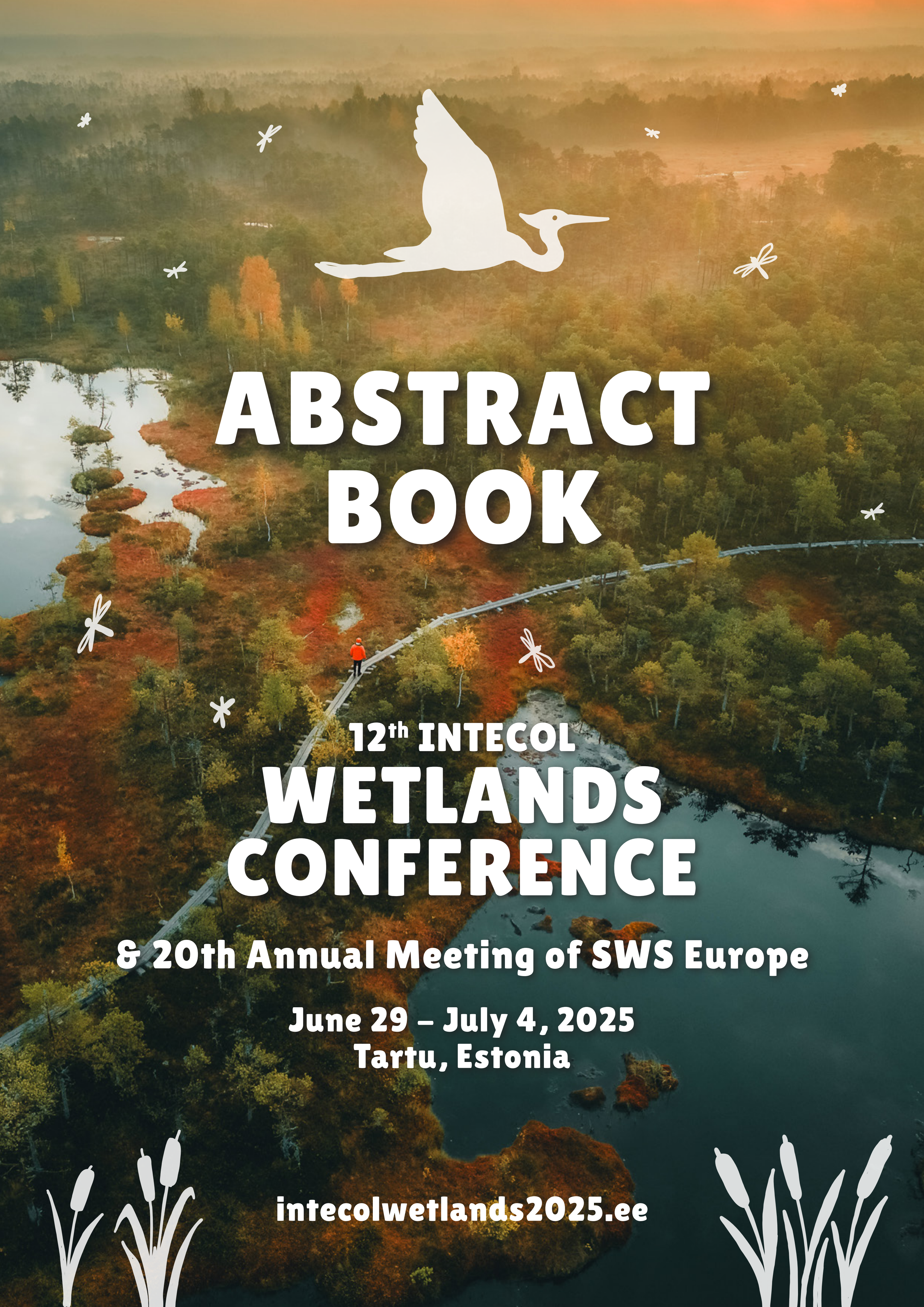

ABSTRACT BOOK

12th INTECOL WETLANDS CONFERENCE

& 20th Annual Meeting of SWS Europe

June 29 – July 4, 2025
Tartu, Estonia

intecolwetlands2025.ee

Local Scientific Committee

International Scientific Committee

ISBN 978-9908-9702-0-2

Acknowledgements

Conference Organisers

International Association for Ecology
University of Tartu
Society of Wetland Scientists Europe Chapter

The organisation of the conference is led by the Department of Geography

Conference Secretariat

PCO Publicon
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T: +372 5919 2019
www.publicon.ee

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PLENARY PRESENTATIONS

Interactions Between Human Well-Being and Wetlands Health in the Anthropocene

Prof. Max Finlayson

Charles Sturt University, Australia

The continued loss and degradation of wetlands indicates a failure by wetland managers and policymakers to come to grips with the increasing human impact on wetland biodiversity and ecosystem services. As humans face the ecological consequences of the Anthropocene epoch past ways of considering wetlands and responding to the drivers of adverse change may be even less successful than in the recent past.

Solutions for addressing wetlands loss and sustaining healthy wetlands can be built on more nuanced understanding of the relationships between humans and wetlands. This raises questions around the foundational concepts and approaches for wetland management that were largely developed from an 'ecological worldview'. There is a strong case for bridging social and ecological divides and providing a safe operating space for healthy wetlands, especially considering the impacts of climate change which requires society to embrace uncertainty and to find systemic solutions. The case for a transdisciplinary approach to wetland management is explored by considering: wetlands as coupled social–ecological systems; understanding the role of values and worldviews in managing wetland systems; developing a social–ecological systems interpretation of wetland wise; and applying a social–ecological systems approach with wetlands as settings for human health and well-being, livelihoods, lifestyles, and culture.

It would be parsimonious to claim that human dimensions of wetlands conservation have not received any attention. On the contrary, local communities have long been associated with successful wetland management. However, the engagement of social sciences has largely been instrumental, mostly focused on justifying conservation action, without challenging or questioning the underlying conservation philosophy. Unless insights from social sciences further permeate the core concepts of wetland policy and management it is hard to see great headway in halting and reversing wetland degradation and loss.

Rights of Wetlands – Transformative Change to Mend the Broken Human-Wetlands Relationship

Dr. Matthew Simpson

35percent
Cobra Collective
Society of Wetland Scientists Europe

The human-wetlands relationship is broken. Despite over 50 years of the Convention on Wetlands, with 172 countries committed to conservation and restoration, wetlands continue to be lost and degraded. The accelerating global biodiversity and climate crises are further impacting wetlands and threatening all life on earth. Wetlands are a key ecosystem for our survival but provide a depressing example of how things have gone so wrong for our planet and how existing strategies have failed. There are calls for transformative change but what does transformative change look like? How do we fix the human-wetlands relationship?

Many national governments and communities are demonstrating how we can transform our relationship with nature by recognizing the intrinsic value and therefore rights of all nature. A Rights of Nature approach requires a behavioural shift from a human centric view of the world, that places people outside of and above nature, to an ecological centered one that ensures the welfare and rights of all nature including humans.

This paper will dispel some of the myths about Rights of Nature and demonstrate how wetland science, practice and policy can inform, and be informed by, a Rights of Wetlands mindset, culture, and policy/legal framework. It will use examples from governments and communities from around the world to illustrate how a paradigm shift for how we humans understand, relate to, and manage wetlands, can deliver a more effective human-wetland relationship and result in the conservation of wetlands.

Permafrost Thaw and Global Warming: Perspectives for Arctic Wetlands?

Dr. Jennifer D. Watts

Arctic Program Director in Woodwell Climate Research Center, USA

The arctic-boreal region represents approximately 20% of Earth's land surface, encompassing large expanses of taiga forest and treeless tundra. Much of this landscape is underlain by permafrost — ground remaining frozen for two or more years — and overlaying active layer soils that experience strong seasonal freeze/thaw cycles. This region is extremely important as it holds over 50% of the global soil organic carbon pool (> one trillion tonnes of carbon) and 20 to >35% of global wetlands. The wetlands here are diverse, spanning ancient and emerging bogs, fens, marshes, and wet tundra, often having connectivity with areas of seasonally dynamic open water, and further characterized by spatial heterogeneity in permafrost thaw. The arctic-boreal region is currently under threat, with air temperatures rising two to four times faster than elsewhere on the planet. Consequences of this warming are widespread, especially apparent in rapidly thawing and collapsing soils, the increasing occurrence and severity of ecosystem disturbances (including changing hydrology and fire), and increasing emissions of carbon dioxide ($CO2$) and methane ($CH4$) from wetlands into the atmosphere. This presentation overviews the importance of wetlands within the permafrost-affected arctic-boreal region from an ecological and climate perspective, highlighting progress in the mapping of these (historically under documented) ecosystems, in understanding of the vulnerability and response of permafrost-impacted wetlands to warming, changes in wetness, and fire disturbance, and how these changes ultimately might impact the crucial ecosystem services (including climate mitigation) provided by these systems. Lastly, this talk offers suggestions for urgent actions that should be taken by the global science and policy communities to protect these vulnerable environments.

Global Lakes in Warming World

Prof. Erik Jeppesen

Aarhus University, Denmark

The world faces substantial challenges to freshwater, land and biodiversity resources and environmental sustainability. Steadily increasing global populations along with increases in agricultural production are leading to increased risks of loss of ecosystems and biodiversity, pollution of surface and groundwater and enhanced pressure on ecosystem services. Many lakes across the world have become highly eutrophic, causing algae blooms and turbid water. With global warming, lakes show enhanced symptoms of eutrophication. Changes in precipitation affect nutrient loading to lakes. Nitrogen (N) and phosphorus (P) loading is expected to increase in the north temperate zone, not least during winter, and decrease in the warm temperate zone and arid streams. Higher temperatures enhance P release from the sediment. Despite reduced loading in arid systems, N and P concentrations may increase here also due to a lower water table in both lakes and streams and a lower oxygen pool in the water, resulting in higher internal nutrient loading. In addition, the lakes in these areas may become more saline. Fish will become more numerous (higher biomass and production per unit of P) and smaller, and the predation pressure from fish on large-bodied zooplankton will increase, reducing grazing on nuisance algae. Moreover, the positive feedback effects of submerged macrophytes on water clarity will become weaker. This, in turn, will reinforce the risk of algae blooms and dominance of potential toxic cyanobacteria, the latter being further reinforced by the higher temperatures. Therefore, the critical nutrient threshold for good ecological status will be lower in a warmer world, and managers must make more effort to reduce external nutrient loading to shift turbid lakes to a clearwater state. It is important that scientists communicate this message to politicians and lake managers. In this talk, I will show results from latitude gradient studies from the Arctic to the tropics, time-series analyses, large- and small-scale experiments and from modelling.

Reviving Peatland Ecosystems with Moss Magic: Harnessing Sphagnum and Brown Mosses for Ecological Restoration

Prof. Line Rochefort

Groupe de recherche en écologie des tourbières, Université Laval, Canada

Peatlands, critical wetland ecosystems known for their role in carbon storage, water regulation, and biodiversity support, are under increasing threat from human activities such drainage for agriculture, overgrazing, mining industry, urban development and peat extraction. Restoring these ecosystems is essential for mitigating climate. One promising approach to peatland restoration involves reintroducing Sphagnum mosses for cutover bogs. These mosses play a pivotal role in peatland ecology due to their remarkable ability to retain water and create acidic, nutrient-poor conditions conducive to peat formation.

Sphagnum mosses, often referred to as "ecosystem engineers," are particularly effective at capturing and storing carbon. Their unique cellular structure allows them to retain large amounts of water, creating saturated conditions that slow down decomposition processes and promote peat accumulation making them invaluable for climate change mitigation efforts. Despite the self-amplifying feedback of *Sphagnum* mosses, peatland restoration worldwide still relies primarily on rewetting actions. Recent studies, including meta-analyses (2024), models (2021), and review syntheses (in press), partly based on monitoring 177 degraded peatlands in Canada, highlight the potential of emergent trait-driven feedbacks for successful restoration.

Fen brown mosses, while less widely recognized, also play a crucial role in peatland carbon sequestration. They thrive in slightly different conditions compared to Sphagnum mosses, often inhabiting minerotrophic (nutrient-rich) peatlands. To improve rich-fen restoration, the water table crux for peatland recovery will be discussed based on more than 200 peatland studies across temperate and northern regions.

Integrating Sphagnum and brown mosses into restoration projects involves careful site assessment, selection of appropriate species, and management of hydrological conditions. Successful restoration efforts not only revive peatland ecosystems but also enhance their capacity to act as carbon sinks, water regulators, and biodiversity hotspots. Harnessing the "moss magic" of Sphagnum and brown mosses thus represents a vital strategy in the global effort to restore peatland ecosystems and mitigate climate change.

Knowing Living Ground Water

Prof. Anne Poelina

University of Notre Dame, Broome, Australia

First Australians, Indigenous peoples of Australia have managed the living water systems of Australia from the beginning of time. This knowledge and lived experience showcase relationships and connectivity of our people, to land and water as being alive and in communication with human and non-human kin. This presentation is a provocation for an alternative conception to the scientific hydrogeological knowledge and approach that informs extractive and exploitative interests in the Martuwarra Fitzroy River, see: www.livingwaterheritage.org. In this alternative view, developed on a foundation of ancestral personhood, we tease out the entangled skeins of Martuwarra knowledges, languages, deep histories, and stories, to propose a just and equitable approach to ground water extraction and the importance of co-governance in water planning, extraction and management for the region. In developing this alternative vision for River governance, we highlight the critical role that Martuwarra Indigenous worldviews and ancient knowledges and practices have in shaping understandings of the River ecosystem. Importantly, why this intergenerational knowledge is important to protect and care for these living water systems and their connectivity to the wellbeing of Country (land), people, biodiversity and our non-human kin, see www.annepoelina.com.

Keywords: indigenous science, groundwater, Martuwarra Fitzroy River, water capitalism, intergenerational knowledge transfer, governance

Breathing with the Peatlands: Greenhouse Gas Fluxes and Climate Resilience in a Changing World

Prof. Annalea Lohila

Finnish Meteorological Institute
Univ. of Helsinki, Institute for Atmospheric and Earth System Research

Since the last deglaciation, peatlands have gradually locked away immense amounts of carbon, quietly influencing the global climate system. But how stable are boreal peatlands as carbon stores in a warming climate? This question is becoming increasingly urgent as these ecosystems face rising pressures from both climate change and human activity. These pressures not only alter their natural functioning but also threaten both their biodiversity and long-term carbon storage capacity. In particular, drainage for agriculture, forestry, energy peat extraction, and horticulture has led to extensive degradation, biodiversity loss, and a reversal of the peatland carbon sink function.

In this presentation, I will focus on insights gained from several case studies conducted in boreal peatlands, where atmosphere-ecosystem interactions have been investigated using long-term flux measurements, short-term campaigns, and process-based modeling. These complementary approaches allow us to explore how climate change and land use affect the carbon and nitrogen cycles of peatlands across different timescales and management regimes.

Key questions I will address include: What can we reliably conclude from greenhouse gas flux measurements, and where do the key uncertainties lie? What have we learned about ecosystem-scale methane emissions in pristine peatlands, and how do these emissions respond to climate variability? What are the controls for the year-to-year variability in CO2 exchange between different peatland ecosystems? In addition, I will discuss the climate impacts of various after-use options for cutover peatlands, comparing the greenhouse gas balances of restoration, afforestation, and other management strategies. By synthesizing results across multiple sites and approaches, I aim to highlight the importance of moving beyond single flux studies toward a broader understanding of peatland-climate feedbacks in a rapidly changing world.

