing species will be subject of future work.

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III-P17

THE RECOVERY DYNAMICS OF ECOSYSTEM CARBON BUDGETS IN YOUNG SILVER BIRCH STANDS CHRONOSEQUENCE AFTER THE CLEAR CUT

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It is a well-known fact that terrestrial ecosystems have a large role in global carbon (C) cycle and forests act as an important C sink by accumulating C both in biomass and soil. Clear-cutting is an extensively used silvicultural method in Nordic and Baltic countries, which strongly influences site carbon (C) budget. However, recovery of C accumulation during post harvesting period is still scarcely studied. In the current study, C dynamics of post clear-cut sites, regenerated with Silver birch was estimated by using C budgeting method. The C budgets of young silver birch stands chronosequence (2-8 years-old) were compiled and both C compensation point and C payback period after the clear-cut were estimated.
High variability of annual NEP was revealed between the stands of similar ages; 4-5 years-old stands acted both as C sinks and C sources, as C accumulation ability of young stands was site specific. Heterotrophic respiration (Rh), the main C efflux of the ecosystem, varied between (3.7 – 6.3 t C ha^{-1} yr^{-1}) across all studied stands however, Rh was not statistically significantly different between studied sites, but showed higher values in older stands. The annual leaching of total organic C was negligible during two study years (15.3 and 36.0 kg ha^{-1} yr^{-1}). Modelling annual NEP dynamics across the chronosequence from 2 to 21 year-old stands, revealed the C compensation point at stand age of 6-years. The estimated cumulative C loss for the period when NEP was negative was near 5 t C ha^{-1} and the amount of lost C could have been recaptured already in the 10-year-old stand. The C sink capacity of studied sites depended mostly on the production of herbaceous plants until the new tree generation started growing intensively and the production of trees became the main driver of ecosystem net primary production. Hence, site C accumulation capacity depends largely on the density and quality of new forest regeneration.

III-P18

POST CLEAR-CUT RECOVERY DYNAMICS OF CARBON ACCUMULATION IN SCOTS PINE AND NORWAY SPRUCE STANDS IN ESTONIA

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Clear-cutting is the most widely used regeneration cutting method in the Nordic and Baltic countries. However, it changes drastically the functioning of an ecosystem, usually turning a carbon (C) accumulating forest into a C source. For the relevant estimation of the clear-cut method from climate warming aspect, it is important to clarify the length of the C source period of the clear-cut areas, as well as to estimate the amount of lost C during that period.

The C budgeting method was used for studying post clear-cut areas of different development stages. Sites regenerated with Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) were included into the study. In both cases four development stages of young forest ecosystems between 0-16 years were studied. All development stages had three replications.

Clear-cut areas and 4-5-year-old stands acted as C sources; net ecosystem production (NEP) was negative. Already 7-8-years-old pine stands turned into C accumulating ecosystems (average NEP + 0.9 t C ha^{-1} yr^{-1}). However, two 6 and 7-year-old spruce stands growing in fertile sites acted as C sources due to high heterotrophic soil respiration efflux but 8-year-old stand was already as a strong C sink.

Older Scots pine and Norway spruce stands (aged between 13-16 years) acted always as C accumulating ecosystems. Still, spruce stands demonstrated significantly higher average annual NEP than pine stands, 5.3 and 1.9 t C ha^{-1} yr^{-1}, respectively.

Carbon compensation point was reached at the age of seven years in scots pine stands and at the age of eight years in spruce stands.

BIOGEOMON 2022

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Poster presentation abstracts

IV SESSION

Soil and microbial processes, trace elements and micropollutants, biodiversity issues

IV-P1

SOIL WARMING DURATION AND MAGNITUDE AFFECTS DYNAMICS OF FINE-ROOTS AND RHIZOMES AND RELATED C AND N POOLS IN BELOWGROUND OF SUBARCTIC GRASSLANDS

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Climate predictions for the subarctic region show a higher rise in atmospheric temperature than the global mean, which will subsequently raise the soil temperature (Ts) in those regions. However, we know very little about belowground plant biomass (BPB) response to warming soils in subarctic regions.

We investigated the effects of medium- and long-term soil warming (11-yr and >60-yr, respectively) duration and magnitude (from +0.2°C to +6.2°C) on total BPB in geothermally warmed subarctic grasslands. We aimed to understand the belowground adaptation mechanisms in plant communities by analysing biomass dynamics of fine-roots (FRB) and rhizomes in relation to plant community composition and soil chemistry along with different soil warming magnitudes and durations. We evaluated the change in BPB, carbon (C) and nitrogen (N) pools in BPB in the context of ambient, Ts < +2.8°C and Ts ≥ +2.8 °C from the ambient.

Both duration and magnitude of soil warming significantly influenced the BPB in the topsoil, whereas only magnitude significantly affected BPB in the subsoil. The effect of Ts increase on C and N pools in belowground biomass was driven by a decrease in FRB and a change of C:N ratio in rhizomes. We found a negative overreaction in BPB in the high warmed plots of medium-term warmed grassland. The significant decrease of C and N pools in BPB after 11-yrs of soil warming recovered in >60-yrs. Belowground adaptation to soil warming in subarctic grassland communities occurred with changed biomass distribution into fine-roots and rhizomes and a change in their chemistry. Furthermore, plants belowground traits changed together with a shift in the functional composition of the plant community.

We highlight the potential effect of the changed proportion of short-living fine-roots and long-living rhizomes to soil biota in response to soil warming. We conclude that the disturbance in C and N pools in BPB caused by soil warming takes more than 11 years to recover.

IV-P2

VEGETATION COMPOSITION AFTER FOREST REGENERATION WHEN DIFFERENT SOIL PREPARATION METHODS USED

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For effective timber production clear felling and sequential forest soil preparation and planting have been used in Latvia for decades in commercial forest stands. Such large scale disturbance as clear felling and soil preparation cause changes in vegetation communities and composition of species. New environmental conditions such as increased sunlight, changed water regime and scarified soil provides favourable ecological niche for ruderal and pioneer species, but meanwhile could lead to decrease growth conditions for typical forest herbaceous, shrub and moss species. Chosen forest management practice, including soil preparation have different impact on environmental conditions, what leads to differences in species composition.

The study was done in 14 forest stands in central and northwestern part of Latvia in the boreonemoral forest zone. These forest stands differed by soil type and water regime. Study sites were reforested with planting in 2017. and 2018. and before planting soil was prepared using two methods – disc trenching and spot mounding. Vegetation species were identified in July of 2019. in randomly distributed 25 square meter sampling plots. The abundance of plant species and micro-location where plant grows (spot mound, mound pit, furrow, till of furrow and unprepared soil) was determined in these plots. The frequency assessment scale for plant species was divided into four groups (Following the methodologies for mapping habitats of EU importance, 2016):

1 – few individuals or their total area do not occupy more than 1 % of the plot area;
2 – individuals occur on average frequency or occupy 1-10 % of the plot area;
3 – individuals occur frequently or occupy 10-20 % of the plot area;
4 – The individual is covered by more than 20 % of the plot area.

Altogether there were detected 136 vascular and 20 mosses species. Comparing vegetation between soil preparation methods in furrows plant communities are more similar to unprepared soil. On spot mound were detected more ruderal plant species, but in mound pit the occurrence of wet plant species was more often detected. Location of the stand also impacts the composition of species, for example nearby road or ditch promote the occurrence of ruderal species and long border with old forest increase occurrence and cover of native forest type species.

In conclusion soil preparation has a positive effect on biodiversity and increase occurrence of wet habitat species in mound pith and furrows and ruderal species on mounds and furrow till.

IV-P3

DYNAMICS OF SOIL MICROBIAL NITROGEN CYCLE DURING A YEAR-LONG STUDY IN A DRAINED PEATLAND FOREST

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Drained peatland forests can be a significant source of nitrous oxide (N_2O), a potent greenhouse gas. These environments are complicated to restore due to the greenhouse gas emissions associated with rewetting. Studying the emissions of N_2O from a drained peatland forest is important in understanding how to restore these environments. The current study aims to investigate the relationship between the different microbial life and emissions of N_2O in a drained peatland forest to estimate the effectiveness of peatlands' current and future management practices.
Soil samples from 12 sites within a drained peatland forest in south-eastern Estonia were collected over a year and analyzed for their physical and chemical properties and the abundance of genes associated with nitrogen cycling. Quantitative polymerase chain reaction was used to evaluate the bacterial and archaeal community abundances by quantifying the abundances of specific 16S rRNA genes and to evaluating the abundances of 9 genes associated with nitrogen cycling: denitrification (*nirS*, *nirK*, *nosZ* clade I, and *nosZ* clade II), nitrification (bacterial, archaeal, and COMAMMOX *amoA*), DNRA (*nrfA*), and nitrogen fixation (*nifH*). This data was paired with N_2O flux data collected in automatic dynamic gas chambers throughout the study period.
Spatial patterns visible in the soil's chemical and physical makeup indicate different vegetation and microbial communities throughout the site. Bacterial and archaeal 16S rRNA and four genes associated with nitrogen cycling, *nirK*, *nirS*, archaeal *amoA*, and COMAMMOX *amoA*, were all found to correlate with N_2O emissions. Archaeal 16S rRNA and archaeal *amoA* both positively correlated with N_2O, and most strongly related to phosphorous and potassium concentrations in the soil. The other significant genes correlated negatively with N_2O emissions but were all strongly linked with water table depth. Over the year, the water table and volumetric water content of the soil were significant factors in the emissions of N_2O and the abundance of nitrogen cycling genes. The site has both hot spots, where N_2O emissions are consistently greater, and hot moments, when N_2O emissions are periodically greater, due to the combination of physical, chemical, and genetic characteristics in the peatland soil.

IV-P4

SEASONAL DYNAMIC OF FINE ROOTS FEATURES OF WHITE POPLAR (*POPULUS ALBA* L.) IN NATURAL TEMPERATE FLOODPLAIN FOREST IN POLAND

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Fine roots are the key component of the carbon cycling in terrestrial environment and substantial input to soil carbon budget. The study of the distribution of fine roots allows to determine the areas of carbon storage in the soil. The vertical distribution of the roots depends on both, the tree species and environmental factors. Research on the architecture of the root system most often includes seedlings and young trees growing under experimental conditions, however little is known about trees in their natural habitat. The aim of this study was to analyze the seasonal dynamic and vertical distribution of fine roots of mature white poplar trees in natural riverside forests of temperate zone in central Europe (Poland) which are periodically flooded. Fine roots of white poplar were sampled using soil coring from four layers of soil (0-10 cm, 10-20 cm, 20-30 cm and 30-50 cm depth) four times during the growing season (April, June, August, October). The study was conducted in two forest sites in the Lover Vistula Valley with different moisture conditions and soil type. The majority of poplars fine roots of both study sites were located in the upper 10 cm of soil and showed a tendency to decrease with depth, however their vertical distribution differed between the sites.