Trajectories of Change: from Expanding Arctic Mires to Threatened Temperate and Tropical Peatlands

Angela Gallego-Sala[1]
Co-authors: Katherine Crichton, Karen Anderson, Josie Handley, Richard Fewster, Dan Charman, Yuwan Wang

[1]University of Exeter, UK

Interest in peatland science has intensified in recent years because: a) the peatland carbon store, previously considered to be mostly inert, has been found to be vulnerable (e.g. peatland fires in SE Asia or Russia); b) peatlands have experienced increases in human land-use that entail drainage and loss of stored carbon, and this have put them in the spotlight in terms of nature climate solutions; and c) new areas of the world, especially in the tropics, have been revealed as peatland-rich in recent years (Amazon, Congo Basin, etc.). Indeed, peatlands store large amounts of carbon, with relatively recent estimates (Nicholls and Peteet, 2019) doubling previous older estimates (Yu et al., 2011). This discrepancy reflects a knowledge gap in the distribution of peatlands worldwide. Not only there is uncertainty on the extent of peatlands, and carbon inventories, but also in how carbon exchange between peatlands and the atmosphere will change in the future. We will present an overview of some of the expected and/or observed changes to peatlands from the poles to the tropics, including the results of a project (ICAAP: Increased Carbon Accumulation in Arctic Peatlands) testing the hypothesis that peatlands will expand into the Arctic and therefore help mitigate some of the carbon releases expected at high latitudes. In the tropics, carbon accumulation rates may decrease in the future (Gallego-Sala et al., 2018), and experts suggest that carbon losses are already underway and are likely to increase as a result of warmer temperatures, drought, land-use and fire (Loisel, Gallego-Sala et al, 2021). If we want to use peatlands as a possible nature based climate solution, we need to improve our understanding of global peatland functioning and changes to peatland extent at high and low latitudes to better safeguard these important ecosystems and use their full potential to store carbon in the future (Alexandrov et al., 2019).

Alexandrov G.A. et al. 2019. The limits to northern peatland carbon stocks. Biogeosciences Discuss., https://doi.org/10.5194/bg-2019-76

Gallego-Sala, A. V., Charman, D.J., et al. 2018. Latitudinal limits to the predicted increase of the peatland carbon sink with warming. Nature Climate Change 8, 907–913.

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Yu, Z. C. 2011. Holocene carbon flux histories of the world's peatlands: Global carbon-cycle implications. The Holocene 21, 761-774.

Ocean Negative Carbon Emissions (ONCE): A Newly Launched UN Decade Program

Dr. Nianzhi Jiao

Xiamen University, China
Chinese Academy of Sciences (CAS)
The World Academy of Sciences (TWAS)
American Academy of Microbiology (AAM)

Current international pledges for emission reductions are very likely insufficient to limit temperature increase less than 2.0°C by the end of the century. To keep this goal alive, an enhanced action plan is needed to take up more atmospheric CO_2. The ocean is the largest active carbon reservoir on the Earth, storing an amount of carbon about 20 times that of the land and 50 times that of the atmosphere, and thus possesses huge potential for CO_2 negative emissions. All the mechanisms for carbon sequestration in the ocean [Biological Carbon Pump (BCP), Carbonate Counter Pump (CCP), Microbial Carbon Pump (MCP), Solubility Carbon Pump (SCP)] are considered to be integrated as BCP-CCP-MCP-SCP (BCMS) for maximum potential of carbon sink and sustainable development.

Global Ocean Negative Carbon Emissions (Global-ONCE) is a 15-year research program endorsed in June 2022 under the UN Decade for Ocean Science for Sustainable Development The objective of Global ONCE is to provide data, knowledge and best practices in the application of ONCE approaches towards achieving the global strategy of carbon neutrality by mid-century. The priority areas for collaborative research of ONCE includes: 1) biological, chemical and physical processes which enable the ocean to take up and store CO_2; 2) methods and models to monitor and evaluate the efficiency of ONCE approaches; 3) ecological and technical engineering solutions to scale up ONCE approaches; 4) social science and governance/legal frameworks needed to put ONCE approaches into practice; and 5) model-data integration, data sharing, interoperability standards, and key ocean variables. The ONCE approaches include not only the well-known individual techniques but also comprehensive ecoengineering practices such as wetland restoration practice, mariculture manipulation technologies, enhancement of alkalinity in waste water treatment effluents, microalgal biomass production and CO_2 sequestration using ocean-based floating photobioreactors, sensor development, numerical modelling, observation and simulation experimental facilities, and expert exchange programs.

Keywords: microbial carbon pump, ocean negative carbon emissions, carbon, wetland restorations, carbon neutrality

Constructed Wetlands for Removal of Nitrogen from Agricultural Drainage Waters

Prof. Jan Vymazal

Czech University of Life Sciences, Prague, Czechia

Diffuse pollution from agricultural drainage is a severe problem for water quality and it is one of the major reasons for the eutrophication of both freshwaters and coastal waters. The ability of natural wetlands to retain nitrogen from freshwater was recognized and has been reported since the 1970s. Constructed wetlands (CWs) for treatment of agricultural drainage waters were proposed as potential treatment systems in the early 1990s. Since then, numerous CWs have been used to treat such waters around the world with the majority of systems being CWs with free water surface. However, in drainage waters, most of the nitrogen occurs in the form of nitrate so subsurface horizontal flow CWs may have greater potential. The objective of this paper is to summarize the results from both surface and subsurface flow CWs treating agricultural drainage around the world. The results from more than 50 free water surface CWs reveal that the removal of nitrogen usually amounts to about 1000 kg N/ha year. The removal of nitrogen in subsurface flow CWs is usually higher, amounting up to 9000 kg N/ha year. This can be explained by the fact that most of nitrogen in tile drainage is in the form of nitrate and anoxic/anaerobic subsurface flow CWs provide better conditions for denitrification. However, it has also been shown that other parameters, such as flow rate, have an effect on nitrogen removal. For subsurface flow CWs, the results clearly revealed that the higher the flow, the lower percentual efficiency and higher removal of nitrogen load. In free water surface CWs, the wetland to watershed area ratio and hydraulic retention time can have a great impact on percentual removal of nitrogen. The results of available data clearly indicate that CWs are a suitable tool for nitrogen removal from agricultural drainage waters.

Tropical Peatlands in South-East Asia – Challenges for Conservation, Management and Restoration

Prof. Lulie Melling

Sarawak Tropical Peat Research Institute, Kota Samarahan, Malaysia

Tropical peatlands in Southeast Asia are vital ecosystems that serve as planetary reservoirs for biodiversity conservation, carbon storage and maintaining hydrological stability. Covering an area of approximately 24 million hectares in Indonesia and 1.54 million hectares in Malaysia, these peatlands sequester around 68.5 billion tonnes of carbon and thus play an important role in global climate regulation. Despite their importance, they are severely threatened by the expansion of agriculture, particularly for oil palm and pulpwood production, as well as by illegal logging, infrastructure development and habitat fragmentation. These activities compromise both the ecological integrity and the socio-economic stability of the regions.

The expansion of oil palm plantations has been a major economic driver but also presents significant sustainability challenges on peatlands. Targeted research is needed to develop and implement sustainable methods for managing oil palm cultivation on peatlands. This research must also extend to increase land productivity and exploring alternative crops that could provide economic benefits without the environmental costs of current agricultural practices.

Significant data gaps on the distribution, condition and ecological functions of peatlands hinder effective conservation strategies. Advances in remote sensing and comprehensive soil surveys are crucial to bridging these knowledge gaps and enable the formulation of precise conservation strategies and effective climate change mitigation efforts.

Challenges in governance further complicate peatland management. Fragmented responsibilities and inconsistent policies combined with insufficient funding for peatland research lead to mismanagement of resources. Inadequate integration of environmental, social and governance (ESG) principles exacerbates socio-economic vulnerability, leading to lower agricultural productivity, loss of traditional livelihoods and community instability. Restoration efforts must integrate environmental and socio-economic needs, including rehabilitation of degraded peatlands, reforestation with sago palm and promotion of sustainable economic activities that improve community well-being.

Emerging global trends in carbon trading offer promising opportunities for the conservation of peatlands through the monetisation of carbon sequestration. This economic incentive can promote conservation efforts and transform ecological restoration into a viable economic endeavour that supports ecological conservation and improves the economic resilience of local communities by providing sustainable sources of income without displacing traditional livelihoods.

An interdisciplinary approach is needed to address the multi-faceted challenges of peatland restoration and management. This strategy should integrate environmental, economic and social dimensions and be supported by improved legal frameworks and comprehensive policy measures. Recognising the socio-economic contribution of oil palm and exploring new potential crops are crucial for balanced development and sustainable land use. The governance framework must also uphold the rights of local communities and ensure equitable participation and profit-sharing in initiatives such as carbon trading.

The future of tropical peatlands in Southeast Asia depends on recognising their dual ecological and socio-economic importance. Strengthening scientific research, improving governance, integrating sustainable development principles and promoting international collaborations are essential to realise their full potential. By prioritising ecological restoration, sustainable livelihoods and community resilience, we can ensure the conservation and sustainable management of tropical peatlands for generations to come.

From loss to recovery – Scaling effective wetland restoration

Dr Filip Aggestam

International Union for Conservation of Nature

In response to Resolution XIV.6, the Convention on Wetlands recently assessed the progress of wetland restoration initiatives worldwide. This study critically evaluates the current state, effectiveness and challenges of these initiatives by synthesising peer-reviewed scientific literature, global datasets, and diverse case studies. Developed under the guidance of an advisory group comprising representatives from leading international organisations, including the UNCCD, the FAO, and the CBD, the assessment emphasises the important role of wetlands in supporting biodiversity, regulating the climate, and underpinning the SDGs. Despite an increasing international consensus on the ecological and socio-economic importance of wetlands, the report reveals that wetland loss and degradation are still occurring at an alarming rate. Restoration efforts are often hindered by insufficient financial resources, limited technical expertise, and fragmented or inconsistent policy frameworks. The assessment therefore advocates the adoption of integrated, evidence-based restoration strategies, calling for enhanced multi-level collaboration between governments, practitioners and local communities to improve restoration outcomes on a larger scale. Key recommendations include harmonising policy and regulatory frameworks at national and international levels, prioritising investment in capacity building and knowledge transfer, and mobilising innovative financing mechanisms. The findings also emphasise the importance of robust monitoring, adaptive management, and inclusive stakeholder engagement to ensure the long-term success and resilience of wetland restoration efforts.

ORAL PRESENTATIONS

Session 1:
Social and economic aspects

30 June
11:15-12:35, Manninen Hall

3 July
14:45-16:00, Manninen Hall

4 July
11:15-12:15, Manninen Hall

Seeing the Bog from the Trees: Social Science Agenda for the Study of Forestry Drained Peatlands

Roosa Rytkönen[1], Kärg Kama[1], Aneurin Merrill-Glover[2], James Palmer[2]

[1]University of Birmingham, Birmingham, United Kingdom
[2]University of Bristol, Bristol, United Kingdom

Scientific and policy interest in peatland restoration as a “natural climate solution” is rapidly growing, spawning diverse projects that aim to improve carbon storage in peat soils. Our ‘Peatscapes’ research project calls for an urgent social science inquiry into the remaking of peatlands for climate mitigation, approaching peatlands as complex ecosystems whose cultural importance, meaning and economic value has long been contested by different groups. Specifically, in this paper, we propose a social science agenda for the study of a ‘peatscape’ characteristic of Northern Europe: forestry drained peatlands. The majority of forestry drainage took place in the post-war decades through state-led efforts to produce raw materials for the forestry industry. In some Northern European countries, restoration of forestry drained peatlands has been practiced for decades, driven by consideration of biodiversity and water conservation. Carbon-based agendas have only recently entered into discussions of the restoration and management of forestry drained peatlands, existing alongside significant resources spent on continued maintenance of the drainage infrastructure. Recent LULUCF inventories have also pointed to the emissions from forest soils, complicating the hegemonic idea of carbon sequestration by trees as the defining climate attribute of forests and drawing instead attention to complex interactions between different forest carbon pools. In practice, the restoration of forestry drained peatlands involves various tradeoffs between carbon, biodiversity and timber production imperatives, and taps into ongoing scientific and public debates about sustainable forest management and nature protection, making it particularly controversial. The paper argues that carbon-based imperatives do not replace, but rather amplify long-standing controversies over different definitions and valuations of ‘nature’ in relation to national socio-economic objectives.

Collateral Damage: Evaluating the Ecological Costs of Aquatic Invasive Species Management

Matthew Marcelino, Brittany Mosher

University of Vermont, Burlington, USA

Aquatic invasive species (AIS) management is essential for preserving ecosystem health and supporting human activities, but it can also have unintended ecological consequences. This systematic review synthesizes existing literature to examine these unintended impacts of AIS management, with a focus on mechanical harvesting. This review identifies critical gaps in understanding the ecological costs of AIS management, particularly regarding less-studied taxa such as reptiles. Mechanical harvesting, while effective for controlling invasive aquatic plants, has limited research assessing its bycatch and effects on long-lived species with slow reproduction rates. Additionally, the literature overemphasizes chemical control methods and studies conducted in North America, neglecting global perspectives and diverse taxa. This study reveals that management strategies often prioritize economic and recreational benefits over ecological integrity. To address these challenges, this review highlights the need for holistic, ecosystem-based approaches that incorporate bycatch monitoring and consider the ecological, economic, and social dimensions of AIS management. By emphasizing the importance of interdisciplinary research and standardized protocols, this work provides a foundation for improving AIS control practices and achieving sustainable ecosystem management.

Scientific Friends of the Court: The Role of Scientists and Scientific Societies in Educating Judges Through Amicus Briefs

Royal Gardner

Stetson University College of Law, Gulfport, FL, USA

In many legal systems, individuals or groups that have a strong interest in a case may file *amicus curiae* briefs or “friend of the court” briefs. The purpose of such legal submissions is to provide judges with information and perspectives that may not be addressed fully by the parties in the lawsuit, including the likely impact of court decisions on the wider public. This presentation will discuss how wetland scientists and scientific societies, including the Society of Wetland Scientists, can effectively collaborate with attorneys as *amici*. The presentation will examine the role of individual scientists and scientific societies—how such briefs are developed, drafted, reviewed, and approved—in Clean Water Act litigation in U.S. courts, including in the U.S. Supreme Court in *County of Maui v. Hawaii Wildlife Fund* and *Sackett v. U.S. Environmental Protection Agency*.

Evaluating the Economic and Environmental Impact of Tourism on Biodiversity and Ecosystem Services in the Lahaul-Pangi Landscape in India

Arghya Chakrabarty[1,2], Ritesh Kumar[1], Krishna Giri[3]

[1]Wetlands International South Asia, New Delhi, India
[2]Rain Forest Research Institute, Jorhat, India
[3]Indian Council of Forestry Research and Education, Dehradun, India

The Lahaul-Pangi landscape in India is home to endemic species that support 171 of India's 573 scheduled tribes and play a vital role in biodiversity and ecosystem services (BDES), with over 80% of the local population engaged in agriculture, livestock rearing, and medicinal plant collection. It provides critical services such as freshwater supply, agricultural productivity, and climate regulation through glaciers. Tourism is a significant economic driver, generating approximately $27 million annually and directly supporting 2,700 jobs. However, over 1.5 million tourists have strained the landscape annually, leading to issues like excessive water abstraction, release of untreated sewage, and habitat degradation. Between 2022 and 2023, the region attracted 400,000 tourists, with a highly educated and affluent demographic. Tourism generated about $26 million during this period. Despite its economic benefits, unsustainable practices threaten the region's ecosystem services, including 324.97 billion cubic meters (BCM) of freshwater and 6,000 hectares of farmland. The study urges the adoption of sustainable tourism strategies, such as water conservation, renewable energy, and waste management, while recommending relocating infrastructure away from sensitive areas and implementing high-value, low-impact nature tourism. Strengthening legal frameworks to regulate tourism based on the landscape's carrying capacity is crucial for ensuring long-term ecological and economic sustainability.