In the forest with lower soil moisture, a significant proportion of the fine roots were also at a depth 10-20 cm, while in the site with higher humidity, almost 2/3 of all fine roots were located only in the surface layer. The results showed that the characteristics of fine roots were significantly influenced by season and soil properties influenced their vertical distribution. The greatest differences between the sites were found in the subsurface layer of soil (0-10 cm). The highest values of the length and surface area of fine roots were observed in August. Very fine roots (0-1 mm in diameter) dominated in the soil samples analyzed. Regardless of the sampling site, the share of the very fine roots in relation to the roots with a diameter of 1-2 mm was comparable. Environmental conditions were not the crucial factors influencing the features of fine roots, which can confirm the important role of tree species in the functioning of their below-ground part functioning.

IV-P5

TRACING NITORGEN FROM LEAF LITTER TO MINERAL SOIL ORGANIC MATTER IN FORESTS OF DIFFERENT AGES

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Forest soils are important for retaining nitrogen (N) in soil organic matter (SOM), especially in areas where anthropogenic activities have led to historically high inputs of N. As forests age and their N demands for biomass accumulation decline, the N retention capacity of soils may change as well, although little work has been done to further our understanding of this process. We conducted a mineral soil reciprocal transplant study in three northern hardwood forests of different ages (young, ~45 years; recently mature, ~100 years; and old growth, >200 years) in New Hampshire, USA to determine how the retention of isotopically labeled N from leaf litter would differ depending on characteristics of the incubated soil's origin and destination. We traced 15N from leaf litter into particulate organic matter (POM) and mineral-associated organic matter (MAOM). After 18 months of incubating the soil bags below the ^{15}N-labeled litter, we did not find total retention of litter-derived N to be related to the age of the forest at the incubation site, but rather that it differed based on the origin of the incubated soil. We found that the soil C content was the strongest predictor of how much of the tracer was recovered in the transplanted soil bags. Furthermore, the C content of soils changed during incubation and tended to change in the direction of equilibrating with the soil C concentration of the incubation site. This finding suggests that site characteristics are important in determining soil C concentrations and consequently N retention capacities.

IV-P6

A COMPREHENSIVE REVIEW: PARAMETERS AFFECTING ENHANCED DENITRIFICATION IN BIO-ELECTROCHEMICAL SYSTEMS

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Excessive nitrogen has become a critical problem for the environment because the nitrogen fixed chemically and used for fertilization pollutes the waterbodies extensively worldwide. Many different processes help remove nitrogen compounds from contaminated soils and waters, and the presence of oxygen is one of the most decisive factors. Denitrification in anaerobic conditions is considered the main removal processes of excessive nitrogen, although lately discovered anaerobic ammonium oxidation (ANAMMOX) and dissimilatory nitrate reduction to ammonium (DNRA) may also have an important role in nitrogen elimination of different systems. To a lesser extent, also nitrification can contribute to nitrogen elimination in watery systems. All previously pointed out removal mechanisms occur in the constructed wetlands and could even be enhanced with the bio-electrochemical systems (BES). BES exploit the ability of the electroactive microorganisms to reduce the oxides of nitrogen.

The approach of utilizing bio-electrochemical systems for treating nitrate-polluted water has been explored in recent times. The major advances in this research has been since the last decade. We compiled together the work of different types of BES, such as microbial snorkel systems, microbial fuel cells and constructed wetland conjugated microbial electrochemical systems in their abilities to treat nitrate polluted water. Different parameters of the working of the systems, such as the hydraulic retention time, number of chambers, electrode materials, polarization, current, nitrate removal efficiencies and their bacterial community structure, were studied and systemically analyzed.

We observed that bacteria from the class *Proteobacteria* are selectively enhanced in these systems. The majority of the nitrate oxidizing bacteria and nitrous oxide oxidizing bacteria are from the class *Proteobacteria*, and thus, the dynamics of this class could be correlated with the nitrate removal ability of the BES. *Pseudomas, Halomonas* and *Thaurea* species have shown to be supported by these systems. The nitrogen transforming community of bacteria has been shown to work in unison with electroactive bacteria to remove nitrate. The presence of the *nirS* gene along with *nosZ* gene is more abundantly found in denitrifiers over *nirK* gene. Therefore, there is relevant evidence of complete denitrifiers on the cathode as the abundances of *nirS*, and *nosZI* genes are observed in recent studies.

Most systems have utilized acetate as an electron donor. The majority of the studies have used graphite felt material as electrodes, but other materials and specifically inoculated microbes have shown to enhance the efficiency of the systems.

The activity of electroactive organisms on the bio-cathode has also been explicitly observed due to the presence of *Geobacter spp*. BES utilize the ability of these microbes for electron transfer and subsequent reduction of nitrate. Abiotic systems have displayed lower nitrate removal efficiencies compared to biotic systems. Neutral pH has been shown to be the most optimum for efficient nitrate removal. BES have shown to reduce nitrate at varying temperatures from 5 °C to 23 °C, i.e. room temperature.

The upcoming advances in these systems show a promising way to deal with nitrate pollution. They can be utilized as an efficient conjugated system in the absence of sufficient carbon sources for the anaerobic processes to occur. This work helps in the development and utilization of BES for efficient nitrate removal.

IV-P7

MICROBIAL NITROGEN CYCLE AND RESULTING NITROUS OXIDE FLUXES IN AMAZONIAN PEATLAND SOILS

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Tropical peatland soils are regarded as major emitters of nitrous oxide (N_2O), a potent greenhouse gas and the most important ozone-depleting emission. Despite their importance in climate change and possible climate control strategies, the microbial nitrogen cycle and resulting N_2O flows in tropical peatland soils remain largely unstudied. The aim of this study was to assess the N_2O potential of microbiological processes in the nitrogen cycle in the Iquitos region of Peru depending on land use, physicochemical parameters and soil N_2O emissions.
Soil samples were collected from four sampling sites near Iquitos, Peru. The first set of samples was collected in September 2019, the second one in March 2020. All sites were current or former palm swamps dominated by *Mauritia flexuosa* palms. Quantitative real-time PCR was used to measure the abundance of bacteria and archaea specific 16S rRNA, nitrification (AOA, AOB and COMAMMOX *amoA*), denitrification (*nirK*, *nirS*, *nosZI* and *nosII*), nitrogen fixation (*nifH*) and DNRA (*nrfA*) marker genes in collected soil samples. Principal component analysis was used to assess variances in physicochemical parameters between sites. One-way analysis of variance (one-way ANOVA) with Tukey's test was performed to assess variances in gene abundances between sites. Spearman correlation analysis was used to determine significant relationships between gene abundances, physicochemical parameters and N_2O emissions.
The results show that the abundance of microorganisms involved in the soil nitrogen cycle was most affected by soil moisture, and natural sampling sites with a higher soil moisture content displayed abundances far greater than sampling sites with current or previous anthropogenic disturbances. The highest N_2O emissions were measured at a moisture content of 80%. As most studies conducted on mineral soils agree on 50-60% soil moisture content as being the optimal range for N_2O emissions, the results of this study might indicate a higher optimal range for N_2O emissions in peatland soils. Relationships between N_2O and marker gene abundance displayed clear seasonality. During the dry season, N_2O fluxes were positively affected by microorganisms with archaeal *amoA* and *nrfA* genes. During the wet season, N_2O fluxes were negatively affected by microorganisms with *nirS*, *nosZII* and COMAMMOX *amoA* genes but positively affected by the proportion of *nir*/*nosZ*. The highest N_2O fluxes were measured from the soils near *Symphonia globulifera* trees. These soils displayed a high abundance of microorganisms capable of DNRA and had a much lower abundance of *nosZ*-type denitrifiers compared with the other natural site. The results of this study suggest that N_2O emissions from tropical peatland soils are mainly affected by soil moisture and might have a higher optimal moisture range than in mineral soils.

IV-P8

PHOSPHORUS CHEMISTRY IN ALPINE SOILS: MEADOW SOILS VS. SOILS IN SCREE DEPOSITS

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Scree deposits in alpine catchments contain undeveloped till soils "hidden" between and under stones in scree areas. These scree soils are without vegetation, but exhibit biological activity and active nutrient (N, P, and organic C) cycling. We compared the chemical and biochemical properties of till soils with developed soils in alpine meadows in 14 catchments in the alpine zone of the Tatra Mountains. The data show that scree soils may serve as an important source of mobile P-forms feeding the waters in high elevation catchments. Detailed soil survey focused on 4 selected alpine catchments with a scree cover proportion > 30% confirmed that scree soils have significantly higher concentrations of mobile P forms, if compared to meadow soils. The average concentrations of oxalate-extractable soluble reactive P was three times higher there (9.3 vs 2.9 mmol kg^{-1}), Olsen P concentrations were even one order of magnitude higher (1.4 vs. 0.13 mmol kg^{-1}). Concentrations of the most mobile P form, water-extractable soluble reactive P, were more than two times higher (8.3 vs. 3.4 µmol kg^{-1}). The scree soils exhibited high specific microbial activity directed towards the extraction of P, and its rapid turnover in microbial biomass. The combination of these properties suggest the importance of their role in the biogeochemical P cycling in alpine catchments.