Scale and Directionality of Threats in Coastal Wetlands: A Systematic Review

Juan Silva[1], Reniel Cabral[1], Nathan Waltham[1], Rodrigo Oyanedel[2], Stefan Gelcich[3]

[1]James Cook University, Townsville, Australia
[2]MarFutura, Santiago, Chile
[3]Instituto Milenio en Socio-Ecología Costera (SECOS), Santiago, Chile

Coastal wetlands provide essential ecosystem services but are among the most threatened ecosystems globally. Positioned at the intersection of terrestrial, freshwater, and marine systems, they are highly vulnerable to multi-scale threats originating beyond their boundaries. These threats are exacerbated by overlapping jurisdictions, conflicting water and property regimes, and diverse actors with competing interests. A critical gap in the literature is a systematic understanding of the scale and directionality of these threats.

This study conducts a systematic literature review following the PRISMA framework to examine and classify threats to coastal wetlands based on their scale (local, subnational, regional, global) and directionality (land-to-sea, sea-to-land, internal). The goal is to develop a typology that can inform governance strategies tailored to specific threats and contexts.

Preliminary results indicate that most threats to coastal wetlands are land-to-sea in directionality and occur at the subnational level, highlighting the need for governance at least at the watershed level to mitigate upstream impacts. In contrast, sea-to-land threats are largely global in nature, requiring international collaboration and mitigation-focused strategies. Local, internal threats often necessitate community-based governance approaches to ensure sustainable management by resource users.

Since most wetlands face multiple threats simultaneously, effective governance must be multi-scalar and adaptive, combining strategies such as community-based management for local threats, co-management for subnational issues, and institutional linkages across scales for complex, multi-level governance.

By systematically categorizing threats, this research contributes to a more nuanced understanding of governance mismatches and helps identify effective policy and management interventions for coastal wetland sustainability. Expanding this analysis across diverse wetland types globally will further enhance the applicability of these governance insights.

Effective Intensities of Conservation Management and Ecological Threats in Improving Ecosystem Services Synergies and Mitigating Its Trade-Offs

Weiwei Liu, Lijuan Cui

State Key Laboratory of Wetland Conservation and Restoration, Institute of Ecological Conservation and Restoration, Chinese Academy of Forestry, Beijing, China

Both natural threats and anthropogenic activities pose a substantial menace to wetland ecosystem services (ES), and conservation management may also influence ES in opposing directions. Wetlands provide critical ES to humanity and contribute to United Nations Sustainable Development goals. However, changes in synergy and trade-off relationships of global Ramsar wetlands ES under the dual impact of conservation management and ecological threats have received little attention. Herein, we assessed the ES of Ramsar wetlands, and evaluated how ES varied with conservation management and ecological threats gradients across 1,977 Ramsar wetlands. The results showed that 58.9% of Ramsar wetlands provided ~70% of important ES, and strikingly, more than half of these wetlands face continual and considerable ecological threats. The effects of conservation management on different ES did not coincide, or even conflict, it did not simultaneously improve both biodiversity and other ES—namely provisioning, regulating, supporting and cultural services. The number of important species and other ES showed a maximum trade-off at a conservation management intensity (CMI) of ~0.60 and an ecological threat intensity (ETI) of ~0.65. Enhancing CMI or reducing ETI homogenized the synergies of others ES. The results highlight trade-off and synergy relationships among ES, and the associated changes in correlation strength along CMI and ETI gradients. Our study offers insights of which intensities are most effective in improving ES synergies and mitigating its trade-offs, as well as providing critical action priorities for Ramsar wetlands to achieve sustainable development goals.

Impacts of Reduced Ditch Network Maintenance on Ecosystem Services of Peatland Forests in Finland

Annastina Saari[1], Annamari Laurén[1,2], Marjo Palviainen[1], Mikko T Niemi[1]

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According to National Forest Inventory, approximately 1.1 Mha of drained peatland forests require ditch network maintenance (DNM) in Finland. Ten years ago, the annual area of DNM extended to 70 000 ha but currently, the annual DNM areas cover only 7000 ha. This leads to gradual shallowing of ditches and rise of water table (WT) in peatland forests. While DNM can increase stand growth, it has adverse environmental impacts, such as increased soil carbon (C) emissions.

To study the impacts of ditch shallowing on ecosystem services, we applied Peatland Simulator SUSI and analysed ecosystem C balances of average peatland forests in Finland using ditch depths of 0.3 m, 0.6 m and 0.9 m. Based on empirical studies we assumed that the ditch depths changed from 0.9 m to 0.6 m, from 0.6 m to 0.4 m and from 0.3 m to 0.2 m during the 20-year simulation period. The study sites included drained peatland forest types from nutrient rich to nutrient poor, with main species as Scots pine (*Pinus sylvestris* (L.) *Karst*.) or Norway spruce (*Picea abies* L.). The simulations were conducted for different parts of Finland. The ecosystem C balances were analysed together with soil C balance, stand volume growth, N and P exports to water bodies, and WT.

The results showed that ditch shallowing can lead to multiple benefits for peatland forest ecosystem services. Ecosystem C sinks increased with ditch shallowing in most sites during the 20-year simulation period when the initial ditch depth was 0.6 m or 0.9 m. Additionally, stand volume growth increased in Southern locations when the initial ditch depth was deeper than 0.6 m. Shallowing can be an economically viable option for sustainable peatland forest management in sites where it does not hinder stand growth remarkably, especially when considering the costs of implementing DNM.

From Structure to Ecosystem Services: A Comparative Study Between the Salt Marshes of North Atlantic

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Most studies that value vaste areas of wetlands for their ecosystem services use average ecosystem service estimates from a few wetlands and then extrapolate those two other wetlands using linear scaling methods. While researchers recognize that the error in this method can be great, not much effort has been focused on develop models that predict ecosystem servicing provisioning of a wetland from structural and functional measurements taken from that wetland. In this talk, we attempt to develop such a model using structural, functional, and ecosystem service measurements from 21 North Atlantic salt marshes extracted from 162 published studies. Specifically, we examined how structural parameters—such as vegetation composition, biomass, and plant diversity—affect key ecological functions, including primary production, carbon sequestration, and habitat, which in turn drive the provision of ecosystem services.

Our findings reveal vibration in structural and functional measurements across the 21 marshes, which includes both abiotic and biotic factors. Our model revealed that some structural measurements, besides individual marsh area, are key predictors of spatial variation in the ecosystem service provisioning of individual marshes. We compare our results against our hypotheses that inclusion of more predictive variables into our model, i.e. the extent of low marsh and high marsh, value of real estate bordering the marsh, plant biomass, and peat thickness, will greatly improve its ability to accurately predict ecosystem service provisioning (e.g. carbon sequestration, coastal protection, food provisioning) of individual marshes relative to the commonly simplified model of using marsh area along.

Training in Wetland Restoration – Thirty Years of Experience

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In 1992, the International Waterfowl and Wetlands Research Bureau based in Slimbridge, UK launched an integrated wetland management training programme for Central and Eastern Europe. Short-term wetland training courses have been organised in different countries of the region almost every year since then. In 1996, coordination of the training programme moved to Czechia, from where the training courses have continued to be organised to the present.

From the onset, wetland restoration has been one of the most frequent topics of the training courses. However, as wetlands function in a broader landscape, an holistic approach - emphasising the need for sustainable management of whole catchments - has always been stressed. The courses emphasise that wetlands and natural vegetation play an essential role in water and matter cycling, keeping matter losses low; whereas, the drainage and destruction of natural vegetation cover lead to the opening of these cycles and bring about high irreversible losses of matter. Wetlands and forest also play a very important role in energy dissipation through evapotranspiration, hence their critical importance in climate amelioration. Some key messages from the training courses will be presented.

Wetlands as a Component in Ecological Footprint and Biocapacity

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Wetlands are a critical aid in mitigating the risks caused by the triple planetary crisis of biodiversity loss, climate change and pollution. Therefore, a diverse range of tools must be applied to convey the importance of these ecosystems in global environmental processes, as well as to advocate for their protection and restoration. This study frames the integration of wetlands as a component in the Ecological Footprint and Biocapacity (EFB) environmental accounting framework, which allocates a spatial area to renewable resource consumption (Ecological Footprint) and regeneration (Biocapacity) measured in global hectares. The EFB methodology assumes that only forested land and oceans contribute to carbon sequestration. However, wetlands play a significant role in carbon dynamics and have historically acted as a major carbon sink, presently absorbing an estimated 20-30% of all carbon stored in soils despite covering only about 5-8% of Earth's surface. While wetlands and forests are both historical carbon sinks, carbon uptake can vary significantly, especially under climate change. Therefore, integration of wetland data would make EFB accounts more representative of Earth systems. The study (1) analyses the available data on wetland ecosystems with a focus on spatial coverage and carbon sequestration in order to select appropriate data sources, (2) compares existing geospatially-derived datasets and models to reported values in European Union CRF tables and (3) investigates the productivity-based scaling factor that would be appropriate for converting wetland hectares to the global hectare unit used in the EFB methodology. The scope of the study is the European Economic Area.

Valuing Social and Economic Aspect of Stakeholder Engagement in Planning and Management of Wetland Restoration Projects

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Europe has been driving restoration of wetlands to deliver sustainable ecosystem services since past several decades, however studies reveal that occasionally even the planned Wetland Restoration Projects (WRPs) either fail to occur or achieve the reasonable restoration goal or progress very slow. Those studies indicate that efficiency of engagement of stakeholders can be an important social as well economic aspect that can lead to deceleration of these planned WRPs. It is so because these projects involve variety of stakeholders who bring diverse value orientations along with their knowledge input throughout the project cycle which sometimes lead to disagreements. Meanwhile, their value orientations are influenced by several social and economic factors.

Therefore, to contribute into this field and investigate the significance and impact of Stakeholder Engagement (SE) in planning and management of WRPs, we carried out a Systematic Literature Review based on SPIDER framework. In this review, we explored the efficiency of present SE approach analyzing how stakeholders are being engaged, what factors are affecting their engagement and what kind of impact SE have on WRPs in European Union with special emphasis on Sweden.

Our review revealed that SE plays a central role in implementation of WRPs from addressing value-based differences to building trust in social network. However, several social and economic factors such as uncertainties related to funds, weak communication, lack of knowledge about the complex legal and regulatory frameworks and the project relying on few key individuals, act as a risk for the efficient SE for the implementation of WRPs.

Hence, for sustainable planning and management of WRPs, it is significant to build trust between the stakeholders by ensuring fair compensation, continuous financial support for management and monitoring, better communication of customized benefits and implications of WRPs to concerned stakeholders.

The Future of Water Management in Lowlands of Schleswig-Holstein, Germany

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The state of Schleswig-Holstein in Northwest Germany has developed a strategy for its lowland areas - around a fifth of the state's area - in order to adapt water management and land uses dependent on it to climate change and the goals of climate and biodiversity protection. Important adjustment screws for improving the landscape water balance are the promotion of water retention in the landscape, the introduction of intelligent, forward-looking drainage control systems, and the rewetting of organic soils. With the state's own funding guidelines, the first measures have started in lowlands characterized by marsh soils as well as organic soils. In addition, training in agriculture and networking between water and soil associations will be improved, among other things. The strategy was developed in close cooperation with stakeholders from water boards, agriculture, as well as nature conservation, ensuring that the suggested measures are accepted by society.

Learning From Payments for Ecosystem Services Implementation in China and European Restoration Experience to Improve Freshwater Ecosystem Status

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One of the biggest challenges that China has (and had) is to balance rapid economic growth with alleviating poverty in rural areas while implementing nature conservation measures. To this end, it has adopted and improved political instruments and economic support to local and regional institutions for the implementation of PES schemes.

Ecological compensation was incorporated into regional and local conservation experiences, before the creation of a consolidated environmental policy at national level, together with mechanisms for monitoring and evaluating the consequences of the PES, with indicators subsequently being integrated, putting a sustainable economy into practice and replicating the PES in other regions.

In 2013, China was considered the world leader in watershed investments, both in the number of PES programs and the value of transactions. With a total government expenditure of nearly US$11.5 billion, watershed compensation programs accounted for 94% of all global investments and over 99% of all payments made in Asia for watershed services. China is at the forefront of innovative mechanisms for watershed environmental compensation agreements implementing novel approaches such as “Implementation Plan for the Reform of the Mechanism for Realizing the Value of Water Ecological Products”. Meanwhile, in Europe, there are still significant institutional and legal barriers to overcome PES Implementation, while significant advances in river restoration are in place that drive this, such as the Water Framework Directive and the New Nature Restoration Law. We present a review of PES implementation for freshwater ecosystem in China and discuss the possibilities of adopting Chinese experience in Europe to manage diffuse pollution at watershed scale, while discussing how can China learn from European river restoration experience to accelerate the ecological civilization concept.

The Action of Philantropic Landowners in NBS Implementation: Mapping the Theoretical Background

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In order to address growing climate risks and foster systemic climate resilience in regions, nature-based solutions (NBS), such as wetlands, are viewed as a promising strategy. The key implementation challenge is that NBS require more land compared to traditional structural flood risk mitigation methods, and much of this land is privately owned. Mobilizing such land for NBS implementation is difficult, and as a result, NBS have primarily been carried out on public land. This creates a significant gap in the application of NBS on privately owned land.

Private landowners may be reluctant to engage in NBS implementation for a variety of reasons, including concerns over financial costs, lack of immediate economic returns, and potential disruptions to traditional land use practices. Furthermore, uncertainties regarding the long-term benefits of NBS, coupled with the lack of clear financial incentives or compensation mechanisms, can discourage landowners from granting access to their land for such initiatives.

However, there exists a subset of private landowners who, despite the barriers mentioned, are open to cooperating or independently implementing NBS on their land. These landowners may be motivated by long-term environmental stewardship, a desire to enhance biodiversity, or a commitment to improving the resilience of their land against climate risks. Understanding the factors that drive these landowners to pursue NBS, such as their perceptions of ecological benefits, social or reputational incentives, or access to alternative funding sources, could offer valuable insights into potential pathways for scaling NBS on private land. Using the extended literature review, the contribution maps existing evidence covering land owner motivations and perceptions on theoretical basis. The conceptualization of „philantropic landowner“ draws from various theories and frameworks (such as, e.g. environmental stewardship, intristic vs. extrinsic motivations, collective action etc.) and represents the important step to identify these land owners and the rationale for their actions.

Session 2: Biogeochemistry

30 June
11:15-12:50, Hurt Hall
14:45-16:00, Hurt Hall

1 July
17:00-18:00, Hurt Hall

3 July
11:15-12:30, Hurt Hall
14:45-16:00, Hurt Hall

The Hidden Half of Plant Productivity Controls on Wetland Methane

Avni Malhotra

Pacific Northwest National Laboratory, Richland, USA

Wetlands can store significant amounts of soil organic carbon but also emit greenhouse gases like methane. Plant roots, particularly fine roots, are integral to wetland functions, influencing nutrient uptake, soil carbon inputs, and decomposition processes, including methanogenesis and methanotrophy. However, understanding how roots respond to environmental shifts and influence wetland carbon cycling remains highly uncertain. In this presentation, I will synthesize findings from our recent studies investigating the response of wetland roots to environmental and nutrient changes, and the effect of root-related changes on soil organic carbon and wetland methane fluxes.