IV-P9

DETERMINATION OF THE KEY PROCESS INVOLVED IN THE N_2O FLUX FROM THE SOIL IN A DRAINED PEATLAND RIPARIAN FOREST DURING FREEZE-THAW PERIOD

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N_2O is a greenhouse gas released both by natural as well as anthropogenic sources. In nature it is released as a byproduct of the nitrogen cycle and is sometimes released due to the incompletion of the cycle which many factors can influence. In a recent study it was revealed that the N_2O fluxes spiked during the freeze-thaw period and then on the onset of the dry period in a drained peatland forest. This study was designed to look more closely at the phenomenon and to investigate what factors and processes could be influencing this sudden spike in N_2O fluxes.
During the freeze-thaw period for over 9 non-consecutive days gas and soil samples were taken from the manual chambers with heating coils installed on the ground to mimic the natural conditions of elevated surface temperature. The control session was performed in the early morning, followed by heating sessions, and for each session, gas and soil samples were taken. Soil samples were then analyzed for nitrates, ammonium, and dry matter while gas samples were tested under GC-ECD for N_2O. Soil surface temperatures at 0, 10 and 25 cm were also taken respectively, along with soil water content (SWC). Soil samples were also subjected to microbial analysis. DNA was extracted from the soil samples from the selected days, and then quantitative polymerase chain reactions (qPCR) were run for bacterial and archaeal 16S rRNA genes, and genes involved in denitrification (*nirS, nirK, nosZI & nosZII*) and nitrification (bacterial, archaeal and COMAMMOX *amoA*)
For the N_2O fluxes from the soil it was observed that on the onset of heating, emission increased but slightly dropped in the second heating session (mean values, 59-118-112 $\mu gNm^{-2}h^{-1}$). This change was also negatively correlated with the amount of nitrate in the soil. In the previous long-term study, the N_2O flux was found positively to be correlated with SWC but the correlation was found positive yet statistically insignificant in this study ($p=0.075$). However, the correlation was significant in the case of temperature at 0 cm as well as 10 cm depth. The negative correlation between N_2O fluxes and the nitrate in soil suggests that denitrification is the main player in the process, as a decrease in nitrates showed the same pattern of change as shown by N_2O. The gene analyses are in progress but will help to clarify the reasons behind the N_2O emissions.

IV-P10

EVALUATING POLLUTION LEGACY USING BERYLLIUM, LEAD AND CHROMIUM SOIL SOLUTION CONCETRATIONS AT THE SOIL-REGOLITH INTERFACE

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Soil solution chemistry reflects equilibrium between soil waters affected by atmospheric deposition and weathering. Weathering can affect contrasting lithologies at different intensities, and under similar climatic controls the leaching susceptibility of soils derived from mafic or ultramafic rocks can be from 10 up to 100-fold higher than for soils formed on granites (Krám et al., 2012; Dannhaus et al., 2018). Lithological heterogeneity regulates the distribution of reactive clays in the porewater system, whilst aqueous chemical variability could arise also from contrasting fluid flow paths along the topographic surface. Complexity in integrating and interpreting multiple factors affecting soil solution chemistry—at any temporal scale—means that studies based on lysimeters are rather uncommon. Nonetheless, the chemical composition of soil solutions can be used to assess nutrients mobility and differential leaching of ions in forest ecosystems (Petrash et al., 2019). The Slavkov Forest was heavily impacted by acid deposition and the pollution burden and on-going recovery has been monitored for over 30 years. Here we evaluated spectroscopic elemental concentrations pertaining soil solutions collected using lysimeters at different depths (10, 20, 30, 60, and 90 cm) across diverse soil profiles from 2012-2014. Diverse soil profiles provide an advantage given that our chosen elemental proxies should exhibit, under unperturbed conditions, a diffusional enrichment profile towards the felsic (Be, Pb), mafic or ultramafic (Cr) regolith. Punctual higher concentrations of these elements in the examined soil profiles relative to regolith-normalized base levels revealed anomalous accumulations that could be considered indicative of legacy pollution. The contribution of groundwater *v*ersus top soil infiltration using a stable $\delta^{18}O$ isotope water generation model showed that groundwater inputs contribute greater to runoff water proportion. This mixed-source water is trapped in our lysimeter networks, and deviations from average elemental concentration values could hint to an effect exerted by water table recharges with potential legacy pollution. Overall, our data suggest rapid equilibration with atmospheric solutes deposited at the top-soil levels, and provide guidance for evaluating legacy pollution in soil profiles of contrasting lithology.

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IV-P11

INTEGRATING MICROBIOLOGICAL AND ISOTOPE METHODS FOR STUDYING SOIL NITROGEN CYCLE PROCESSES IN CONTRASTING WATER REGIMES ON DRAINED PEATLAND FOREST

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Globally, peatlands cover a small amount of land area. Still, they store about one-tenth of the global soil nitrogen. They can be one of the significant sources of nitrous oxide (N_2O) emissions, a powerful greenhouse gas and ozone depleters in the stratosphere. N_2O has a global warming potential 298 times higher than carbon dioxide, and the current atmospheric levels are the highest reported in the last 800 000 years, and the N_2O concentrations are rapidly increasing. The complexity and diversity of nitrogen cycle processes and N_2O-governing microbial communities cause the need to study them using microbiological and isotope methods. Their combined application helps make the most precise estimates of the processes happening, which is crucial for the future management of drained peatlands to mitigate soil degradation and negative atmospheric impact. The purpose of this study was to investigate the effect of drainage and rewetting on different nitrogen cycle processes and N_2O emissions using quantitative PCR (qPCR) and isotope methods.

The triangle-shaped mesocosms were established in July of 2020 to achieve varying oxygen conditions for flooding and drainage experiment in Estonia's Oxalis site-type drained peatland forest. In the experiments, heavy nitrogen tracers of potassium nitrate ^{15}N 98% atom and ammonium chloride ^{15}N 98% atom were applied to soil to intensify and get an insight into N_2O production mechanisms and on its soil moisture dependence. N_2O concentration was measured, and soil samples were collected six times from the study sites between October 2020 and January 2021. Besides different physical and chemical parameters measured in soil samples, quantitative PCR measured the abundance of bacterial and archaeal specific 16S rRNA, nitrification (bacterial and archaeal *amoA* genes) and denitrification (*nirK*, *nirS*, *nosZI* and *nosZII* genes) marker genes from the samples. Isotope composition of soil and gas samples was also measured.

The nitrification genes of the drained sites showed slightly higher abundances compared to flooded sites and slightly higher abundances in the denitrification genes compared to drained sites. This is perfectly logical as nitrification is an aerobic process, and denitrification is an anaerobic process. In addition, we saw that the *nirS* genes were more temperature-dependent as the colder it got, the abundance of the *nirS* genes decreased. From drained as well as flooded treatments, we observed significant differences in tracer labelled ^{15}N-N_2O fluxes for drained and flooded treatment sites. The N_2O emissions from the flooded treatment were nearly negligible, whereas the N_2O fluxes from the drained site peaked at 147 µg ^{15}N $m^{-2}h^{-1}$. This suggests nitrification as the driving mechanism producing N_2O fluxes in drained sites. Based on the genetic data and N_2O fluxes, we saw that the nitrification and denitrification processes could not be easily separated only based on the site preference and $\delta^{18}O$ values. In addition, genetic data confirmed that nitrification was the main process compared to denitrification in the drained sites for N_2O emissions, and low N_2O emissions in flooded sites were because the denitrification process was complete, and the result was N_2.

IV-P12

CHARACTERISTICS OF DISSOLVED ORGANIC MATTER IN BOREAL MINERAL SOILS UNDER VARIOUS AGRICULTURAL PRACTICES

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Soil organic matter (SOM) consists of a wide variety of compounds that have varying characteristics affecting its lability and affinity to soil minerals. Dissolved organic matter (DOM), which is considered as the most mobile and readily degradable fraction of SOM, is a heterogeneous mixture of compounds with polymorphic characters. DOM is continuously involved in dynamic soil processes driven by many physicochemical and biological factors, but it is scarcely studied particularly in mineral soils under agriculture, where soil disturbance, fertilization, and the addition of organic amendments are likely to change the characteristics and dynamics of DOM (Graeber et al., 2015; Evans et al., 2020). In addition, agricultural soils rich in organic matter may increase the discharge of DOM into surface waters (Manninen et al., 2018; Sharma et al., 2017) where the chemical characteristics of DOM further determines its effects on the receiving waters. DOM can be characterized by fractionating the compounds into groups according to their molecular weight, as carried out in peatlands previously, to better understand its ecological role in soil and water environment. Our study focuses on ecologically the most meaningful compound groups of DOM, namely aromatic compounds, proteins and carbohydrates, in fine and coarse mineral soils with various agricultural practices in Finland. Firstly, we collected water-extracted SOM, representing DOM, and fractionated it into three different molecular weight fractions by performing similar tangential ultrafiltration procedure as described by Kiikkilä et al. (2014). Secondly, we measured the concentration of the fore mentioned compound groups in each molecular weight fraction. Combining these two analyses gives us relevant information about both degradability and mobility of DOM in mineral soils under various agricultural practices. We present preliminary results to assess whether agricultural practices affect characteristics, and hence, the fate of DOM, and whether leached DOM has potential adverse effects on surface waters.

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IV-P13

ORIGIN OF Mg, Ca AND Sr IN RUNOFF FROM A SMALL POLLUTED GRANITIC CATCHMENT: ISOTOPE CONSTRAINTS

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We studied magnesium (Mg), calcium (Ca) and strontium (Sr) isotope systematics in a Central European headwater catchment underlain by granite. The Uhlirska catchment, situated in the northern Czech Republic, is recovering from acidification of soil and water following 40 years of acid rain. A combination of isotope and non-isotope data was used to constrain the origin of base cations exported from the catchment via runoff. Whole-rock δ^{26}Mg, δ^{44}Ca values and ^{87}Sr/^{86}Sr ratios were complemented by isotope analysis of apatite, biotite, plagioclase, orthoclase and titanite. Isotope composition of Mg, Ca and Sr in precipitation, throughfall and runoff was monitored for 12 months. Five soil horizons, soil solutions and tree organs of Norway spruce (fine roots, xylem, bark and needles) were also isotopically analyzed. The non-isotope data included a 24-year time-series of input/output fluxes of Mg and Ca, and a time-series of Sr fluxes starting in 2010. Because of its high relative reactivity and high mass contribution to bulk bedrock, biotite was the likely main source of geogenic Mg. Apatite and plagioclase were the likely main sources of geogenic Ca, and plagioclase was the likely main source of geogenic Sr. Magnesium in biotite was isotopically too heavy to dominate runoff. In contrast, apatite and plagioclase contained Ca whose isotope composition was indistinguishable from the whole-rock and could play a major role in runoff generation. For Mg and Ca, isotope compositions of atmospheric deposition, bulk bedrock, soil solutions, and runoff were statistically indistinguishable. Plagioclase had a significantly lower ^{87}Sr/^{86}Sr ratio than bulk bedrock, close to the low ^{87}Sr/^{86}Sr ratio of runoff. Plagioclase weathering was consistent with a sizeable geogenic Sr contribution to runoff but if only bulk-rock ^{87}Sr/^{86}Sr was considered the predominance of geogenic Sr in runoff would be unlikely. Systematically higher Mg, Ca and Sr runoff fluxes, compared to atmospheric input, were consistent with a geogenic control of runoff. Decrease in runoff fluxes of Mg and Ca observed since 1994 coincided with a decrease in deposition fluxes of the same elements but there may not be a strong causal relationship that would point to a large atmospheric contribution of base cations to runoff; decreasing fluxes of base cations in runoff were related to decreasing sulfate export accompanying the retreat of acidification.

IV-P14

SPATIAL TRENDS IN THE ISOTOPE COMPOSITION OF ZINC AND LEAD DOWNWIND FROM AN INDUSTRIAL POLLUTION SOURCE (SILESIA, SOUTHERN POLAND)

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The densely populated Central European region is characterized by a high degree of industrialization. Numerous coal-burning power plants, base-metal smelters and steelworks are situated in the Upper Silesian Basin near the border between Poland and the Czech Republic. Despite introduction of state-of-the art emission-control devices in both power plants and smelters, emissions of potentially toxic trace elements, such as Zn, Pb, Cu, As, Cd and Sb, continue to contribute to severe environmental pollution and negatively affect life expectancy. We studied changes in the isotope composition of zinc ($\delta^{66/64}$Zn values) and lead (^{206}Pb/^{207}Pb ratios) in atmospheric deposition at four rural sites northeast of the industrial city of Olkusz, southern Poland. Our objective was to quantify the relationship between the distance from point sources of pollution and the Zn-Pb isotope composition at the surface of the snowpack. Mid-winter snow sampling was performed on farmland in 2011, 2018, 2019 and 2021. Sampling site no. 1 was situated mere 8 km from Olkusz, sampling site no. 2 was situated 20 km northeast of site no. 1; sampling sites no. 3 and 4 were situated further northeast (*i.e,* further downwind), also 20 km apart. During the years of the study, a sharp (5-to-10 fold) decrease was found in the concentrations of Zn, Pb, Cd and Sb and in S in the snowpack. With an increasing distance from the industrial polluters, the isotope composition of Zn and Pb exhibited "mirror-image" patterns. At the most polluted site no. 1, we found a low mean $\delta^{66/64}$Zn value and a high mean ^{206}Pb/^{207}Pb ratio. The next site no. 2 had the highest mean $\delta^{66/64}$Zn value and the lowest mean ^{206}Pb/^{207}Pb ratio. Further downwind sites no. 3 and 4 were characterized by decreasing mean $\delta^{66/64}$Zn values and increasing mean ^{206}Pb/^{207}Pb ratios. The least polluted site no. 4 had then nearly identical Zn and Pb isotope composition, respectively, to the most polluted site no. 1. While the isotope composition of deposited Pb was controlled only by mixing of pollution from various sources, the isotope composition of deposited Zn could have been additionally affected by an isotope fractionation. Site no. 1 was primarily affected by the nearest one major pollution source (low-$\delta^{66/64}$Zn, high-^{206}Pb/^{207}Pb, seen especially in the most polluted year 2011). In contrast, starting at site no. 2, we observed mixed Zn and Pb isotope signatures reflecting an entire cluster of ~17 major pollution sources west and south of Olkusz. Along the straight line connecting more remote sites no. 2, 3, and 4, we likely observed an increasing contribution of the Central European background isotope signatures (low $\delta^{66/64}$Zn and high-^{206}Pb/^{207}Pb).

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IV-P15

COLLUVISOLS AS A RECORD OF PROCESSES FORMING AGRICULTURAL LANDSCAPE

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Soil erosion by water is process often discussed in agricultural landscape as one of the major threats to soils with a negative impact on ecosystem services, crop production, drinking water, and carbon stocks. Sedimentation and accumulation is part of the erosion process leading to formation of colluvial soils as significant part of the changing soil cover of intensively exploited agricultural lands. They act as reservoirs of soil organic carbon (Zádorová et al., 2015), can be used to study the intensity of actual and past soil erosion, and they attract more attention as a promising key to our understanding of the landscape dynamics in the changing climatic conditions. This contribution aims to show the less common possibilities of studying Colluvisols and the interpretation of specific results in relation to the development of the landscape on the example of Chernozem area (SE Czech Republic), where Colluvisols can reach depths of up to 4 m.

Based on the infrared spectra of soils (Dried samples ground to analytical fineness without any dilution with KBr, diffuse reflectance infrared spectroscopy with Fourier transformation in the spectral range 4000–400 cm^{-1} and with resolution 4 cm^{-1} were used.), it is possible to monitor some mineralogical properties of soils, such as the presence of carbonates indicating, for example, erosion of the soil-forming substrate in the higher parts of the slope. However, these spectra was mainly used for the evaluation of organic matter in the soil. It is possible to estimate its quantity on the basis of them. The results of spectral analysis correlate well with the results of direct analytical measurements. It was found that the highest amount (concentration and stock) of carbon in these soils is at a depth below 150 cm, i.e. much deeper than where it is normally assessed. On the base of spectra evaluation, description of soil organic matter qualitative parameters was processed. Indexes characterizing organic matter in the soil in terms of its aromaticity or hydrophobicity (based on the presence of spectral bands of aromatics and aliphatic chains) were used (Thai et al. 2022). The results show considerable variability of these parameters within the soil profile, but it is possible to identify parts of the profile corresponding to the original horizons of the buried Chernozem.

Analyses of 137 Cs and organic pollutants (Dichlorodiphenyltrichloroethane – DDT) with high persistence, low mobility and high abundance in arable soils were used for distinguishing different colluvial layers and their relating with a specific period of land management. The use of DDT was banned in the Czech Republic in 1974. The layer that contains highest DDT amount and highest 137 Cs activities is at a depth of approximately 70–120 cm. It is therefore likely that the soil layer 0–70 cm was formed as a result of intense erosion over the last 50 years.

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IV-P16

SPECIES COMPOSITION, RICHNESS AND DIVERSITY OF GROUND VEGETATION IN FOREST STANDS, FERTILIZED WITH WOOD ASH AND AMMONIUM NITRATE

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Fertilization is a silvicultural practice to improve tree growth and increase economic gain from forests, however it may have a negative environmental impact, which should be monitored. In boreal forests, nitrogen-containing fertilizers are most commonly used. As the use of forest biofuels is increasing, large amounts of wood ash are generated and application as forest soil amendment is a way to utilize the ash. Nitrogen-containing fertilizers and wood ash may have an impact on forest ground vegetation through direct damage, ecosystem eutrophication and changes in soil pH. The effect depends on soil properties, initial species composition and the dosage of a fertilizer. Previous studies show that in general nitrogen fertilization results in changes in composition towards more nitrophilous vegetation and replacement of dwarf-shrubs by grasses (Hedwall et al., 2014).

The aim of the study was to investigate, how application of ammonium nitrate and wood ash affects forest ground vegetation depending on soil properties and dominant tree species. Our study was conducted in 25 forest stands, where the dominant tree species are Scots pine, Norway spruce or Silver birch, representing six forest site types. Wood ash and ammonium nitrate were spread in 2013-2017. The mean projective cover of each species in moss and herb layer was determined. Species composition, richness and diversity were compared between control (unfertilized) and fertilized plots. Detrended Correspondence Analysis, correlation analysis between Shannon diversity index, the number of species and soil/forest stand metrics as well as GLM analysis were carried out.

Results show that in both control and fertilized plots the general species composition is typical of the studied forest site types. The differences in species richness and species diversity is the most pronounced in silver birch stands. DCA ordination reveals that in most cases species composition is rather dependent on environmental gradients than the application of wood ash and ammonium nitrate. More pronounced differences in ground vegetation of control and fertilized areas may occur later, when the effect of thinning diminishes, therefore long-term observations are required.

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IV-P17

VARIABILITY OF SOIL CH_4 CYCLING WITHIN A BOREAL CATCHMENT – EFFECT OF METHANOGENIC AND METHANOTROPHIC COMMUNITY COMPOSITION

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Boreal forest soils are generally a sink for the greenhouse gas methane (CH_4), but during years of high precipitation, this sink can decrease and even switch to a CH_4 source (Lohila *et al*, 2016). Likewise, higher soil moisture is likely to change the balance between CH_4 production and consumption in peat soil, including forestry-drained peatlands. These patterns may become more common in the northern latitudes with the ongoing climate change.

To better understand how CH_4 cycling contributes to the carbon balance of boreal areas, and how this is affected by the predicted moisture changes, we need to assess related microbial processes and their drivers in different boreal soil types. Currently, both methanogenic archaea and methanotrophic bacteria are poorly characterized in upland forest soil and forestry-drained peat, limiting us from evaluating the effect of their community composition.

For the above purpose, we sampled seven varied sites on an upland hilltop-pristine peatland-gradient located on the previously studied (Lohila *et al*, 2016) Pallaslompolo catchment in Northern Finland (67° 59N, 24°13E). To reveal the CH_4 cycling microbes present, and potentially active, we utilized a novel probe-targeted metagenomic approach based on functional genes *mcrA*, *pmoA* and *mmoX*. This community data will be evaluated against various other markers, including potential CH_4 production and oxidation (lab-scale), soil CH_4 fluxes, vegetation composition and water table levels, which were followed throughout the season. Here, we will present preliminary results from these analyses.

The resulting detailed view of the boreal soil CH_4 cycling will help us estimate how it responds to the predicted increase in extreme precipitation events. Due to the inclusion of all dominant soil types, it will be useful in the modelling of catchment-scale CH_4 dynamics.

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IV-P18

USING AI AND SMARTPHONE IMAGES TO ASSESS THE GROWTH OF FINE ROOTS OF NORWAY SPRUCE SEEDLINGS MANIPULATED BY AIR HUMIDITY AND SOIL NITROGEN SOURCE

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A new insight into measuring root growth dynamics is presented in this study, where pictures of root growth were taken with personal mobile phones and analyzed by the machine learning-based program RootPainter (Smith et al. 2020). Today's smartphones provide high-quality photos, and user-friendly free software enables rapid processing of these images. We aimed to explore 1) how the changes in relative air humidity and dominating soil nitrogen source and their interactions influence root growth and 2) how accurate the results are of the deep learning segmentation models created for assessing root growth.