Across multiple studies, we find that warming or drying significantly increase fine-root growth across boreal peatlands, with highly variable responses ranging from a 44% to a 900% increase in fine-root growth under warmer or drier conditions. This root growth response, in turn, enhances overall decomposition rates despite increased root carbon inputs to soil. The influence of root growth changes on wetland methane involves a range of complex interactions among gas transport and carbon provision processes. Nevertheless, our experimental work suggests that high root biomass and belowground plant allocation are associated with increased methane emissions, particularly under low water table conditions. Understanding root dynamics is vital for forecasting the carbon cycle and methane implications of wetlands.

A Six-Year Comparison of CO_2 and CH_4 Fluxes and Environmental Drivers in Adjacent Boreal Bog and Fen

Eyrún Gyða Gunnlaugsdóttir[1], Angelika Kübert[1], Xuefei Li[1], Timo Vesala[1], Aino Korrensalo[2,3], Elisa Männistö[3], Pavel Alekseychik[4], Eeva-Stiina Tuittila[3], Ivan Mammarella[1]

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Peatlands are broadly classified into bogs and fens based on water supply. Bogs rely solely on precipitation while fens also receive mineral-rich groundwater. Therefore, fens become more nutrient-rich and less acidic than bogs. These differences shape the vegetation composition, Sphagnum mosses and shrubs dominating bogs but aerenchymatous vascular more abundant in fens.

This study examines CO_2 and CH_4 fluxes of two adjacent bog and fen ecosystems in the Siikaneva peatland complex, southern Finland. We analysed their responses to environmental drivers during the growing season (May-October) using eddy covariance and environmental data from the years 2011 to 2016.

Our results suggest that the bog showed lower temporal variability in CO_2 and CH_4 fluxes, on a seasonal and diurnal scale. The fen was a stronger CO_2 sink (except in 2016) and a greater CH_4 source (except in 2011). Additionally, CH_4 emissions peaked earlier and lasted longer in the fen (DOY 205–225) than in the bog (DOY 210–215), with mean growing season CH_4 emissions of 10.77 g C/m^2 in the fen and 8.53 g C/m^2 in the bog.

At both sites, CH_4 fluxes correlated most with soil temperature at 35 cm depth. After normalizing for temperature, CH_4 emissions showed no clear dependence on watertable depth ($p>0.05$) but increased with gross primary production ($p<0.05$).

The fen was more productive, with a higher net ecosystem exchange (NEE) during growing season (mean -91.60 g C/m^2 vs. -76.86 g C/m^2 in the bog). Its greater productivity and higher abundance of aerenchymatous plants (Aerench. LAI: fen 0.27, bog 0.10 m^2/m^2) likely explained its higher CH_4 emissions, as CH_4 is transported via plant aerenchyma tissue.

Further analysis will focus on the years 2011 and 2016 to identify factors driving lower CH_4 emissions in 2011 and higher CO_2 emissions in 2016 in the fen.

Initial Response of CH_4 Fluxes to Restoration in a Forestry-Drained Peatland and the Effect of the Ditch Blocking Methods

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While peatlands in their natural state act as long-term carbon sinks, drainage can turn them into net carbon sources, enhancing the current climate warming. In addition, drainage threatens peatland biodiversity, water quality and the local hydrology. Restoration of forestry drained peatlands is known to positively impact peatland biodiversity, to efficiently reduce soil carbon dioxide (CO_2) emissions and to increase methane (CH_4) emissions. However, several knowledge gaps related to GHG dynamics following restoration still exist.

In this study we focus on how different ditch blocking methods and environmental variables affect CH_4 emissions following restoration. We conducted gas flux measurements in nutrient-poor peatlands in Ilomantsi, Eastern Finland, one and two years after the restoration. The site was composed of three different ditch-blocking treatments: (a) blocking the ditches with dams (dammed), (b) filling the ditches with peat (filled), and (c) tightly filling the ditches with peat and digging pools in strips between the ditches (blocked). Additionally, we measured undrained and drained control sites.

The restored site had significantly higher CH_4 flux (on average 2.10 mg m^{-2} h^{-1}) compared to the drained site (0.47 mg m^{-2} h^{-1}) but still lower flux than the pristine site (3.50 mg m^{-2} h^{-1}). The ditch blocking methods caused differences in CH_4 flux, with the blocked treatment having lower CH_4 flux (1.03 mg m^{-2} h^{-1}) than the two other treatments (2.47 mg m^{-2} h^{-1}). CH_4 flux was significantly controlled by Leaf Area Index (LAI), temperature and water table depth. At the restored site the fluxes were higher and closer to the undrained site fluxes during the second year, despite a clearly lower water table depth, which highlights the role of developing vascular plant vegetation for controlling CH_4 fluxes.

Seasonal and Diurnal Dynamics of Greenhouse Gas Fluxes in Typha-Dominated Wetland Treating Diffuse Agricultural Pollution

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Treatment wetlands are multifunctional ecosystems that effectively treat agricultural runoff but can also become significant methane (CH_4) emission hotspots due to dense vegetation and nutrient availability. To balance nutrient removal with greenhouse gas (GHG) mitigation, effective wetland management strategies are necessary. Typha-dominated wetlands can modulate microbial processes and plant-mediated fluxes of CO_2, CH_4, and N_2O. Understanding these emission patterns requires capturing seasonal trends and diurnal fluctuations. This study examined seasonal and diurnal GHG flux variations in a Typha-constructed wetland treating agricultural runoff from May to October 2024. Using closed opaque and transparent chambers with a LI-7810 and LI-7820 gas analyzer (LICOR Biosciences), CO_2, CH_4, and N_2O fluxes were measured biweekly at five vegetated and five non-vegetated sampling sites. Additional environmental parameters—including water temperature, pH, dissolved oxygen, oxidation-reduction potential, turbidity, conductivity, leaf area index (LAI), and water depth—were recorded. To assess diurnal variability, three 24-hour measurement campaigns were conducted on June 15, July 22, and August 18, with hourly GHG flux and environmental parameter measurements. Results showed CH_4 fluxes varied across vegetated sites from 1.82 to over 346.36 nmol CH_4 m^{-2} s^{-1}, while non-vegetated sites exceeded 692.71 nmol CH_4 m^{-2} s^{-1}. N_2O fluxes ranged from -0.15 to above 1.89 nmol N_2O-N m^{-2} s^{-1}. A distinct diurnal pattern was observed for CO_2, CH_4, and N_2O. CO_2 uptake peaked mid-day (> -7.57 µmol CO_2 m^{-2} s^{-1}), driven by photosynthetically active radiation (PAR), with net CO_2 release at night. CH_4 and N_2O emissions peaked at 173.18 nmol CH_4 m^{-2} s^{-1} and 2.21 nmol N_2O m^{-2} s^{-1}, respectively, influenced by dissolved oxygen and temperature. Our studies show how plant growth, microbial activity, and environmental factors interact to regulate GHG fluxes in treatment wetlands. Understanding seasonal and daily variations is important for monitoring greenhouse gas fluxes and improving wetland management practices.

Carbon Flux Dynamics in Agricultural Freshwater Marsh Ditches: Linking CO_2 Fluxes to Trophic Structures

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Agricultural freshwater marshes are critical components of wetland ecosystems, playing a key role in carbon cycling and greenhouse gas emissions. However, the specific contributions of their managed ditches remain underexplored. This study presents a comprehensive year-long analysis of a temperate marsh managed ditch (southwest France) where monthly measurements of water-air CO_2 fluxes and planktonic food webs were carried out simultaneously to better understand these relationships and their controls on carbon dynamics in these systems.

Preliminary results show significant seasonal variability in CO_2 fluxes, with the ditch system shifting between net CO_2 source (emission) and sink (uptake) periods during the year. The highest water pCO_2 values were recorded in April (6834 ppmv), while a temporary sink behavior was observed in May (207 ppmv). Environmental parameters, particularly oxygen and pH, showed strong negative correlations with water pCO_2, suggesting a biological control on water carbon dynamics rather than a temperature-driven effect. Monthly water pCO_2 fluctuations seemed to align with shifts in planktonic food web structure and nutrient availability throughout 2024. For instance, in May, water-air CO_2 flux values decreased when omnivorous food webs dominated.

Additionally, hydrological conditions strongly influence seasonal CO_2 flux patterns in these wetlands, as ditches are influenced by both climatic variations and agricultural water management. Spring drainage for grazing aerates soils, potentially enhancing CO_2 degassing, while summer and autumn drying or reduced water levels shift CO_2 exchange from water-air to sediment-air fluxes. These hydrological shifts regulate the balance between biological and physical CO_2 flux drivers, shaping whether the system acts as a carbon sink or source.

This ongoing research enhances the understanding of biotic interactions and biogeochemical processes in managed wetlands, offering insights for optimizing wetland management strategies to enhance carbon storage in agricultural landscapes.

Vapour Pressure Deficit and Soil Moisture Constrain GPP in a Drought Affected Temperate Bog

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Atmospheric droughts have been reported to increase in the northern hemisphere, where most global peatlands are located (3.4–4 million km^2). They are known to cause dire climate-C feedback by triggering C emissions through peat oxidation and elevated vapour pressure deficit (VPD). But, the impacts of higher VPD and soil moisture (indicated by soil water content (SWC)) on gross primary productivity (GPP) are still unequivocal. While it is well-established that rising VPD limits GPP, there is ambiguity around the impact of SWC drawback on GPP. We aim to fill this knowledge gap by studying the role of air temperature (Tair), VPD, shortwave radiation (SWR) and soil moisture on peatland GPP under severe atmospheric droughts. Here, we investigated the temporal variation of energy and water limitation of GPP in a restored, drought-affected bog ecosystem (Burns Bog) in Vancouver, Canada. A causal analysis investigated how environmental factors influenced GPP by leveraging weekly time step eddy covariance data for five years (2016–2020). The results suggest that stomatal regulation in response to increased VPD caused the reduction of GPP in 2016 (~2.5 gC m^{-2} day^{-1} as opposed to ~3 gC m^{-2} day^{-1} in 2018). In contrast, in 2019, water-table drawdown limited GPP through relaxed stomatal regulation to maximise C assimilation after the onset of drought. We found the threshold at which water-level drawdown started to limit GPP at about −8 cm water table depth (82.5% soil moisture).

The Role of Constructed Wetlands in Mitigating Environmental Antimicrobial Resistance Across Different Sectors

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Antimicrobial resistance (AMR) is acknowledged as one of the greatest challenges to human health globally, with estimates that, by 2050, AMR will cause 10 million deaths a year, unless action is taken. Efforts to tackle AMR have commonly focused on clinical and veterinary practice but recently the role of the environment in transmitting antimicrobial resistant organisms (AROs) has gained greater attention. Conventional wastewater treatment is often considered a hotspot for AMR and release of AROs into the natural environment. However, less is known about the role alternative treatment options such as constructed wetlands may play in the dynamics of AROs transmission in the environment. This project specifically focuses on Integrated Constructed Wetlands (ICWs), a concept that integrates water management, landscape fit and biodiversity. ICW systems are shallow, free surface-water wetlands, which are densely vegetated with appropriate plant species to treat through-flowing waters. The objective of this study is to examine various microbial parameters in influents and effluents in ICWs serving different sectors, including agricultural and food processing sectors, on a monthly basis. The parameters being examined include total viable counts, extended-spectrum beta-lactamase producing Enterobacterales, fluoroquinolone resistant Enterobacterales, carbapenemase producing Enterobacterales, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*. Enterococci and *Escherichia coli* in the effluents are being enumerated as indicator of faecal pollution. Culture-based approaches are used to identify the target bacteria which are subsequently screened by MALDI-TOF.

To date, our findings indicate that ICWs have the potential to effectively lower the quantity of AROs present, with *Escherichia coli* being the predominant species isolated.

By generating high-resolution, long-term data on AMR trends within ICWs, this research provides crucial insights into their role as potential mitigation tools for environmental AMR dissemination. The findings contribute to deliver evidence based data on the presence and behavior of AMR in ICWs using a ONE-HEALTH approach.

Understanding Bioaccumulation of Heavy Metals in Australian Pelicans at Gippsland Lakes Ramsar Site

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Gippsland Lakes, a key Ramsar wetland and one of the last two remaining pelican rookery sites in south-east Australia, is critical for biodiversity. The Australian pelican (*Pelecanus conspicillatus*), as a top-order predator, is a valuable bioindicator of wetland health. However, the Gippsland Lakes ecosystem faces increasing threats due to urbanization, agricultural practices, coal mining, commercial fishing, and military activity. Pelicans in the area are exposed to environmental contaminants, waste, which can exacerbate the risks of heavy metal accumulation.

This study investigates the bioaccumulation of heavy metals in Australian pelicans from Gippsland Lakes. Liver, kidney, blood and feather samples were collected from pelicans, and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is being used to analyze heavy metal concentrations. While the study is still in the early stages, initial observations suggest elevated levels of zinc, lead, and copper in the tissues. Previous studies have reported high levels of mercury in mussels and other species such as dolphins in the region, indicating significant environmental contamination.

Although the results of the pelican sample analysis are still pending, early findings raise concerns about the potential impacts of heavy metals on pelican health, including liver and kidney function, neurological effects, and reproductive success. These findings underscore the need for continued monitoring and conservation efforts to protect both pelican populations and the health of the Gippsland Lakes Ramsar site.

Internal Nitrogen Loading from the Water Column Supports Productivity in Two Shallow, Eutrophic Lakes

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Phytoplankton often rely on regeneration of ammonium to produce biomass and, for some cyanobacteria, nitrogen-rich toxins, despite low or unmeasurable ammonium concentrations in water. Thus, measuring ammonium turnover rates (uptake and regeneration) is necessary to determine its actual availability. Here, water column ammonium dynamics, in-lake water quality parameters driving these dynamics, and the importance of internal nitrogen loading in supporting community ammonium demand were explored in two large, shallow, eutrophic lakes (Lakes Võrtsjärv and Peipsi, Estonia). Stable isotope incubations were conducted almost monthly in Võrtsjärv and several times per year in Peipsi (from March 2019 to March 2022). Despite being located at higher latitude, ammonium turnover rates in Võrtsjärv and Peipsi were similar to those reported for other large eutrophic lakes. Ammonium turnover rates were strongly related to seasonally changing water quality variables, such as water temperature, nutrient concentrations, and chlorophyll a concentrations, which, combined, explained 68–71% of variation in measured rates. Water column ammonium regeneration supported, on average, 65% (in Võrtsjärv) and 76% (in Peipsi) of community ammonium uptake during the warm season (May – October). Internal nitrogen loading from ammonium regeneration in the water column vastly exceeded external nitrogen loading into Võrtsjärv. These results emphasize the importance of internal nitrogen loading in driving primary productivity in shallow, eutrophic lakes and the necessity to reduce external nitrogen loading, in addition to phosphorus, into lakes.