Picea abies trees were grown separately in transparent boxes in growth chambers in moderate or elevated air humidity and on either nitrate or ammonium-fertilized soil. The pictures of roots were made from each side of boxes every week, together six sessions. The pictures were analyzed with RootPainter twice, one with total root projection area and second with only young white roots.

The total root growth was highest in trees growing in moderate air humidity and on ammonium source and lowest in elevated air humidity grown on nitrate source. The young root projection area was highest at the beginning of the experiment, and was affected by the soil nitrogen source. The amount of older brown roots increased over time and were affected by the air humidity treatment. We compared a subset of automatically measured pictures to manually annotated pictures (F-measure = 0.88). The magnitude of the false positives and false negatives were relatively low. We did not discover treatment-specific bias in our error measurements. We conclude that the combination of smartphone images and RootPainter gives accurate and reliable results and is easy to use in future plant growth manipulation experiments.

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IV-P19

GREY ALDER AT REGENERATION STAGE – ANY LONG-TERM SOIL OR TREE EFFECTS IN NORWAY SPRUCE STANDS?

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Increasing soil N availability is an effective way to enhance soil organic carbon (SOC) sequestration and tree growth in N-limited ecosystems, such as boreal Norway spruce forests. Alder has a root nodule symbiosis with *Frankia*, a N_2-fixing bacterium, and can thus add plenty of N into soil with its N-rich leaf litter. The objective of this study was to find out whether the presence of grey alder at the regeneration stage has any long-term effects on soil C and N cycling and stocks and spruce growth. The study sites were two relatively fertile 40-yr-old Norway spruce stands (Luhdansuo and Porkkola) in Southern Finland. In part of the spruce stands there had been plenty of grey alder growing at the regeneration stage (alder plots), while in the other part, no alder had been present (control plots). Alders had been cut in 1995-2000 (Luhdansuo) or in early 1990s (Porkkola). We did not find any differences in the plant-available N fluxes, measured with microdialysis technique, or SOC stocks between the treatments. However, we found that the total N stock (O horizon + 0-30 cm mineral soil) was slightly larger and O horizon was thicker, while microbial biomass C:N and C mineralization rate were lower in the alder *vs*. control plots in Luhdansuo. Overall, the soil results did not suggest higher N availability or SOC stocks due to past presence of alder. The tree ring widths were larger in the alder *vs*. control plots for approximately 5 years after alder removal in both sites but no differences were found in the current tree diameters or diameter increments. In conclusion, most of the soil properties or tree dimensions did not show any significant differences between the treatments, probably because the effect of alder had faded out after 20-30 years since its removal, and because the sites were initially relatively fertile.

IV-P20

ON THE RELATIONSHIP BETWEEN FOREST STATUS FOLLOWING BARK-BEETLE DISTURBANCE AND MINERAL NITROGEN IN SOILS OF UNMANAGED MOUNTAIN CATCHMENTS

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Forest dieback reduces the nitrogen uptake of trees. In unmanaged ecosystems, large amounts of organic plant material end up in the soil where it undergoes a transformation by microbes. Different N availability, associated with the vegetation status and microbially mediated transformation of litter, determine the effectivity of mountain forest soils to retain N and produce nitrates. N availability also affects leaching of other elements from the soil and the chemistry of lakes. From 2005 to 2020, we measured mineral N fluxes in the soils of two spruce-forest catchments (Plešné (PL) and Čertovo (CT) lakes in Šumava National Park, Czech Republic, non-intervention regime, above 1000 m a.s.l.) using ion exchangers to quantify nitrogen fluxes in the soil during the forest dieback and subsequent regeneration. Forest dieback in PL increased the flux of mineral N through the soil by up to 400% (2100 mmol N m^{-2} $year^{-1}$) compared to a nearly intact control catchment CT (500-1000 mmol N m^{-2} $year^{-1}$). During the forest dieback, the ratio of nitrates to ammonium ions in the soil was 1:1, indicating a high rate of N mineralization. N fluxes peaked two years after the forest dieback and then decreased significantly due to vegetation regeneration (100-200 mmol N $m^{-2}year^{-1}$). During the recovery phase at PL and in the catchment area of CT over the entire study period, nitrates dominated in the soils (~ 85%). Compared to the runoff of mineral N from the catchment to the lake, mineral N fluxes through the soil were ten times higher at the onset of disturbance culmination (2100 vs. 210 mmol N $m^{-2}year^{-1}$), indicating relatively effective use of N in the soils despite minimal N immobilizations by the trees. The measured fluxes represent the maximum potential of such an ecosystem to supply a new generation of trees with available N if all biomass is left on site. This potential should be considered when defining management measures following disturbances in production forests.

IV-P21

IMPORTANCE OF CYANOBACTERIA FOR THE HEALTHY BOREAL FOREST CRYPTOGAMIC COVERS

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Cryptogamic cover (CC) of feathermosses, acrocarpous mosses and lichens are characteristic to the boreal forests and they contribute substantially to the forest carbon pool, and biological nitrogen availability. Proper functioning of the CC is thus important in serving as vital seedbed for the multilateral forest ecosystem and, in turn, acting as a globally important carbon sink. Nitrogen and carbon fixing, moss-associated cyanobacteria, *Nostoc* sp., have an essential role in healthy CC as they transfer majority of the assimilated nitrogen directly to CC, and fuel the otherwise nitrogen poor forest ecosystem. However, previous findings have shown the capability of CC and cyanobacteria to emit methane (Bižić et al., 2020 and Lenhart et al., 2015) and N_2O (Lenhart et al., 2015). To which level different organisms of the multilevel plant-cyanobacteria-heterotroph-community participate in nutrient turnover, and how much of the freshly assimilated carbon and nitrogen are circulated back to the atmosphere, can only be hypothesized.

The most common feathermoss species, *Hylocomium splendens* and *Pleurozium schreberi*, were collected from Southern, Central and Northern Finland and the spatial and temporal occurrence of cyanobacteria was analyzed. We found that *H. splendens* was more often colonized by nitrogen-fixing *Nostoc* sp. cyanobacteria than *P. schreberi* and cyanobacteria were most abundant in Northern Finland at the end of the growth season (8,7 % of 16S rRNA amplicon sequencing reads). Preliminary data also showed the methane emission hotspots in moss shoot communities, but further investigations are needed to link the spatial and temporal variation of the moss community to the flux measurements. So far, we have not been able to link methane emission directly to the cyanobacteria because isolation of *Nostoc* sp. cyanobacteria was not successful from the studied species. However, on the contrary to the general textbook view, we found that symbiotic *Nostoc* sp. cyanobacteria have loose CO_2 concentrating mechanism that explained their poor vitality in environments where CO_2 concentration may become scarce, such as laboratory conditions or large terrestrial colonies. Thus, we conclude that proper functioning of the nitrogen fixing cyanobacteria in the moss communities is strongly dependent on the microclimate build by multilevel heterotrophic bacterial community. We are currently testing the targeted sequencing approach in order to figure out the role of microbes in methane and nitrogen cycles of the feathermoss communities. This approach may help us to overall better understand the nitrogen and carbon turnovers in multilevel boreal forest ecosystems.

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IV-P22

BIODIVERSITY AND ECOSYSTEM SERVICES IN THE RAMPILLON ARTIFICIAL WETLAND BUFFER ZONES – SEINE ET MARNE (FRANCE)

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The artificialization of land and the intensification of agricultural practices have led to the homogenization of landscapes and the decline of biodiversity. Indeed, the loss of habitat diversity leads to a decrease in species richness in many regions. Among various actions to respond to these challenges, ecological engineering is developing to restore ecosystem functions and services based on nature-based solutions. This is the case of the Artificial Wetland Buffer Zone (ZTHA) whose primary function is to intercept non point source pollution (nitrate and pesticide) and improve water quality in the context of agricultural drainage. However, it turns out that this tool also promotes habitat diversity in the context of large-scale farming.
The experimental site is located in Rampillon (France) in an intensive farming area of Paris area. The main crop production gathers winter wheat, corn, barley and sugar beet. After land reclamation and subsurface drainage operation from 1950 to 1990, almost all natural components disappeared and the landscape became uniform and homogeny. In 2010, a network of four artificial wetlands were rebuilt in 400ha experimental catchment to mitigate non point source pollution, and nowadays contribute also to landscape diversity.
In order to know the biodiversity of the ZTHA, inventories on 7 taxa (Amphibians, Chiroptera, Lepidoptera, Mammals, Odonata, Birds and Reptiles) were carried out in 2017. The result is that on an area of about 1 hectare it is possible to find more than 40% of the species among the taxa of Amphibians, Odonata and Birds known in Île-de-France.
The ZTHA also promotes green and blue corridors on a homogeneous territory, which diversifies the landscape and promotes connectivity. In addition, educational and recreational issues add to the overall benefit with the installation of an educational trail on the study site. The above issues stimulate ecosystem services and are shared on a single land site: the ZTHA. In fine, their deployment on a larger scale is proposed, which will participate in the ecological development of the territories and will allow the agroecosystems to have a reduced environmental footprint.

IV-P23

LONG-TERM STUDY OF CARBON DYNAMICS IN A GREY ALDER PLANTATION GROWING ON ABANDONED AGRICULTURAL LAND

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A long-term growth, development and biomass production study was conducted in a grey alder plantation, growing on former agricultural land for clarifying its C sequestration capacity, and the dynamics of net primary production (NPP) as well as net ecosystem production (NEP). Moreover, the dynamics of soil carbon and nitrogen stock was estimated annually during the 28-year study period.
The total aboveground biomass and mean annual increment (MAI) of the 28-year-old grey alder plantation was almost 200 t DM ha^{-1} and 6.3 t DM ha^{-1} yr^{-1}, respectively. The studied grey alder plantation acted as a strong C sequestrating ecosystem with the NEP over 7 t C ha^{-1} yr^{-1}. Annual woody biomass increment formed the largest share of NPP. Both soil organic carbon and nitrogen content increased significantly in upper soil layers, indicating a positive effect of alder stand to soil carbon and nitrogen status after afforestation of previous agricultural land.
According to the results, grey alder plantations could be considered as a highly prospective resource of renewable bioenergy with a great carbon sequestration capacity.