Ammonium Dynamics in the Shallow Littoral Zones of Eutrophic, Medium-Sized Lakes in Estonia: Implications for Water Column Primary Productivity

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Synthetic and organic fertilizer use, combined with the effects of climate change, has increased nitrogen (N) levels and drives eutrophication and cyanobacteria blooms in aquatic systems. Internal nutrient loading from microbial activity in sediments and the water column can intensify these blooms, and ammonium (NH4) is a key N form for internal N cycling and algal growth. NH4 regeneration and potential uptake rates were measured in two medium-sized, shallow, eutrophic lakes in Estonia (Kaiavere and Veisjärv). Water samples from two sites in each lake were amended with 15N-labelled NH4 and incubated in light and dark bottles for ~24 hours at near-in situ temperature and light. Isotope dilution models were used to quantify NH4 regeneration and potential uptake rates. NH4 regeneration and rapid uptake represent a 'hidden' component of the N cycle not captured in concentration measurements. Results from autumn 2023 and spring, summer, and autumn 2024 showed that potential NH4 uptake rates exceeded NH4 regeneration rates in both lakes in all seasons. Potential NH4 uptake rates in Kaiavere were highest in autumn of both years, while Veisjärv had the highest potential NH4 uptake rates in summer and autumn in 2024. NH4 regeneration could support ~60% of the potential uptake in Veisjärv in spring and near the nutrient input (River Amme) in Kaiavere in summer. NH4 regeneration could support ~16 – 40% of potential NH4 uptake at all other sampling sites and times. Internal N loading (as NH4 regeneration) from the water column of these eutrophic lakes is ultimately driven by external N loading and could support significant proportions of community NH4 demand (mostly non-N-fixing cyanobacteria), even when ambient NH4 concentrations were low or undetectable. Thus, watershed management and lake restoration efforts focusing solely on reducing external or internal phosphorus loads are insufficient to mitigate eutrophication in these and other lakes.

In Situ Measurements of Nitrous Oxide Emissions in Various European Wetlands: Patterns & Drivers

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Wetlands play a complex role as both sources of greenhouse gases (GHGs) and carbon sinks, making it essential to understand their dynamics and effects on biodiversity. The increasing pressures from climate change and human activities can disrupt the natural balance of these ecosystems, resulting in elevated GHG emissions. Therefore, enhancing our understanding of the factors influencing GHG production in wetlands is urgent for improving large-scale modelling of these processes. This study focused on N_2O, which is primarily produced through the microbial process of denitrification, and for which a satisfactory large-scale model formulation is lacking. Our objective was to quantify and characterize these emissions in situ and to identify unifying abiotic factors (humidity, carbon, temperature, and nitrate). To achieve this, in the framework of the European project Alfawetlands, we selected contrasting study sites that varied by wetland type (floodplains, peatlands, drained forests…) and climate zone, thereby gathering extensive data essential for our modelling efforts.

A total of 21 sites were selected across Belgium, Estonia, Finland, France, and Spain. For each location, three treatments were applied directly in soil: water, water with nitrate, and water with nitrate and acetate. N_2O emissions, soil moisture, and soil temperature were regularly measured during one or two days after treatment.

The results indicated that N_2O emissions varied significantly based on wetland type and latitude. Drained forests located in north-boreal vegetation regions in Finland demonstrated the lowest N_2O fluxes, while floodplains and mountain peatlands respectively in Belgium and Spain showed the highest fluxes. As the lowest fluxes were observed in the highest latitudes, soil temperature could be an important factor to control denitrification and N_2O emissions. Ongoing data analysis and measurements are focused on further elucidating the spatial and temporal heterogeneities of denitrification processes, with the goal of effectively incorporating these factors into our modelling efforts.

Integrative Carbon Budget of a Temperate Salt Marsh Revealed by Exchange Interface Process and Flux Measurements at Various Time Scales

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Despite their small surface area, salt marshes represent a significant part in carbon stored on Earth and air-sea CO_2 exchanges from wetlands and estuaries worldwide (i.e., 17%). However, their exact role in regional/global carbon cycling and flux studies must be still detailed. In the context of rising greenhouse gas emissions, climate change/mitigation and their consequences on human society, it is crucial to increase integrative and multidisciplinary approaches to better understand interlinked processes, flux dynamics and main controlling factors at terrestrial-aquatic-atmospheric exchange interfaces at the concerned spatiotemporal scales. In this objective and the framework of the ANR Pampas (2019-24) and LEFE Dycidemaim (2021-22) projects, integrative carbon process/flux measurements were carried out between 2019 and 2022 over a temperate salt marsh located on the French Atlantic coast. Atmospheric Eddy Covariance CO_2 exchange along with aquatic carbon concentration, planktonic metabolism, horizontal flux and sediment/soil carbon stock and sequestration values were obtained upon the different exchange interfaces (soil/sediment-air and water-air) and time scales (diurnal, tidal, seasonal, interannual to multidecadal) to draw the whole carbon budget of the studied marsh. The cumulated net ecosystem exchange of the studied salt marsh varied from -483 (in 2020) to -551 gC m^{-2} yr^{-1} (in 2021); organic carbon burial rates varied spatially from 75±7 to 104±7 gC m^{-2} yr^{-1} (in 2021), both results endorsing its significant carbon sink behavior. Involved processes and environmental controls reflecting the various fluxes of the budget and obtained from our published studies will be specifically presented and compared to other worldwide and nearby marsh carbon budgets. The existence of competing processes requires specifically understanding each of them to better model carbon behavior and budget of such dynamic systems in the context of global change and associated submersion risk.

ELM-Wet: A New Wet-Landunit Approach for Patch-Level Resolution of Carbon and Methane Fluxes from Wetlands in ELM

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We improved the realism of wetland representation in the U.S. Department of Energy's Exascale Earth System Model (E3SM) Land-surface Model (ELM). We developed an updated version, ELM-Wet, where we activated a separate wet-landunit that handles multiple eco-hydrological functional patch types within the model wetland. We introduced a wetland-specific hydrology through prescribing site-level (whole-wetland) constraints on surface water elevation and including a patch-level characteristic maximal inundation depth that enables resolving different sustained inundation depth for different patches, and if data exists, prescribing inundation depth at the site and patch levels. We modified the calculation of aerenchyma transport diffusivity to allow incorporating observed conductance for different vegetation types. We developed and used a new 'Bayesian Optimization for Anything' (BOA) toolpack, to parameterize CO_2 and CH_4 fluxes in the wet-landunit. Site-level simulations of a coastal freshwater wetland in Louisiana (US-LA2) were performed with the updated model. Eddy covariance observations of CO_2 and CH_4 fluxes from 2012-2013 were used to train the model. Flux data from 2021 were used for validation. Patch-specific chamber flux observations and observations of CH_4 concentration profiles in the soil porewater from 2021 were used for evaluation of the model performance in terms of fluxes and soil concentration profiles at the patch level. Our results show that ELM-Wet with BOA optimization and prescribed inundation reduced the model's predicted CH_4 emission error by up to 33%. The updated model was able to represent inter-daily and seasonal CO_2 and CH_4 flux and concentration dynamics across the wetland's eco-hydrological patches, and correctly predict the effects of extreme events such as drought and hurricane-driven storm surge.

Mauritia Palm Forest on Nutrient-Rich Peat Soil Emits Much Higher Ghg Than Shorea-Albida Forest on Nutrient-Poor Peat Soil

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Ecosystem dynamics and vegetation growth in tropical peat swamp forests (PSF) are dependent on nutrient availability commonly characterized as ombrotrophic and minerotrophic PSF. Differences in nutrient status lead to different dominating vegetation, altering the above and below-ground processes influencing the soil and stem greenhouse gas (GHG) fluxes. This shows the need to characterize the different effects of dominating vegetation on the GHG fluxes from stem and soil to improve the accuracy of the ecosystem carbon budget estimation. Currently, there are limited simultaneous observations of soil and stem carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) fluxes supporting the effects of these dominating species on the ecosystem GHG fluxes for both nutrient-rich and nutrient-poor PSF.

Therefore, this study investigates soil and tree stem CO_2, CH_4, and N_2O fluxes from two study sites: ombrotrophic PSF in Maludam National Park, Malaysia, and minerotrophic PSF in Quistococha, Peru. It aims to understand the physical ecosystem interactions and the role of tree species in influencing these fluxes. Observations were conducted from 2023 to 2024 using static soil and stem chamber systems in Maludam National Park and automated chamber systems in Quistococha.

Results reveal that both ecosystems exhibited similar seasonal trends for soil and stem fluxes: CO_2 fluxes peaked during drier periods, while CH_4 fluxes peaked during wetter periods. N_2O fluxes, however, showed no clear seasonal variation. Notably, the *Mauritia*-dominated forest exhibited higher CO_2, CH_4, and N_2O emissions compared to the *Shorea albida*-dominated forest for both soil and stem sources.

These findings underscore the need to disentangle tree-mediated effects from other environmental regulators of greenhouse gas fluxes in tropical peat swamp forests. Understanding these species-specific contributions is crucial for refining ecosystem carbon budgets in these critical ecosystems.

Anthro-Natural Ecosystems Drive Gobal Warming

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Current greenhouse gas budgets do not account for most of indirect anthropogenic impacts. In this perspective, we call for attention on greenhouse gas fluxes from human-impacted natural ecosystems and their mitigation measures. The article highlights the increasing greenhouse gas (GHG) emissions from natural ecosystems, including CO_2, CH_4, and N_2O. These emissions are becoming significant drivers of global warming, surpassing those from fossil fuel combustion. We introduce the concept of "anthro-natural emissions" here, referring to emissions from natural ecosystems indirectly impacted by human activities. The concept helps bridge the gap between natural and anthropogenic impacts, providing a more comprehensive understanding of GHG emissions. Anthro-natural emissions are expected to rise as climate warming progresses, contributing to the overall GHG balance. Peatlands, which store approximately 30% of the world's soil carbon, are under increasing pressure from climate warming and human activities. The article emphasizes the importance of addressing both natural and human-impacted ecosystems to mitigate climate change effectively. Increasingly frequent droughts are identified as a major threat to global terrestrial ecosystems, particularly wetlands. The drying of wetlands challenges their capacity to act as carbon sinks and alters their roles in climate regulation. The insights provided are essential for developing effective adaptation strategies relying on soil carbon sequestration as a long-term solution against climate warming. According to our study, the proportion of natural, anthro-natural and directly disturbed peatlands is approximately 40 to 20 to 40, and the ratio is increasing towards anthro-natural peatlands. We highlight a change of paradigm for assessing importance of different GHG sources: global warming impacts anthro-natural ecosystems and fuels global warming. Further, it highlights the need for conservation and restoration of peatlands and renaturalization of forest ecosystems.

Optimized Strategies for Effectively Eliminating Organic Micropollutants Using Reactive Materials in Constructed Wetlands

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Organic micropollutants in wastewater pose a significant threat to aquatic ecosystems and drinking water quality. While not primarily designed for this purpose, constructed wetlands can effectively eliminate some micropollutants, particularly when their substrate is enhanced with reactive materials such as iron (hydro)oxides and manganese oxides. These materials are known for their high adsorption capacity and can act as electron acceptors in anoxic environments, facilitating abiotic and biotic degradation processes and promoting environmental sustainability. This research investigated the effects of iron (hydro)oxides and manganese oxides on the removal of organic micropollutants. It examined how the interactions of these reactive materials with water-saturated (anoxic/anaerobic) and unsaturated (aerobic) filtration beds and the presence of plants influence the removal of organic micropollutants. The study tested experimental vertical flow CWs treating artificial domestic wastewater containing 31 organic micropollutants at 10 or 50 µg/L concentrations. Results showed that CWs achieved a removal efficiency of 93% to 95% under unsaturated conditions for organic micropollutants. However, minimal differences were shown in the overall removal effects between amendments. Conversely, the removal rates were lower under saturated conditions, 63%, 61%, and 77% for the constructed wetlands with sand, manganese oxides, and iron hydroxides, respectively. Notably, certain compounds, such as carbamazepine, diclofenac, fipronil, fluconazole, furosemide, hydrochlorothiazide, lamotrigine, and sulfamethoxazole were poorly removed under unsaturated conditions.

Both reactive materials demonstrated enhanced removal capabilities compared to sand alone. Apart from removing organic micropollutants, the constructed wetlands with iron hydroxides and manganese oxides improved the removal of phosphates (91%) compared with sand-filled constructed wetlands (42%). Further studies are planned to explore the underlying mechanisms and potential stimulation techniques, including the use of electron shuttles.

Partially-Saturated Constructed Wetlands: Can They Be Considered Performance All-Rounders?

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Constructed wetlands (CWs) have been commonly used for the treatment of sewage and other types of wastewater like agricultural wastewater. Both fully-saturated, FS-CWs and unsaturated, US-CWs, have been used for the treatment of sewage. In the case of agricultural wastewater usually FS-CWs, sometimes with additional organic carbon (like woodchips, WCs), have been applied. The CWs with partially-saturated beds (PS-CWs) combining both saturations within one bed have been rarely used, despite their potential for improved removal of TOC, TN and organic micropollutants, MPs, (thus considered performance all-rounders in our previous research (Ren, T., et al. (2023). *Chemosphere*, *314*, 137645) including only limited number of MPs). Currently, the treatment performance for 30 organic MPs (including pesticides), TN and TOC was tested in several experiments using small-scale outdoor systems mimicking CWs treating simulated sewage or agricultural wastewater. All the systems were planted with *Iris pseudacorus.* For the sewage: PS-CWs provided 63% overall removal of MPs compared with 65% removal in US-CWs and 37% in FS-CWs. Additionally, the use of WC increased the removal of MPs to 74% in PS-CWs and to 79% in US-CWs. The enhancement was observed mostly in the case of mobile compounds indicating the effect of an extra source of organic carbon rather than adsorption. The PS-CWs with WC achieved the highest TN removal (46%). For agricultural wastewater, the PS-CWs with WC reached the highest MPs removal (72%) together with the US-CWs with WC. The addition of WC improved the removal of MPs by 13-33% in all the tested types of CWs. The PS-CWs with WC also outcompeted other CWs in the removal of TN (72%). In both cases the removal of TOC was comparable in the PS-CWs and US-CWs, but considerably lower in the FS-CWs. PS-CWs can be considered performance all-rounders in terms of MPs, TN and TOC removal.

Eutrophic Lake Sediments as Sources or Sinks of Bioavailable Nitrogen in Shallow, Eutrophic Lakes in Estonia

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Eutrophication, harmful algal blooms, and biodiversity loss are symptoms of anthropogenic nutrient inputs, especially from agriculture. Nutrient legacies (both nitrogen (N) and phosphorus (P)) from these agricultural inputs accumulate in lake systems and can be released later into the water column, potentially delaying water quality improvements after external load reductions. Sediments in eutrophic lakes act as both sources and sinks for nutrients and can release both N and P (internal nutrient loads), which can be assimilated by harmful algae to produce biomass and toxins. In eutrophic lakes Kaiavere and Veisjärv (central Estonia), intact sediment cores were incubated in a continuous-flow system, with and without 15N-ammonium or 15N-nitrate tracers, to measure microbial N transformations, which determine whether lake sediments are a net source or sink for bioavailable N. Denitrification, a N sink, was stimulated by 15N-nitrate addition in both lakes, suggesting additional capacity for N removal. N fixation, a N source, consistently exceeded denitrification in Veisjärv, but Kaiavere sediments varied between net N fixation and denitrification, especially during summer and autumn. Anaerobic ammonium oxidation (anammox, a N sink) and dissimilatory nitrate reduction to ammonium (DNRA, a N recycling mechanism) were not observed consistently in either lake. In addition to microbial transformations, bioreactive N (e.g., ammonium and urea) and, occasionally, phosphate were also released from sediments in both lakes, but molar N:P of these sediment nutrient releases was very high, indicating N excess relative to P. External N loads must also be reduced, in addition to historical focus on P loading reductions, to minimise internal N loading from legacy N accumulations and effectively manage eutrophication and algal blooms in lakes. Failure to manage external N inputs from the watershed may prolong eutrophic conditions and detrimental effects from toxic cyanobacterial blooms and delay system recovery after external nutrient loading reductions.