Poster presentation abstracts

V SESSION

Ecosystem restoration and rehabilitation, peatland processes

V-P1

IMPACT OF THE VOLCANIC ASH DEPOSITION ON THE PEATLAND PLANT COMMUNITIES. EVIDENCES FROM LONG-TERM PALAEOECOLOGICAL STUDIES FROM KAMCHATKA PENINSULA, CHANGBEI MTS. AND PATAGONIA

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Modern observations show that tephra (aerially transported volcanic ejecta) deposition on peatlands can lead to changes in plant communities due to altered nutrient supply and acidification. The main factors in the survival and recovery of vegetation after tephra deposition are the chemical and physical features, as well as the thickness of the tephra layers. In volcanic regions, tephra layers in peat profiles are often visible to the naked eye. The understanding of past impacts of volcanic ash on peatland plant populations in various biogeographical zones can yield important knowledge about the resilience these ecosystems to disturbances and aid in further protection and management. In our studies we hypothesize that the impact of volcanic dust deposition on peatland vegetation depends on the ecological amplitude of plant species. Stenotopic plant species can disappear after tephra deposition, whereas species with broad amplitude occurring in habitats with wide pH variation survive these disturbances. To examine past impact of tephra layers on the plant communities we conducted plant macrofossil analysis (continuously sampled) and geochemical studies (non-destructive X-Ray fluorescence and isotope analysis) supported by radiocarbon dating on peat cores sampled at three peatlands in Kamchatka Peninsula (one peat core, 470 cm long), Changbei Mountain (NE China, two peat cores 200 and 215 cm long) and Patagonia (Chile, two peat cores, 280 and 374 cm long). Based on our results we find that: i) the sources of the tephra (identified by elevated concentrations of sodium, silicon, titanium and aluminium) were local volcanoes; ii) the length of our records span variable time periods, ranging back to ca. 2000 BP (Changbei Mts.) or encompassing the whole Holocene (the last ca. 11,700 years, Patagonia); iii) the impact of tephra on plant populations varies between studies sites; iv) vascular plant populations in which members of the Cyperaceae family were dominant seems to be resistant to and can even benefit from tephra deposition; v) *Sphagnum* species, due to various ecological amplitudes, varied in their tolerance to tephra deposition. For example, in the Kamchatkan peatland, *Sphagnum teres* disappeared after volcanic ash fall and whereas *S. papillosum* survived disturbances and was quite common in plant macrofossil records. In contrast, plant communities dominated by *S. magellanicum* (main peat-forming moss species) were resistant to volcanic ash deposition in Patagonia.

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V-P2

THE HOLOCENE RECORD OF ENVIRONMENTAL CHANGES IN THE MAKOWLANY ALKALINE SPRING-FED FEN SEDIMENT SEQUENCE, NORTH-EASTERN POLAND

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Alkaline fens are valuable ecosystems inhabited by a number of endangered and legally protected species of plants and animals. Their existence depends on the active supply of soligenous waters rich in calcium ions. The time-varying environmental conditions, including changes in temperature and intensity of water outflow onto the surface of the fen, contribute to the formation of peat and calcareous tufa intercalations. These sediments are a valuable source of knowledge about the history of the fen.

The Makowlany alkaline fen is located in north-eastern Poland, about 50 km south from the Last Glacial Maximum. The top of this highest cupola-type alkaline fen in Poland is located 8 meters above the bottom of the Makowlanka River Valley. The aim of the research is to reconstruct the environmental conditions during the deposition of peat-carbonate sediments and to determine the time frame for the deposition of calcium carbonate. In order to recognize the internal structure of the cupola, 20 probings were made along two perpendicular cross-section lines. The 567 cm thick sediment core collected for further analysis, i.e., malacological, plant macrofossils, LOI - loss on ignition analyses, and $\delta^{13}C$ and $\delta^{18}O$ composition in carbonates, was divided into 1 cm-thick samples. The chronology of the sediments is based on 8 radiocarbon dates from plant macrofossils. The age of the oldest sediments was estimated at 11200 cal. yr. BP. The numerous charcoal pieces present in the sediments accumulated in the early Holocene testify to dry conditions. Calcium carbonate deposition, which began around 10730 cal. yr. BP, associated with the activation of groundwater circulation was a result of the permafrost thawing and the rapidly increasing temperatures. Once tufa started to precipitate brown mosses typical of alkaline fens, such as *Campylium stellatum, Drepanocladus intermedius, Cratoneuron commutatum* or *Calliergon giganteum*, occurred. The period of the most intense and stable carbonate deposition between ca. 8800 and 5800 cal. yr. BP was associated with the Holocene Thermal Maximum. The presence of mollusc assemblages consisting of: aquatic (*Valvata cristata, Bathyomphalus contortus*), hygrophilous (*Carychium minimum*) and terrestrial (*Nesovitrea hammonis, Vallonia pulchella*) species was limited to carbonate sediments, and reflected the mosaic character of the ecosystem. The dominant species *Galba truncatula*, indicate the presence of shallow depressions filled with water. The termination of tufa deposition ca. 5370 cal. yr. BP was concurrent with the analogous change at several other alkaline fens in northern Poland. The primary reason was the major climate deterioration in central Europe.

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V-P3

THE IMPACTS OF DISPROPORTIONATE ADVANCE OF GREENUP AND SNOWMELT ON THE TUNDRA ECOSYSTEM IN ALASKA

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Disproportionate changes in temperature and precipitation at the high latitude regions may alter the latitudinal gradients in the greenup and snowmelt timings, therefore affecting vegetation growth and carbon dynamics of tundra ecosystems. In this study, we analyzed remote-sensing datasets (MODerate resolution Imaging Spectroradiometer phenology data, MCD12Q2.V006, and snow cover data, MOD10A1.V006) and ground measurements (eddy-covariance flux tower data) and implemented a process-based model (the Ecosystem Demography model version 2, ED2) at seven tundra flux tower sites in Alaska for 18 years (2001–2018). The results showed that the rates of advance of greenup timing (8.4 ± 1.5 days per decade, $p < 0.05$ at one site) have been largely driven by the increasing rates of spring temperature (0.5 - 2.2 °C per decade, $p < 0.05$ at five sites), which shows latitudinal gradients over the study sites, while the snowmelt timing did not show such trends ($p > 0.05$ at all sites). We also noticed that that ecosystem response to early greenup or delayed snowmelt is largely varied depending on the local climatic constraints. Specifically, at the higher latitude sites that are strongly colimited by temperature and water, increases in the net ecosystem productivity (NEP) due to warming-driven early greenup were amplified. On the other hand, at the lower latitude site that is only weakly limited by water, we found that the NEP decreases caused by delayed snowmelt were alleviated due to a relief of water stress. Our results highlight the importance of understanding the role of snowmelt timing on the phenology of the Arctic tundra ecosystem, as well as its impact on vegetation growth and carbon dynamics under different climatic limits, under ongoing climate change.

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V-P4

EFFECT OF CRUSTOSE LICHEN (*OCHROLECIA FRIGIDA*) ON SOIL CO_2 EFFLUX IN A SPHAGNUM MOSS COMMUNITY OVER WESTERN ALASKA TUNDRA

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Soil CO_2 efflux-measurements represent an important component for estimating an annual carbon budget in response to changes in increasing air temperature, degradation of permafrost, and snow-covered extents in the Subarctic and Arctic. However, it is not widely known what is the effect of curstose lichen (*Ochrolecia frigida*) infected sphagnum moss on soil CO_2 efflux, despite the significant ecological function of sphagnum, and how lichen gradually causes the withering to death of intact sphagnum moss. Here, continuous soil CO_2 efflux measurements by a forced diffusion (FD) chamber were investigated for intact and crustose lichen sphagnum moss covering over a tundra ecosystem of western Alaska during the growing seasons of 2015 and 2017. We found that CO_2 efflux in crustose lichen during the growing season of 2016 was 14 % higher than in healthy sphagnum moss community, suggesting that temperature and soil moisture are invaluable drivers for stimulating soil CO_2 efflux, regardless of the restraining functions of soil moisture over emitting soil carbon. Soil moisture does not influence soil CO_2 efflux in crustose lichen, reflecting a limit of ecological and thermal functions relative to intact sphagnum moss. During the growing seasons, there is no significant difference between soil CO_2 effluxes in intact and crustose lichen sphagnum moss patches, based on a one-way ANOVA at the 95 % confidence level ($p < 0.05$). Considering annual soil CO_2 effluxes simulated by temperature, as well as monitoring of snow depth by time-lapsed camera, average snow-covered and snow-free CO_2 contributions to annual carbon budgets correspond to 28.4 % and 71.6 % in intact sphagnum moss cover, and 25.0 % and 75.0 % in a crustose lichen sphagnum moss colony, respectively. Therefore our findings demonstrate that soil carbon emissions in the crustose lichen-infected sphagnum moss community would be steadily stimulated by a widespread outbreak of airborne plants over intact sphagnum moss, and by a rapid degradation of permafrost in response to drastic changes in climate and environment in the Subarctic and Arctic.

V-P5

GREENHOUSE GAS EXCHANGE OF DIFFERENT FEN PALUDICULTURES DURING ESTABLISHMENT

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Drainage is necessary for conventional agriculture on peatlands, but this practice causes high emissions of the greenhouse gases (GHG) carbon dioxide (CO_2) and nitrous oxide. Paludiculture is an option to mitigate these adverse environmental effects while maintaining productive land use. Whereas the GHG exchange of paludiculture on rewetted bog peat, i.e. *Sphagnum* farming, is relatively well examined, data on GHG emissions from fen paludicultures is still very scarce. Typical fen paludiculture species are aerenchymous plants. Thus, the release of methane (CH_4) is of particular interest when optimising the GHG balance of such systems. An option to reduce the methane emissions upon rewetting is the removal of topsoil but retaining a nutrient rich topsoil might foster the biomass growth.
In this project, *Typha angustifolia*, *Typha latifolia*, and *Phragmites australis* are grown at a fen peatland formerly used as grassland. In parts of the newly created polder surrounded by a peat dam, the topsoil is removed. In order to be able to separate the effects of topsoil removal and water level, four smaller sub-polders are installed. Here, the water levels can theoretically be adjusted independently from the main polder. Water levels were intended to be kept at the surface or slightly above it, but technical problems caused water levels to be variable during the first year after establishment. Greenhouse gas exchange is measured for all three species with and without topsoil removal. Additionally, a reference grassland site close by and a site on the dam are included in the measurements. Using manual chambers and a portable analyser for both CH_4 and CO_2, campaign-wise GHG measurements take place every two to four weeks. Emissions of nitrous oxide were measured using vials and gas chromatographic analysis. Here we present the measurement results regarding the GHG exchange in the first year after planting the paludicultures.