Calculating Leaching of Dissolved Organic Carbon and Biogenic Elements from Drained Peatlands in Latvia Using Meteorological Data

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This study evaluates the impact of different land-use types on groundwater dissolved organic carbon (DOC) concentrations, annual DOC leaching, and leaching of biogenic elements nitrogen (N), phosphorus (P), and potassium (K) from drained peatlands to catchment runoff, emphasizing the role of evapotranspiration and water balance in controlling carbon and nutrient leaching dynamics. We measured groundwater chemical properties and environmental variables, calculated daily runoff and evapotranspiration, and estimated their influence on monthly and annual DOC and nutrient leaching. The highest DOC concentrations were observed in Scots pine forests (113.7 mg L^{-1}) and active peat extraction sites (109.7 mg L^{-1}), while the lowest concentrations occurred in Silver birch forests (51.9 mg L^{-1}) and croplands (18.6 mg L^{-1}). Significant negative correlations were found between DOC concentrations and groundwater chemical parameters such as pH, electrical conductivity (EC), Ca, Mg, and K concentrations. The highest annual DOC efflux was observed in active peat extraction sites at 513.1 kg ha^{-1} y^{-1}, while the lowest were in grasslands at 61.9 kg ha^{-1} y^{-1}. The highest annual nitrogen leaching was found in peat extraction sites (35.78 ± 2.41 kg ha^{-1} y^{-1}), while the lowest occurred in croplands (6.74 ± 0.64 kg ha^{-1} y^{-1}) and birch forests (7.75 ± 0.60 kg ha^{-1} y^{-1}). The lowest annual phosphorus leaching was in peat extraction sites (0.05 ± 0.007 kg ha^{-1} y^{-1}), whereas grasslands had the highest (0.62 ± 0.07 kg ha^{-1} y^{-1}). The highest annual potassium leaching occurred in peat extraction sites (9.16 ± 2.51 kg ha^{-1} y^{-1}), and the lowest in birch forests (1.06 ± 2.51 kg ha^{-1} y^{-1}). Future studies should include expanded temporal and spatial sampling, direct runoff and evapotranspiration measurements, and microbial assessments to better determine the factors controlling DOC and nutrient leaching.

Regional and Seasonal Dynamics and Trends of N_2O and O_3 in the Lower Stratosphere

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Nitrous oxide (N_2O) is among the most important tropospheric greenhouse gases with a long lifetime and a global warming potential approximately 300 times higher than CO_2. Furthermore, in the stratosphere, it is the primary ozone(O_3)-depleting gas not regulated by the Montréal protocol. Increasing anthropogenic N_2O emissions, cause its impact on the Earth's climate to also increase. This paper examines the dynamics of N_2O and O_3 in the lower stratosphere using data about both gases gathered by the Aura satellite's MLS (Microwave Limb Sounder) instrument between 2005-2021. The study focuses on the lower stratosphere (pressures between 68-22 hPa, corresponding to ~18-26 km at the equator), at more than 30 selected areas located above equatorial and temperate land regions. Both the long-term trends of both gases and correlations between simultaneously measured N_2O and O_3 concentrations were examined. The results showed weak or indistinct trends for O_3 and more noticeable ones for N_2O, with the latter including a number of negative trends, though that is likely related to the MLS instrument's sensor drift. Regarding the relationship between N_2O and O_3, it was observed that the correlation between the gases changes with altitude differently depending on the latitude of the study regions. Near the equator, close to no correlation between the gases at 68 hPa was found but with an increase in altitude, negative correlations that increased up to at least 22 hPa were observed. At higher geographic latitudes of both hemispheres, an inverted version of this phenomenon was observed. Seasonal dynamics of both gases were also investigated, again finding differing patterns depending on altitude and latitude and generally comparatively higher variations in O_3 concentrations, especially at higher latitudes.

Green House Gases Emissions From 15 Years Old Artificial Wetland: 1.5 Years of Field Monitoring

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Artificial wetlands provide several ecological services. In a first step, the artificial wetland of Rampillon was built in 2010, to mitigate non point source pollution from agricultural area. Indeed the artificial wetland intercepts surface flows from subsurface drained area characterized by intensive agriculture in East part of Paris. Several studies focused on nitrogen pesticides mitigation and showed average efficiencies about 15% and 40% nitrate and pesticides removal respectively. This restored area constitutes also a refuge for biodiversity leading this area to be considered as a nature based solution: a net gain of species was highlighted.

A new question raises about green house gases emissions. In order to assess the emissions, we set tup a protocol, in the frame of Alfawetlands Horizon project (www.alfawetlands.eu), to quantify the fluxes of N_2O, CH_4 and CO_2 based on bimonthly monitoring of accumulation chambers. Gas from floating chambers were sampled every 15 min from 0 to 45 min. 8 points distributed on the 0.5ha of artificial wetland were distributed on the surface area. For each point, water level, pH, dissolved oxygen, temperature, electrical conductivity, anions/cations and total organic and inorganic were analysed.

Starting in September 2023 to February 2025, we analysed fluxes for different seasons and hydriperiods. Relationships with parameters are interpreted to propose rules to manage artificial weltand in agricultural area to limit green house gases emissions.

Comparative Analysis of Greenhouse Gas Flux Measurement Techniques in Rice Fields Under Different Water Management Strategies

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Methane (CH_4) is a potent greenhouse gas, with rice paddies contributing ~9% of global anthropogenic CH_4 emissions. Anaerobic conditions in flooded rice fields promote methanogenesis, making irrigation strategies crucial for CH_4 mitigation. Arkansas, the leading U.S. rice producer, predominantly employs continuous flooding (CF) water management. Climate-smart irrigation strategies such as alternate wetting and drying (AWD) can reduce CH_4 emissions by 48–93%. Accurate CH_4 flux quantification is essential for validating emission reductions, yet measurement methods vary in precision and spatio-temporal scalability.

This study compares CH_4 monitoring methods to assess inter-method agreement and improve flux estimation accuracy for climate-smart agriculture. During the 2024 growing season, CH_4 fluxes were measured in two adjacent Arkansas rice fields—one managed under CF, one under AWD—using weekly static chamber measurements with gas chromatography (GC) and the LI-COR LI-7810 Trace Gas Analyzer, along with continuous eddy covariance (EC) monitoring. Statistical analyses assessed inter-method agreement, variability, and biases.

Methane fluxes varied between treatments, with CF exhibiting higher overall emissions and AWD displaying greater temporal variability. Fluxes in the CF field increased steadily after flooding, peaking in the heading stage of rice growth, whereas emissions in AWD exhibited distinct peaks following drying events. Highest cumulative CH_4 emissions were measured with GC in both fields (130.3 and 52.8 kg C ha^{-1} $season^{-1}$ in CF and AWD, respectively). Method agreement was stronger in the CF field, while AWD exhibited greater variability and weaker correlations between EC and chamber methods. However, GC and LI-7810 showed the strongest relationship in AWD (R^2=0.97), suggesting their reliability for flux estimation in this system. Discrepancies between methods increased at higher flux values, highlighting greater methodological differences during peak emissions. Our findings underscore the need for integrating multiple measurement approaches to enhance flux estimation accuracy and reduce uncertainty in achieving climate-smart agriculture goals.

Soil Degradation Proxy Can Help Predict Denitrification Potential in European Wetlands

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The input and output of nitrogen (N) controls primary production in ecosystems, particularly at high latitudes. The primary microbial process for N removal is denitrification, which reduces nitrate into N_2, with large potential for nitrous oxide (N_2O) emissions - a potent greenhouse gas. While it is well known that denitrification activity is favored by anaerobic conditions, nitrate, and organic carbon availability, our ability to predict denitrification and N_2O emissions in ecosystems remains limited.

The NEMIS model, initially developed for agricultural soils, offers a promising approach for large-scale denitrification modeling due to its simple formulation and input variables. The model and its more recent formulation modulate a maximal "potential" denitrification activity (D_p) using parametrization of the effect of temperature, nitrate, and water saturation. The D_p of a given soil is directly related to soil carbon content and organic matter turnover rate, implying that soil carbon supply to denitrification is the rate-limiting process once all other limiting factors are alleviated. Although the model has been applied to large-scale denitrification estimates, its formulation has not yet been validated across all types of wetlands, which serve as key hotspots for denitrification.

In the EU-funded ALFAwetlands project, we tested the formulation of NEMIS' Dp across 20 natural, drained, and restored wetland sites from five countries (Finland, Estonia, Belgium, France, and Spain). We evaluated *in situ* soil capacity for organic matter degradation using the cotton strip methods, which use the loss of tensile strength as a proxy for organic matter degradation, and maximal denitrification rate using the acetylene block assay. We found a log-linear relationship between the two variables (r^2=0.64), indicating the NEMIS models can be used across warm temperate to north boreal wetlands.

This work clarifies our mechanistic understanding of soil microbial interactions and will contribute to improving denitrification models.

Inorganic Carbon Lateral Flux from an Intertidal Salt Marsh in Coastal Louisiana, USA

Songjie He

University of Southern Mississippi, Ocean Springs, USA

Saltmarshes are biogeochemical hotspots storing carbon in sediments and in the ocean following lateral carbon export. This transfer of carbon and alkalinity from the land to the ocean represents an important process in the global carbon cycle. Here, we measure lateral carbon fluxes – import and export of carbon via tidal channels – in a saltmarsh in the Barataria Basin in Louisiana and evaluate the impact factors on lateral carbon fluxes. We hypothesized that porewater carbon export is an important process for blue carbon loss which contributes significantly to lateral carbon flux. To test this hypothesis, environmental parameters such as salinity, temperature, pH, dissolved oxygen, fluorescent dissolved organic matter, as well as carbon concentrations, including dissolved inorganic carbon (DIC), dissolved organic carbon (DOC), and total alkalinity (TA) concentrations were measured since 2021 for lateral carbon flux calculations. Radon concentrations were measured continuously for over 24 hours during five field trips to evaluate porewater carbon export. Our preliminary results showed that porewater carbon exports contributed significantly to lateral carbon fluxes. Lateral carbon fluxes mirrored the water flux pattern and positive (ebb-directed) lateral carbon fluxes were mostly driven by higher carbon concentrations during ebb flow associated with porewater drainage versus flood flow. Lateral flux of DIC was generally higher than TA flux, which has significant implications for coastal acidification and carbon budget. This exported TA represents a long-term carbon sink in the ocean while the ratio of TA/DIC impacts the carbonate chemistry of coastal waters.

Impact of Grazing Exclusion and Climate Variability on Greenhouse Gas Emissions in Pyrenean High-Mountain Peatlands

Sílvia Poblador[1,2], Laura Escarmena[1], Violeta Martinez[1], Isabel Anaya[1], Blanca Bautista[1], Annika Grundeus[1], Carolina Olid[1], Aaron Pérez-Haase[1], Francesc Sabater[1,2]

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Peatlands are globally significant carbon sinks, storing organic carbon due to slow litter decomposition under water-saturated, anoxic conditions. However, these ecosystems are increasingly threatened by climate change and land-use pressures. In the Pyrenees, mountain peatlands are now relict ecosystems, fragmented into small, isolated patches. Rising temperatures, reduced water availability, and intensive livestock activity (e.g., horses and cows) further degrade their hydrology and vegetation. Effective management strategies are urgently needed to prevent large greenhouse gas (GHG) emissions. The ALFAwetlands and Pyrepeat projects assess the impact of grazing exclusion (areas fenced since 2016) and hydrological variation on GHG fluxes in two Pyrenean peatlands, Rubió (pH 5.97) and Estanyeres (pH 7.78). Monthly measurements of CO_2, CH_4, and N_2O fluxes were conducted over two years across three plot types, both inside and outside exclusion zones: (1) low livestock trampling and soil disturbance, with barely vegetation gaps (mosses and sedges species); (2) pugged soils with wide exposed peat areas increasing CO_2 oxidation potential, and large vegetation gaps; (3) peatland margin areas with the driest condition, rarely flooded, and continuous vegetation cover of grass-like plants. Within enclosures, pre-existing plot types have shown partial recovery. Preliminary results highlight peatlands' vulnerability to climate change. CO_2 emissions were highest in drier plots, where reduced moisture accelerated organic carbon oxidation, particularly outside exclusion zones. CH_4 emissions were higher in wetter areas, consistent with methanogenesis under anaerobic conditions, while N_2O emissions remained low due to nitrogen limitation. These findings underscore that climate-driven drying and livestock disturbances significantly threaten peatland carbon storage. Management actions, such as grazing exclusion, are critical to maintaining peatlands' function and mitigating GHG emissions. This research contributes to strategies aligning peatland conservation with climate change adaptation.

Water Table Is a Limited Driver for Methane Emissions in Rewetted Peatlands

Nichlas Hermansen[1], Jesper Riis Christensen[2], Thomas Alexander Davidson[1], Susanna Liebner[3], Joachim Audet[1], Dominik Zak[1]

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Methane (CH_4) emission in peatlands is a critical component in global greenhouse gas (GHG) budgets, with water table depth (WTD) often considered the primary driver of CH_4 emissions in GHG assessments. While a strong correlation between WTD and CH_4 emissions exists, the relationship is evidently weakened when WTD rises above -20 cm below surface, both in rewetted as well as natural peatlands, showing considerable variability. This study re-evaluates the role of WTD in CH_4 emission, focusing on rewetted peatlands with high water table regimes, using 126 annual CH_4 estimates from existing literature. Our findings suggest that water table acts more as a switch that enables CH_4 emissions, rather than a reliable predictor of increasing CH_4 flux under near-surface and inundated conditions. We argue that incorporating drained peatlands into models skews the CH_4 vs WTD relationship observed in rewetted peatlands masking the influence of other environmental factors, such as nutrients and temperature. Given the limitations of WTD-centric models, particularly in rewetted fens in temperate regions with high WT, we highlight the need for a multifactorial approach that considers temperature, vegetation, and nutrient availability to improve prediction of CH_4 emission. This study calls for moving beyond simplistic WTD-driven models to more accurately assess CH_4 fluxes in rewetted peatlands, particularly sites with consistently high water tables, i.e., those higher than -20 cm below surface.

Session 3:
Hydrology

1 July
17:00-18:05, Manninen Hall

3 July
11:15-12:30, Manninen Hall

Performance of ARTIFICIAL WETLAND to Reduce Pesticide Flows: A Review of 10 Years of MONITORING Coupling Mesocoms and Field Results

Julien Tournebize, Cedric Chaumont

INRAE-HYCAR, Antony, France

The use of pesticides in large-scale farming results in the dissemination of residues in all environmental compartments. In the specific case of agricultural drainage, even if the annual pesticides fluxes in drained waters rarely exceed 0.1% of the applied quantity, the concentrations in surface waters can generate an impact for aquatic organisms.

In addition to actions based on the reduction of pesticide use, intercepting drained flows is an option that has been tested for more than 10 years on an experimental watershed in Paris suburb (France). Nature Based Solution implies a role of natural interface between agricultural production areas and aquatic environments. In the case of agricultural drainage, artificial wetland buffer zones (AWBZ) are the most suitable to store drainage water and promote biogeochemical processes of pesticide retention.

We propose to present a multi-year analysis of the retention efficiency of a hundred pesticide molecules applied at the scale of a 355ha watershed. These full-scale experimental results are compared to the results of in situ mesocosm experiments exploring the retention potential by playing on different factors.

The Rampillon experimental ZTHA was constructed in 2010 on a 0.5ha land area. The AWBZ intercepts the drainage water of a 400ha fully drained upstream watershed. The performance monitoring started in 2012. Monitoring of inflow and outflow based on flow-sensitive composite sampling shows variability in retention for all pesticides monitored and an average of 37% removal.