V-P6

ENVIRONMENTAL FACTORS AND MANAGEMENT AFFECTING VARIATION IN MERCURY CONCENTRATIONS AND GREENHOUSE GAS EMISSIONS IN HEMIBOREAL PEATLANDS

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Peatlands regulate water supply and mitigate flood risks, preserve biodiversity, mitigate climate change, provide materials for energy production and other purposes and serve as recreational areas. Their importance in environmental regulation is widely acknowledged, but at the same time the complex processes of, for example, mercury (Hg) accumulation, transformation and biomagnification through food chains and greenhouse gas (GHG) emissions require further study. Water monitoring results in Latvia reveal elevated Hg concentrations in freshwater biota, and previous research results suggest that, for instance, CH_4 emissions from naturally wet and drained organic soils are highly variable.

This study assessed variation in total mercury (THg) concentrations and GHG emissions in 22 pristine and managed hemiboreal peatlands in Latvia and aimed to identify environmental factors potentially affecting this variation. Previous management activities included drainage and peat extraction, with or without subsequent afforestation and grassland, bilberry and cranberry plantation establishment.

The spatial variation of THg concentrations in soil ranged up to 194.4 µg kg^{-1}. Neither at 0-10 cm depth nor at 50 cm depth statistically significant differences in mean THg concentrations between disturbed and undisturbed research sites were found. During the warm season mean CO_2 emissions (sum of autotrophic and heterotrophic respiration) from soil ranged up to 104.6 ± 22.7 mg CO_2-C m^{-2} h^{-1}, N_2O emissions - up to 13.4 ± 11.6 µg N_2O-N m^{-2} h^{-1}, but the highest spatial variation was found for mean CH_4 emissions – they ranged up to 3448.9 ± 1087.8 µg CH_4-C m^{-2} h^{-1}. If mean GHG emissions from soil between undisturbed and disturbed research sites were compared, statistically significant difference was found only for CH_4 emissions. Higher CH_4 emissions in undisturbed research sites were generally related to soil moisture conditions. We identified a complex impact of management and environmental factors on the variation of THg concentrations and GHG emissions that should be taken into consideration in peatland management, to minimize adverse environmental effects caused by changes in the biogeochemical cycle of biophilic elements of soil organic matter and contaminants, such as Hg.

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V-P7

A *SPHAGNUM* INCUBATION STUDY USING ^{15}N-LABELLED ATMOSPHERIC N_2 REVEALS CONTRASTING POTENTIAL FOR BIOLOGICAL N_2 FIXATION AT THREE MEDIUM-POLLUTED CENTRAL EUROPEAN PEAT BOGS

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Microbial N_2-fixation helps to sustain carbon accumulation in pristine peatlands and to remove CO_2 from the atmosphere. Recent work has provided evidence that this energetically costly process is not completely downregulated at sites with higher availability of reactive nitrogen (N_r). We studied nitrogen (N) cycling at three high-elevation, mainly rain-fed, *Sphagnum*-dominated peat bogs in the northern Czech Republic receiving medium to high amounts of reactive nitrogen (N_r) *via* atmospheric deposition. $^{15}N/^{14}N$ isotope ratios were determined in N_r deposition, along vertical peat profiles, and in a laboratory incubation study using fresh *Sphagnum* and ^{15}N-enriched atmospheric N_2. Our objective was to assess the potential for biological N_2-fixation at the selected study sites in light of various biogeochemical parameters. Historically, all the peat bogs experienced similar changes in atmospheric N_r (mainly NO_3^--N and NH_4-N) inputs. N_r depositions at all three sites peaked between 1980 and 1990. During that time period, the highest annual depositions were close to 10 kg ha^{-1} yr^{-1} at the slightly more polluted site Uhlirska (UHL) than at Male mechove jezirko (MMJ) and Brumiste (BRU). Since *ca.* 1990, atmospheric deposition of N_r has been steadily decreasing. Living *Sphagnum* had variable N concentrations with similar means for all three sites (1.1, 1.0 and 0.9 wt. % at MMJ, BRU and UHL, respectively). Downcore, peat density remained nearly constant at MMJ but increased at BRU and UHL. Ash contents were below 10 wt. % at least to the depth of 20 cm. With an increasing peat depth, both N concentration and $\delta^{15}N$ values generally increased, while C/N ratios tended to decrease. At depths > 10 cm, N/P ratio was lower at UHL than at the other two sites and remained nearly constant downcore. N/P ratio at MMJ increased from ~10 to ~20 with an increasing depth, whereas the N/P ratio exhibited a zigzag vertical pattern at BRU, reaching a value of 40 in deeper segments. The potential for biological N_2-fixation was investigated using a replicated laboratory incubation of fresh *Sphagnum* in a closed system following an application of 98 % enriched atmospheric N_2. The experiment lasted for 7 days. The control *Sphagnum* samples had $\delta^{15}N$ values of -4.0 ‰ (BRU and UHL) and -3.7 ‰ (MMJ). At the end of the incubation, the $\delta^{15}N$ significantly increased only in MMJ moss reaching + 70 ‰, while it remained unchanged in BRU and UHL moss. Biological N_2 fixation was thus recorded at only at MMJ, a site with the lowest N/P ratio in the topmost 2-cm thick sections. Potential N_2 fixation rates at MMJ were similar to values previously reported for Finland (Leppänen et al. 2015) but ~7 times lower than at sites located in Patagonia, Chile (Knorr et al. 2016).

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V-P8

INFLUENCE OF SUBSURFACE IRRIGATION AND GRASSLAND RENEWAL ON THE WATER QUALITY AT A GRASSLAND ON BOG PEAT

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Drained agriculturally used peatlands are hotspots for greenhouse gas (GHG) emissions and nutrient losses from peatlands. To reduce GHG emissions, raising water levels by subsurface irrigation is broadly discussed. Using this technique, the management can usually be kept at the intensity required for dairy farming. While there are first results on GHG emissions, the effect on nutrient losses is largely unknown although raising water levels will strongly affect redox conditions and thus nitrogen (N) and phosphorus (P) cycling. In our project, we are evaluating the effects of subsurface irrigation on GHG emissions and solute losses from bog peat under intensive grassland use in Northwest Germany. Here, we report on three years of water quality data.

We investigated a reference (REF) site with intensively used, deeply drained grassland typical for the region and a site with subsurface irrigation (SI). Here, groundwater from a deeper aquifer is used in summer to achieve constant water levels of around 30 to 40 cm below surface. After a mechanical grassland renewal, the installation of the SI system took place in 2019. At both sites, water samples for the analysis of pH, electric conductivity (EC), dissolved organic carbon (DOC), P and N species were collected from ditches, drainage pipes and suction plates at 15, 30 and 60 cm depth.

Within the period of investigation, water chemistry at the SI site was strongly influenced by both the grassland renewal and the use of groundwater for irrigation, while concentrations were less dynamic at the REF site. Initially, N, and P concentrations were extremely high at the SI site (median in 15 cm depths during the first summer: nitrate > 200 mg NO_3-N L^{-1}, phosphate > 15 mg PO_4-P L^{-1}). These high nutrient concentrations may be a result of several interacting factors: After the destruction of the old grass sward for grassland renewal, drought inhibited the growth of the newly seeded grass despite fertilizer application. Further, raising water levels may have created optimal conditions for mineralization. When the new grass sward was finally established in early 2020, nutrient concentrations decreased and were similar to those of the REF site.

At the SI site, the use of groundwater resulted in distinct differences between summer and winter periods regarding pH values as well as concentrations of DOC, dissolved organic nitrogen (DON), and phosphate. Over the course of the study, pH values increased and DOC concentrations decreased in the drainage pipes and ditches of both sites, especially in winter. This might be explained by a transition from extremely dry (drought year 2018) to moister conditions with shorter residence times in the peat body. The change in pH and DOC at the SI site is thus not (only) caused by irrigation with groundwater.

Overall, the study highlights the risk for increased nutrient losses after grassland renewal and stresses the relevance of drained bog peatlands for P losses. The effects of increased water levels are so far largely hidden due to a simultaneous recovery from a drought and the grassland renewal.

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V-P9

PEATLAND PRODUCTIVITY AND ITS VARIABILITY DURING 8-YEARS EDDY COVARIANCE MEASUREMENTS

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Peatlands are a type of ecosystem with relatively low net productivity but a very long-term storage period (thousands of years). They play a very important role in the global carbon cycle since store one-third of global soil carbon while they cover only 3% of the land area. The hydrogenic origin of these ecosystems results in their high sensitivity to climate parameters e.g. temperature and precipitation. The shift in thermal and hydrologic conditions can change the peatland from net absorbers to emitters of CO_2 to the atmosphere. Thus, the peatland-climate interaction study is crucial for their understanding and prediction of their faith in the future (Harenda et al. 2018).
Since 2004, the eddy covariance (EC) technique has been used for the monitoring of CO_2/H_2O net fluxes by the open-path infrared gas analyzer (IRGA, model LI-7500, LI-COR Inc., Nebraska, USA) at Rzecin peatland site, Poland (52°45'N, 16°18'E, 54 m a.s.l.). The eddy covariance tower works in collocation with the meteorological station, thus the standard meteorological parameters e.g. air temperature, precipitation, humidity, irradiance are measured along with flux observations. These common measurements and satellite-derived normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI) were the basis for the estimation of the impact of biophysical factors on peatland carbon balance.
The results of the 8-years EC data analysis show that Rzecin peatland is usually a CO_2 sink with mean net ecosystem production (NEP) of 110 $gCO_2\text{-}C \cdot m^{-2} \cdot yr^{-1}$ during study years. The high inter-annual variability of NEP exceeds 150 $gCO_2\text{-}C \cdot m^{-2}$ which underlines high ecosystem sensitivity to the meteorological conditions (usually heat and drought stress). On the other hand, annual NEP exceeding 160 $gCO_2\text{-}C \cdot m^{-2}$ during 4 out of 8 years, suggests a high photosynthetic capacity of the ecosystem under optimal conditions. Higher spring air temperatures were followed by higher NEP in this period (r^2=0.65), while higher summer ambient temperature, as well as vapour pressure deficit, affect the ecosystem to be less net productive (r^2=0.63). Values of the NDVI representing the plant phenology stage explained near 84 and 92% of the gross ecosystem production variance during the spring and summer periods, respectively. The peatland response depends on many factors that interact, but in some cases, the extreme value of a given variable out
weighs other factors (e.g. drought, reduced radiation).

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V-P10

PROFILE DEVELOPMENT AND SOIL PROPERTIES OF 3 LIGNITE FOREST RECLAMATION CHRONOSEQUENCES

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After a Mining Act was imposed in 1957 in the Czech Republic, carrying out of restoration and rehabilitation practices after the excavation has finished has become a compulsory practice (Chuman, 2015). Sokolov mining basin was, and still is, one of the biggest lignite mining areas in the Czech Republic. Forestry reclamation practices have been very popular in the second half of the last century, and many spoil heaps have been converted to forests since. In our experiment, three forest chronosequences of different age (~ 100,~ 50 and~ 30 years) and vegetation covers (maple and cherry, maple and alder) have been investigated. In each of the three stands, two soil profiles have been dug, and soil samples have been taken from all horizons. All samples have been tested for pH (H_2O, KCl), cation exchange capacity (CEC), oxidizable carbon content (Cox), organic matter quality (Q4/Q6) and plant available nutrients following the standards from Valla et al. (2008). Comparison of these properties throughout the profile, as well as between the stands is presented. A significant role of stand age in soil profile development was observed.

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RELIABILITY OF DINSAR SURFACE DEFORMATION ESTIMATES IN THE NATURAL BOG

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Northern peatlands are significant pools of stored carbon. Peatlands can change from being a net sequester of greenhouse gases into an emitter, depending delicately on water regime. A proxy for peat wetness is the phenomenon called bog breathing – short term intra-seasonal vertical peatland surface displacements initiated by changes in the water table. Synthetic Aperture Radar Interferometry (InSAR) could be a promising tool for direct monitoring of bog breathing. However, accounting for relatively large peat surface displacements may cause propagation of ambiguity errors and thus unreliability (Heuff & Hanssen 2021, Marshall et al. 2022). This concern is often overlooked while the absence of ground levelling data for validation has been characteristic to InSAR research in peatlands.

We applied the advanced differential InSAR (DInSAR) technique and calculated distributed scatterer (DS) time series over 2014–2020 for the C-band radar satellite Sentinel-1 relative orbits number (RON) 80 (descending) and 160 (ascending). For comparison we have the high frequency continuous in situ ground levelling measurements covering the snow and ice-free period of 2016 (April–October) from Umbusi raised bog from a levelling plot at the hummock nanotope. Hummocks are the least dynamic microforms in the natural bog. The DS point locations around the plot stay at the distance of 125–315 m.

Concerning only the dates when we had SAR acquisitions, the vertical surface change ranged to 6.6 cm for RON 80 and 7.5 cm for RON 160. The comparison with the levelling data showed severe underestimation by InSAR. Despite, the DS time series contained useful signal as the Spearman correlation coefficient (r_s) between the SAR and the levelling data was 0.84 for RON 80 and 0.81 for RON 160 (both cases, $p < 0.001$). Conventional DInSAR technique using exclusively consecutive acquisitions (temporal baseline of 12 or 6 days) yielded $r_s = 0.93$ ($p < 0.001$) at the radar pixel location corresponding to the levelling plot because 6- or 12-day surface changes are relatively small and usually do not need ambiguity resolution. However, DInSAR was unable to correctly resolve the ambiguity when the changes were larger than the sensor's unambiguous deformation range of ~2.8 cm.

Our findings indicate C-band DInSAR deformation estimates are prone to unwrapping errors in natural hemiboreal bogs and we insist there not trusting the DInSAR results not validated in situ.

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V-P12

GROUND VEGETATION AND GROUNDWATER LEVEL DYNAMICS FOUR YEARS AFTER HABITAT RESTORATION IN A CAPERCAILLIE (*TETRAO UROGALLUS*) LEK SITE

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Drainage of wetland forests has altered their natural condition, structure and species composition characteristic to wetlands, thus putting several rare and protected species at risk. To restore the habitat quality and ecological function in these forests, controlled restoration of natural groundwater regime is necessary. Rapid, prolonged raising of groundwater level may destroy both the tree stand and ground vegetation.

The aim of our study is to evaluate the impact of hydrological regime restoration on the structure of forest habitats in capercaille lek sites after complete ditch filling.

The study is based on BACI experimental design (*Before-After-Control-Impact*). The evaluation of the impact of hydrological regime change pertains to tree stand structure, vegetation structure and hydrology. Before filling of ditches, in six forest stands on drained peat soils permanent sample plots for the evaluation of the environmental aspects were established. In the impacted area (ditches filled) five of the sampled stands were located, but in the control area (ditches retained) – one stand.

Five years long monitoring of groundwater level, condition of tree stand and ground vegetation after the filling of ditches was carried out, to evaluate the changes and the length of time period necessary for forest tree species to colonise the filled ditches.

Results of dispersion analysis revealed year as a significant factor because mean annual grounwater level differed significantly. In 2017, the groundwater level between control site and impacted sites did not differ significantly, but in all other years of the study (2018, 2019, 2020) the groundwater level in the control site was significantly lower than in the impacted sites.

In the impacted sites four years after the filling of ditches no significant changes in the tree stand structure were detected, and only a few trees had died (2,7% of the total number of trees).

Results of *adonis* analysis (analysis of variance using distance matrices) revealed no significant differences of ground vegetation in the impacted objects between years (p=0,84). Similarly, in the control object no significant differences between 2017 and 2021 were detected (p=0,63). After the ditch filling, significant species composition differences in plots located on the filled ditches were found between 2017 and 2021 (p=0,004), while no change was detected in the control object. Detrended correspondence analysis displayed a different grouping of the ditch plots in 2017 than in 2021 in the impacted object, while no changes in the forest stand and in the control object as a whole were not detected.

V-P13

DRAINAGE IMPACT ON GREENHOUSE GAS FLUXES FROM DRAINED NUTRIENT-RICH ORGANIC SOILS UNDER GRASSLANDS IN THE HEMIBOREAL ZONE

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Organic soils are one of the largest natural terrestrial carbon stores, mainly in boreal, temperate and tropical wet climate zones. These environments are deficient in oxygen; therefore, organic matter decomposes slowly and accumulates. In Europe, organic soils account for a very small proportion of the total utilized agricultural area. However, as a common management practice, drainage turns those carbon-rich soils into a significant greenhouse gas (GHG) source. Drainage causes increased carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions due to increased soil mineralization. Methane (CH_4) emissions, on the other hand, are reduced compared to natural wetlands where no soil drainage and tillage are done. Land use, climate zone, soil nutrient status, and drainage status are closely linked to estimating GHG budgets from managed sites on organic soils.

The main objective of our study is to calculate a carbon and nitrogen budget and adjust GHG emission factors for GHG from drained peatland grasslands in the Baltic States. Drainage impact on GHG fluxes throughout two full-year is studied in hemiboreal Estonia, Latvia, and Lithuania from 2021. Results of the first full-year period from Estonia and Latvia will be presented. Fluxes in nutrient-rich perennial peatland grasslands with different drainage statuses were determined on seven sites: (I) two on excessively drained fens soils, (II) two on moderately drained fens soil, (III) one on drained fens soil with increased groundwater levels, and for comparison (IV) two non-managed fens as reference sites. Measurements were made biweekly in Estonia and once a month in Latvia using the manual dark closed chamber (N_2O, CH_4) and the dynamic chamber methods for heterotrophic respiration (CO_2). In addition, different environmental parameters were measured automatically and manually – air temperature, soil moisture and temperature, water temperature, pH, conductivity, oxygen content, and water level depth.

Our preliminary results show that drained grasslands (I, II) were annual CH_4 sinks (emissions varied from -77.7 to 108.88 µg CH_4 m^{-2} h^{-1}), while fens soils with higher groundwater levels (III, IV) were a source of CH_4. All studied sites were annual emitters of N_2O (emissions varied from -1.73 to 241.38 µg N m^{-2} h^{-1}). At the same time, moderately drained soils (II) were the highest emitter (38.94±7.73 µg N m^{-2} h^{-1}). Higher N_2O emissions and temporal variability were associated with sites where the water level had high seasonal fluctuations. Soil CO_2 fluxes peaked over all the study sites during the vegetation period in summer.

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V-P14

METHANE EMISSIONS FROM A REWETTED BOG – ANNUAL BALANCES, IMPACT OF VASCULAR PLANTS AND ROLE OF PLANT FUNCTIONAL GROUPS

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Natural raised temperate bogs are characterized by *Sphagnum*-dominated vegetation, facing increasing threats by vascular plant encroachment in the recent past. The VESBO-project is investigating the influence of this shift in vegetation composition on the water and carbon cycle in a rewetted bog in north-west Germany. Two study sites were established in close proximity on the same former peat extraction area, one showing near-natural *Sphagnum*-dominated vegetation and one exhibiting an increasingly dense birch stand and *Eriophorum vaginatum* cover, low in *Sphagnum* density.

As methane (CH_4) emissions from rewetted bogs are of strong interest regarding the greenhouse gas balance, one focus of our project is to disentangle how vascular plant encroachment is influencing total ecosystem CH_4 emissions and to quantify the contribution of different plant functional types, especially in relation to the different peat water levels on both sites. Besides this, little is known about the diurnal cycle in CH_4 emissions and which bio-meteorological parameters are its drivers.

We used closed chambers in combination with the Picarro GasScouter G4301 to measure methane fluxes on-site. The measurements were performed every 3-4 weeks over one year and on multiple variants equipped with different chamber designs: soil chambers which were located either on hummocks (*Eriophorum*-dominated) or hollows (*Sphagnum*-dominated) and branch/leaf chambers for *Betula*-branches and *Eriophorum*-leaves. In order to more precisely quantify the influence of birch roots on the gas exchange, the soil plots were further divided into plots located in close proximity and separated from birch trees.

The campaigns included transparent and opaque measurements over the course of the day to cover both the diurnal and annual ranges of soil temperature and photosynthetic active radiation, as well as to capture net ecosystem exchange and respiration.

We will show the preliminary results of the methane fluxes from September 2020 to October 2021. The data will provide the first part of the carbon balance of both study areas, which will clarify the contribution of methane regarding the greenhouse gas emissions. It indicates that the methane fluxes increased strongly with a combination of increasing soil temperature and increasing water level. Further analysis will relate the CH_4 emissions to plant functional groups and flux-driving parameters.

In conclusion, the available data will provide valuable information on the contribution and the drivers of methane emissions to the greenhouse gas emissions in bogs, which is particularly important for planning and reporting of rewetting and restoration activities in peatlands.

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