In parallel, fate tests of 11 pesticides applied at environmental doses (between 1 and 10µg/L) were performed on so-called in situ mesocosms (1m²) as they were directly deployed in the center of the AWBZ. The results show that the AWBZ concept has a real retention potential for the 11 molecules tested, since 50% of the quantity initially added is dissipated in 10 days on average.

Regeneration of Riparian Wetland Trees After an Extreme Flood: Integration of Biogeographical Analyses and Hydraulic Modeling

Keonhak Lee[1], Chaebin Kim[2], Jieun Choi[2], Tae Hyo Baek[3], Chang-Lae Jang[3], Daehyun Kim[2]

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An extremely heavy rainfall and the consequent record-breaking flood occurred in southern Korea in the summer of 2020, substantially impacting the Seomjingang River wetlands. The purpose of the present study is to explain the regeneration pathway of disturbed riparian wetland tree communities in the Hahan region (ca. 0.5 ha) of Seomjingang River. We collected precise GPS coordinates of regenerated tree individuals in the disturbed wetland in 2021 and 2023. Furthermore, we numerically modeled the local flood regime during the 2020 extreme flood to reproduce spatially heterogeneous flood impact on the riparian wetland. Spatial point pattern analyses showed that biological interactions among regenerated tree individuals explained the geographical patterns of regeneration. Interspecific facilitation and competition, represented by relative proximities among tree individuals, were detected between newly generated willow and legume species. Furthermore, local variation of disturbance intensity during the flood was correlated with the regeneration speed of wetland trees. The trees, which suffered less shear stress during the peak flood, resprouted faster than those suffered more. Using an integration of biogeographical analyses and hydraulic modeling, we investigated the pattern and speed of tree regeneration in the disturbed riparian wetland. In this era of rapid disturbance regime change, this multifaceted approach to wetland ecology is essential for unraveling the spatially and temporarily complex ecosystem dynamics.

Spatiotemporal Dynamics of Groundwater Levels in a Tropical Peat Dome: Influences, Trends, and Implications

Masjuki Muhaini Fahemah, Wong Guan Xhuan, Ajok Agusten Rabar, Melling Lulie

Sarawak Tropical Peat Research Institute, Sarawak, Malaysia

Tropical peatlands are critical for global climate regulation due to their substantial carbon storage which is highly vulnerable to changes in groundwater levels (GWL). Events like the 2020–2022 triple-dip La Niña can alter rainfall patterns and raise GWL, but long-term GWL data remain scarce, limiting our understanding of peatland hydrology and carbon dynamics. To address this gap, we present a comprehensive 13-year dataset (January 2011 – December 2023) from a tropical peat dome in Sarawak, Malaysia, analysing long-term GWL trends across four vegetation types on the peat dome: Mixed Peat Swamp (MPS), Alan Batu (ABt), Alan Bunga (ABg), and Padang Alan (PA) forests. Our results show that the mean GWL in MPS, ABt, ABg, and PA forests was -10.8 cm, -4.7 cm, -5.1 cm, and 2.4 cm, respectively, with a mean rainfall of 2825 mm. The strong correlation between rainfall and GWL in MPS and ABt forests is influenced by the basin's dome-shaped landscape. The forest's vegetation also plays a role, with tall, dense trees at the edges and shorter, sparser trees in the centre, influencing water flow and retention. This interaction between topography and vegetation regulates groundwater dynamics across the peat dome. In 2019, GWL dropped significantly at all sites, with Site MPS reaching -58.3 cm due to exceptionally low rainfall (29 mm). This highlights the impact of extreme climatic events, such as the positive Indian Ocean Dipole (IOD), which led to prolonged dry conditions. In contrast, during the triple-dip La Niña, increased rainfall during the 2020 dry season led to a 20 cm rise in GWL, highlighting peatland hydrology's sensitivity to precipitation shifts. This long-term dataset is crucial for developing accurate hydrological models to simulate GWL fluctuations and their influence on carbon dynamics. It helps understand peatland responses to climate change, supporting effective management and conservation.

A Hydrological Switch Drives the Transition from Saltmarsh to Reedland Ecosystem

Archontoula Valsamidou[1,2], Malou Bastiaanse[1,3], Daphne van der Wal[1,4], Maarten Kleinhans[2], Gabriele Keller[2], Max Rietkerk[2], Johan van de Koppel[1,5]

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Coastal peatlands are freshwater biogeomorphic landscapes that accumulate organic material and store large carbon quantities over millennia, yet the processes driving their initiation under brackish conditions remain unclear. Geological records highlight transitional reed-marsh phases preceding ombrotrophic peatlands, suggesting shifts in the saltmarsh biogeomorphological feedbacks. This study investigates how *Phragmites australis* (reed), a precursor species for coastal peatlands establishes on saltmarshes causing new interactions at the local scale that generate a hydrological switch that alters the landscape.

Using a saltmarsh development model (SFERE) we simulated the interactions between vegetation, hydrology and sedimentation processes during reed establishment and expansion. Domain-wide hydrological metrics (topographic wetness index, residence time) were used to assess the new system's state hydrological behavior. These results were compared with field observations from reed-established and saltmarsh areas of Saeftinghe. Field data included vegetation and elevation remotely sensed time series to assess the reeds clogging influence on the tidal creek network, and soil salinity samples from reed and no-reed vegetation patches to identify the reduction of the tidal influence within the reed patches.

Our comparative approach demonstrates the hydrological switch driven by *Phragmites australis*, and highlights how this process could be a key factor for historical peatland development as well as for carbon accumulation potential in reed-based peatlands in the future. Model results show that root and organic matter accumulation by the reed reduces the creek network complexity, and leads to a higher, more homogeneous freshwater landscape that further facilitates reed growth. The flattened topography and reduced drainage density of the landscape increase the residence time of flow and the surface wetness potential. These findings align with the empirical observations and measurements in Saeftinghe. Reed expansion is persistent and within the reed patches there is significant creek elevation increase, that leads to altered hydrological conditions and reduced surface soil salt content.

Soil Hydrogeomorphology and Tree Water Use in Hardwood Floodplain Forests of the Lower-Middle Elbe

Lizeth K. Vásconez-Navas[1,2], Joscha N. Becker[1,2], Simon Thomsen[3,2], Alexander Groengroeft[1], Annette Eschenbach[1,2]

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Hardwood floodplain forests are shaped by hydrogeomorphic processes that influence soil formation, nutrient availability, and tree water use. However, increasing drought and declining groundwater levels threaten these ecosystems, requiring a better understanding of soil properties and species-specific physiological responses. This study assessed soil physicochemical variability and sap flow velocity in *Quercus robur* and *Ulmus laevis* across floodplain gradients of the lower-middle Elbe.

We analyzed 135 soil samples and 18 reference pits from 45 hardwood floodplain forest sites, identifying distinct soil types. Sandy soils dominated the active floodplain (Fluvic Arenosols, Cambisols), while areas further from the river (Gleyic Fluvisols, Fluvic Gleysols) had higher clay and silt content. The most Phosphorous-rich soils were found in low-lying areas of the active floodplain influenced by sediment deposition and higher pH values.

Tree water use analysis, performed in the active floodplain under periods of drought, revealed *U. laevis* exhibited higher sap flow velocity than *Q. robur*, particularly in loam dominated soils, but showed greater sensitivity to drought. In contrast, *Q. robur* maintained more stable sap flow velocity but was highly influenced by soil texture, reducing sap velocity significantly in sandy soils. A Jarvis model highlighted the strong role of soil water potential in regulating sap flow, predominantly in sandy soils where it overrode vapor pressure deficit effects.

These findings highlight the interaction between soil properties, hydrology, and species-specific responses to drought, offering valuable insights for floodplain forest conservation and restoration in a changing climate.

Hydrological Impact of Drainage Ditches in Active Peat Extraction: A Case Study from Aizkraukles Mire, Latvia

Jānis Bikše, Inga Retike

University of Latvia, Riga, Latvia

Peat extraction relies on drainage ditches that lower the water table, potentially affecting adjacent natural peatlands. At Aizkraukles Mire, Latvia, a rain-fed bog is hosting both the Natura 2000 site "Aizkraukles Mire and Forests" and an active peat extraction area, that are separated by a 100-meter buffer zone. To assess the hydrological impact of drainage ditches on the natural mire, water levels have been monitored for a decade in 17 wells arranged in two 250 m long transects.

The analysis is complicated by bog breathing, which affects well stability and water level readings. To account for these movements, periodic GPS surveys have been conducted. Extreme precipitation deficits and subsequent droughts in 2018–2019 led to prolonged water table declines, affecting both the impacted and natural areas of the mire.

Results indicate that in one transect with longer record of peat extraction, drainage ditch significantly lowers water levels at distances of 20–25 m from the extraction site, with the impact extending up to 30 m during summer. In the other transect where peat extraction started recently, a clear impact is observed up to 6 m, with minor effects detectable up to ~20 m. These findings highlight the spatial variability of drainage impacts and the importance of buffer zones in mitigating hydrological alterations in peatlands.

The study is supported by a donation from the "SIA Mikrotīkls", which is administered by the University of Latvia Foundation.

Contrasting Nutrient Balances in a Drained Peatland: A View Through a Geological Window

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Temperate peatlands, historically altered for agricultural use, have transformed from carbon sinks to sources, significantly impacting global greenhouse gas emissions and nutrient cycling. This study investigates the nutrient balances of a ditch-drained riparian fen peatland in Central Jutland, Denmark, focusing on nitrogen (N) removal and phosphorus (P) release prior to rewetting.

The Vejrumbro study site, spanning 11.3 hectares, was analyzed for water flow, water quality, and nutrient fluxes over three years. The peatland displayed two distinct hydrological regimes: groundwater inflow from a sand aquifer dominated the western area, while precipitation influenced the eastern area. Nutrient concentrations and fluxes in groundwater and ditch outflows were measured, revealing significant spatial and seasonal variations.

Results indicated that the western area exhibited substantial nitrate (NO_3-N) removal, attributed to denitrification processes in water-saturated peat layers, while both areas showed consistent release of organic N (TON), ammonium (NH_4-N), and P. In the western area, the large removal of NO_3-N from incoming groundwater counterbalanced the release of TON and NH_4-N manifold, while this was not the case for the eastern area.

Additionally, current risk assessments of P release after rewetting do not account for P release in the drained state. This gap poses a significant challenge for restoration efforts, as P release from drained peatlands may counterbalance the negative impacts of rewetting.

The study underscores the effect of spatial heterogeneity on nutrient dynamics, particularly the presence of a geological window in the western area, further complicating restoration efforts. It highlights the complex interactions between hydrology, soil properties, and nutrient dynamics in drained peatlands, emphasizing the need for tailored strategies to mitigate nutrient pollution and restore ecosystem functions.

Monitoring CO_2 Emissions from Dutch Organic Soils Using a Process-Based Model Framework

Gilles Erkens[1,2], Joost Keuskamp[2,3], NOBV Team[1,4,5,6,7,2]

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[7]Wageningen University, Wageningen, Netherlands

Drained peatland in the Netherlands are currently contributing ~5 Mton of CO_2 per year to the national Dutch greenhouse gas emissions. With the National Climate Agreement, the Netherlands aims to reduce net CO_2 emission from organic soils by 1 Mton per year by 2030.

To meet the greenhouse gas (GHG) emission reduction targets for organic soils, a set of measures that raise groundwater levels have been proposed and is currently being tested in pilot projects. The Netherlands Research Programme on Greenhouse gas dynamics in Peatlands and organic soils (NOBV) investigates the effects of these measures on the GHG emission balance under different environmental conditions.

It is imperative to annually monitor the progress in reducing GHG emissions. To this end, the NOBV consortium developed SOMERS (Subsurface Organic Matter Emission Registration System). Within SOMERS, existing models are supplemented by two newly developed models for assessing groundwater dynamics and peat decomposition, which require limited data input and have a short runtime. Using numerical models that simulate groundwater levels and carbon dynamics, CO_2 emissions derived from peat decomposition are calculated at the parcel level.

The process-based models in SOMERS are used to i) annually monitor the achieved reduction by the implemented measures, ii) determine the yearly emissions as part of the LULUCF emission reporting, and iii) establish the effects of measures under standardized conditions for policy development.

The outcomes of the models are tested with annual carbon flux estimates from over 10 measurement sites. In the long run, we will include emissions of CH_4 and N_2O in the modelling.

In this contribution, SOMERS will be introduced, and the calibration and validation approach will be discussed. The new national peatland CO_2 emission budget based on SOMERS will be presented, forming the base of the LULUCF-sector reporting for organic soils in the Netherlands from 2025 onwards.

Mapping the world's inland surface waters: an upgrade to the Global Lakes and Wetlands Database (GLWD v2)

Bernhard Lehner

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In recognition of the importance of inland waters, numerous datasets mapping their extents, types, or changes have been created using sources ranging from historical wetland maps to real-time satellite remote sensing. However, differences in definitions and methods have led to spatial and typological inconsistencies among individual data sources. The Global Lakes and Wetlands Database (GLWD), published in 2004, with its globally seamless depiction of 12 major wetland classes at 1 km grid cell resolution, has emerged over the last decades as a foundational reference map that has advanced research and conservation planning addressing freshwater biodiversity, ecosystem services, greenhouse gas emissions, land surface processes, hydrology, and human health. GLWD version 2 introduces a new iteration of this map, generated by harmonizing the latest ground- and satellite-based data products into one single database representing contemporary conditions (~1984-2020). The classification of GLWD v2 differentiates between natural and non-natural lakes, rivers of multiple sizes, and several other wetland types. It incorporates information on seasonality (e.g., permanent vs. intermittent vs. ephemeral); inundation vs. saturation (e.g., flooding vs. waterlogged soils); vegetation cover (e.g., forested swamps vs. non-forested marshes); salinity (e.g., salt pans); natural vs. non-natural origins (e.g., rice paddies); and a stratification of landscape position and water source (e.g., riverine, lacustrine, palustrine, coastal/marine). GLWD v2 represents 33 wetland classes and—including all intermittent classes—depicts a maximum of 18.2 million km^2 of wetlands (13.4% of the global land area excluding Antarctica). The spatial extent of each class is provided as the fractional coverage within each grid cell at a resolution of 500 m, with cell fractions derived from input data at resolutions as small as 10 m. GLWD v2 aims to support the study and protection of wetland ecosystems around the world and is available at https://www.hydrosheds.org/products/glwd.

Session 4:
Wetlands ecology and biodiversity

30 June
16:45-17:50, Hurt Hall

1 July
11:30-12:30, Hurt Hall
15:00-16:15, Hurt Hall

3 July
16:45-17:15, Hurt Hall

4 July
11:15-12:15, Hurt Hall

Peatland Fungi: Biodiversity, Functions, Perspectives

Maarja Öpik[1], Kaido Soosaar[1], Mikk Espenberg[1], Jordi Escuer-Gatius[2], Tanel Vahter[1], Inga Hiiesalu[1], Siim-Kaarel Sepp[1], Ülo Mander[1]

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Diversity of fungi in wetlands, including peatlands, has been thought to be low. In recent years, their relevance has been increasingly recognised in particular regarding nutrient cycling and ecosystem responses to global environmental change. Accordingly, more data has become available regarding peatland fungal biodiversity, their contribution to greenhouse gas emissions and their dynamics under perturbations.

I will present current understanding of diversity and function of fungi of different functional types (guilds), including different mycorrhizal types, in peatlands globally.

Fungal guilds in peatlands differentially contribute to carbon and nitrogen cycles. In temperate forests, the interplay can be between saprotrophic fungi and mycorrhizal fungi from ecto- and ericoid mycorrhizal types. In tropical peatlands, the saprotrophic vs mycorrhizal fungal (and plant) interplay takes shape of arbuscular vs ectomycorrhizal fungi and plants' interactions, and much less is known about these.

I will present preliminary data on fungal guilds distribution from European wetland restoration systems. Further, I will explore how arbuscular mycorrhizal fungi respond to temporal flooding in an Estonian wet forest system, and to which degree arbuscular mycorrhizal fungi, ectomycorrhizal fungi and saprotrophic fungi are related to greenhouse gas emissions in this system. Further, I will present data on how arbuscular mycorrhizal fungal diversity in combination with bacterial diversity relates to greenhouse gas emissions in an experimental setting. It is apparent how mycorrhizal fungi, and bacteria of different functions (e.g., nitrifying or denitrifying bacteria) have different temporal dynamics in an experiment. These data, from different spatial and temporal scales and systems, indicate that plant and fungal mycorrhizal type and their interactions with bacteria importantly contribute to different aspects of carbon and nitrogen cycling of ecosystems.

I will conclude with outlining the knowledge gaps and future research questions in relation to diversity and functioning of fungal guilds in peatlands.

Soil Carbon Storage and Greenhouse Gases Fluxes in Chinese Coastal Wetlands

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Coastal wetland is considered as an important carbon pools and play a critical role in the global climate change due to its unique anaerobic environment with slow decomposition rate of soil organic matter. However, greenhouse gas emissions increased under combined effects of human activities and climate change, thereafter influence soil carbon pools. In this study, we estimated the soil carbon storage based on different methods, and analyzed the patterns of greenhouse gases emission (GHG, including CO_2, CH_4, and N_2O) in coastal wetlands in China. Results showed that soil carbon storage in 0-100cm of coastal wetlands in China was 117.34 ± 5.47 Tg C, soil carbon density is dependent on different wetlands types and vegetation type. Soil carbon density in mangrove wetlands was significantly the highest, followed by saltmarsh wetland and mudflat. CO_2 flux ranged from 10.32 to 3899.92 $mg \cdot m^{-2} \cdot h^{-1}$, with the average value of 1136.79±66.46 $mg \cdot m^{-2} \cdot h^{-1}$, CH_4 flux ranged from 7.77 to 4413.50 $\mu g \cdot m^{-2} \cdot h^{-1}$, with the average value of 417.27±54.41 $\mu g \cdot m^{-2} \cdot h^{-1}$. Spearman correlation and SEM analysis showed that the chemical component and sources of dissolved organic matter (DOM) played a critical role in the GHGs generation and emission in coastal estuarine wetlands in China, mean annual temperature, Fe, NH_4^+, and microbial biomass carbon were also the key factors influencing GHG fluxes. Overall, these findings have essential implications for carbon cycle processes and management for the coastal wetlands.

Atmospheric CO_2 Flux and Planktonic Food Web Relationships in Temperate Marsh Systems: Insights from in Situ Water Measurements

Xaus Lucila[1,2], Raphaël Moncelon[1], Jérémy Mayen[3,2], Lauriane Bergeon[1], Bénédicte Dubillot[1], Philippe Pineau[1], claire emery[1], Marie Vagner[4], François-Xavier Robin[5], Frédéric Azémar[6], Michèle Tackx[6], Christine Dupuy[1], Pierre Polsenaere[2]

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“Blue Carbon” ecosystem , like marshes, are starting to get attention thank to their carbon sequestration and storage capacity. Extensive research on the dynamics of water CO_2 partial pressure (pCO_2) and planktonic food webs (PFWs) separately is starting to appear. Nonetheless, there has been limited exploration of their potential interconnections, especially in different marsh typologies. This study focus on searching : (1) if PFW topologies could explain water pCO_2 atmospheric and CO_2 flux variations, and (2) determine if these potential relationships remained the same in two distinct “Blue Carbon” ecosystems. Measures of biotic and abiotic variables were held in two distinct wetlands at the French Atlantic coast: a saltwater (SM, L’Houmeau) and a freshwater marsh (FM, Tasdon). SM acted as a weak carbon source over the whole studied period (pCO_2 between 542 and 842 ppmv). On the contrary, depending on seasons and stations, FM exhibited both strong atmospheric CO_2 source or sink characteristics (pCO_2 ranging from 114 to 3201 ppmv). Certain pCO_2 range values were related to five PFW topologies in the two marshes: three stable topologies ('biological winter', 'microbial', 'multivorous' PFW) showed high pCO_2 values (FM: 971, 1136, 3020 ppmv; SM: 'biological winter' not observed, 842, 832 ppmv), while two transient topologies ('weak multivorous' and 'weak herbivorous') presented lower and more variable pCO_2 values (FM: from 127 to 1402 ppmv; SM: from 638 to 749 ppmv). Apparently, seasonality was a main influencing factor for both pCO_2 dynamics and PFW. Yet, a possible obstacle for a clearer understanding on the relationships between pCO_2 and PFW, could be the lack of PFW seasonal equilibrium state since its restoration in FM has. This study presented, for the first time, a direct potential association between PFW topologies and pCO_2 dynamics over “Blue Carbon” marsh environments.

Environmental Context Impacts Wet Grassland Plant Biomass Allocation and Inputs to the Soil

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Wet grasslands are important wetlands that support high plant and animal diversity. These habitats provide many important ecosystem services including nutrient removal, carbon sequestration and flood attenuation. Often residing within agricultural landscapes, wet grasslands are affected by fertilization and drainage. We established a mesocosm to determine how fertilization and hydrology affected the biomass allocation and plant exudation inputs in *Carex acuta* and *Glyceria maxima*, two common wet grassland plant species in Central Europe. We predicted that both species would be affected by hydrologic changes, but fertilization would have a more positive effect on *G. maxima*. *C. acuta* plants allocated more biomass to leaves and were taller than *G. maxima*, which had larger belowground mass noted by the root-to-shoot ratios. As expected, fertilization had a greater effect on *G. maxima* while *C. acuta* was influenced more by hydrologic changes, growing better in dry and saturated conditions. Both species were stressed under prolonged flooded conditions. Surprisingly, *C. acuta* produced more ramets than *G. maxima*. Non-structural carbohydrate (NSC) concentrations, notably glucose, sucrose and total NSC, were the highest in leaves compared to roots or rhizomes. Fructose concentrations were greater in *G. maxima*, especially in the stems and rhizomes, while *C. acuta* stored more starch in its belowground structures. *G. maxima* also exuded more TOC and TN from their roots to the soil than *C. acuta*, related to its greater below ground biomass. Our results provide information for predicting and modelling the response of these two species to management and climate change effects. In the case of *G. maxima*, our results may aid in controlling invasive populations of this species.

Effects of Shrub Invasion on Methane Emissions from Temperate Wetlands and Their Regulatory Mechanisms

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Although the effects of shrub invasion on soil microbial communities and methane emissions have been widely studied, researchers have rarely systematically investigated its microbial-mediated methane metabolism pathways. We investigated the effects of different levels of shrub invasion on the composition, function and diversity of the soil microbiota (bacteria and fungi) and their mediated methane metabolism pathways using macro-genomic techniques. Shrub invasion was classified as no expansion (CK: a=0), mild expansion (SI: 0<a≤30%), moderate expansion (MI: 30%<a≤70%), and severe expansion (HI: 70%<a≤100%) according to the degree of shrub cover (a) of the bog. Shrub invasion significantly increased soil ammonium nitrogen content while reducing soil moisture. Invasion did not significantly affect bacterial α-diversity, but moderate and heavy invasion (MI/HI) significantly increased fungal Chao1 and ACE indices. Invasion significantly suppressed methanogenic acetic acid pathway genes (comB, hdrA abundance decreased by 20-30%), but the abundance of methylotrophic methanogenic genes mtαA increased in heavy invasion (HI) (40% increase over CK); the abundance of oxidative pathway genes mmoB and DAK increased (35-50% increase in HI compared to CK), whereas the genes PGAM and ppc were suppressed. Methane fluxes decreased significantly with increasing invasion (HI accumulation was only 28% of CK), and peak fluxes (15 August) were 2-3 times higher in the non-invaded sample site (CK) than in the invaded sample site. Structural equation modelling (GOF = 0.731) indicated that invasion suppressed methanogenic genes (β = -0.617) and activated oxidative genes (total effect β = 0.728) by enhancing soil physicochemical properties (β = 0.865); oxidative genes contributed the most to methane abatement (pathway weighting of 72.4%), with methane accumulation decreasing by 0.803 units for each unit of increase in their abundance (β =-0.803). This finding underscores the critical importance of studying shrub invasions in response to global change.

Vegetation Biodiversity of Boreal Forest Ditches, Straightened Streams and Streams

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Across the boreal biome, drainage ditches have been constructed, and streams straightened to enhance forest production, altering ecosystems and transforming the stream network. The well-established preferential flow paths of these waterways may now serve as refugia for aquatic or wetland plants that were once more widespread, though largely overlooked in Sweden's forestry landscape. With approximately 68% of small waterways in Sweden human-made or modified, urgent knowledge is needed to inform effective biodiversity management. We examined riparian vegetation along a gradient of catchment sizes and soil types in northern Sweden, comparing biodiversity among ditches, straightened streams, and natural streams. This research aimed to assess riparian vegetation biodiversity in boreal forest ditches and straightened streams to determine their similarities and differences from 'natural' headwater streams. Our results show that riparian vegetation biodiversity does not significantly differ between straightened and natural streams, highlighting the role of modified channels in supporting aquatic biodiversity. While till ditches shared a similar community composition, they had significantly lower biodiversity than till straightened and natural streams. In contrast, peat ditches supported fewer species, exhibited lower species turnover, and had distinct community compositions due to differences in soil characteristics and catchment size. Species richness and diversity increased with catchment area across both natural and artificial channels, aligning with well-documented patterns in natural systems but less explored in anthropogenic waterways. To support biodiversity, we recommend minimizing ditch cleaning in till ditches and straightened streams, as natural erosion helps them develop stream-like features. Conservation strategies should prioritize preserving straightened streams on till soils and maintaining vegetation buffers to support diverse plant communities.

Spatial Distribution of Soil Properties in a Temperate Riparian Wetland, South Korea: The Role of Vegetation, Anthropogenic, and Geomorphic Factors

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Research on the spatial distribution of riparian wetland soils often focuses on one or two major factors, overlooking their combined effects. However, adopting a holistic approach that integrates vegetation, anthropogenic, and geomorphic factors can facilitate for a more comprehensive understanding of wetland ecology.

This study aims to evaluate the influence of vegetation type and anthropogenic disturbance on the spatial distribution of soil properties in a riparian wetland of southern Korea. The study site, located on the Seomjingang River, exhibits spatially distinct separation of vegetation cover as well as disturbed and undisturbed areas, making it suitable for analyzing their combined effects. We conducted t-tests and ANOVA on a total of 78 soil samples collected across the wetland. The analyses revealed that the classification of vegetation cover and the presence of anthropogenic disturbances had significant explanatory power for the spatial distribution of soil properties (especially, soil pH), whereas topographic variables (e.g., surface elevation and wetness index) did not. These results potentially indicate that the influence of topography may have been diluted by the vegetation and anthropogenic factors.

These findings contrast with conventional geomorphological perspectives that assume the significant role of topography in determining soil properties. Such assumption alone may be insufficient to explain soil distribution, is particularly in modern river systems, experiencing increasing frequency and intensity of anthropogenic disturbance. In complex riparian wetland environments where multiple interacting factors are present, a more holistic approach as attempted in this study is needed. The present study will enhance the knowledge of the vegetation-anthropogenic-soil triangle relationship, improving our understanding landscape patterns and processes.

Plant Community Structure and Geomorphic Stability Across Tidal Creeks at the Skallingen Salt Marsh, Denmark

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Existing literature indicates that plant species composition can influence the stabilization of soil substrates; however, many of these investigations predominantly rely on experimental methodologies, such as transplantation and numerical simulations. Consequently, there is a notable scarcity of long-term observational studies focusing on plant assemblages, sea-level fluctuations, and sedimentary processes in natural wetland ecosystems. This study examined the intricate relationship between geomorphological changes in multiple tidal channels and plant community structure at the Skallingen salt marsh in southwestern Denmark from 2006 to 2023. Comprehensive vegetation surveys were conducted in the summer of 2006 at eleven cutbank sites and eleven point bar sites. The results revealed that in cutbanks, sites exhibiting more severe erosion (7-8 meters) over the seventeen-year period were predominantly characterized by *Atriplex portulacoides* in 2006, in contrast to less eroded sites (less than 0.5 meters). Conversely, point bars that experienced substantial vegetation advancement were also more dominated by this species in 2006. These findings underscore the critical role of *Atriplex* in regulating plant species diversity and influencing geomorphological changes within tidal channels. While this shrub promotes sedimentation and enhances wetland growth, it simultaneously increases the vulnerability of wetland margins to wave disruption due to the heightened steepness of the marsh platform. This research supports existing hypotheses concerning self-organization in natural systems, suggesting that while functional resilience may improve in the short term, these ecosystems could ultimately face critical collapse over extended temporal scales.

Impact of Microplastic Contamination on Plant Diversity and Ecosystem Health in Urban Wetlands

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Distribution of microplastic in water bodies may pose a threat to the aquatic food chain and the whole ecosystem. The main objective of this research was to identify extent, sources, and fate of microplastics in urban wetlands, their retention by plants, and potential fluctuation in the population diversity of plants as a result of exposure to microplastics. For this purpose, ten urban wetland sites in Sialkot were selected to collect plants, water, and sediment samples for the potential contamination of microplastics. Site-6 and Site-10 showed highest range of microplastic fragments in sediment samples with polyethylene terephthalate (PET) as the most dominating type of microplastic. Whereas, Site-5 showed the lowest microplastics range. Physiochemical properties such as pH, EC, TDS, C, and N of water and sediments were also recorded with varying ranges among sites. Diversity of plants at various sites was determined through quadrant method. The most common plant species were *Pistia stratiotes, Eichhornia crassipes, Leersia hexandra, Oenanthe javanica, Alternanthera philoxeroides,* and *Ipomoea aquatica*. Maximum concentration of microplastics of fiber type was noticed on *P. stratiotes* and *O. javanica*. While *E. crassipes* showed very few microplastics adhered to it. Fresh and dry weights and photosynthetic pigments of these plant species were found to depend on different sites. The diversity of plants seemed to relate to the extent of pollution indicators at the sites. *P. stratiotes* was most frequently occurring plant across sites. Highly polluted site-6 showed the lowest plant diversity. It is concluded that microplastics may have influenced the plant population diversity in various wetlands, by affecting different plant parameters. This fluctuation in diversity of plants occurred either due to microplastic adherence on plants or in the water/sediments in which plants were growing. The study presents results with potential recommendations to phytoremediate different microplastic types by using various plant species.

The Importance of Studying Near-Pristine Ecosystems: A Case Study from the Okavango Delta (Botswana)

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This study addresses the gap in understanding the diversity, species, and functional trait distribution of different algal groups that occur in the Okavango Delta (a near-pristine subtropical wetland in northwestern Botswana) across hydrological and habitat gradients. We systematically characterize the delta's algal flora, addressing the gap left by previous research that was limited to single algal groups (e.g., diatoms) and/or only looking at upstream areas in the Okavango River basin. We analyzed 130 algal samples from 49 upstream and downstream sites with higher and lower flooding frequency, respectively, across a river-to-floodplain habitat gradient. Chlorophyta and Bacillariophyta dominated both abundance and taxon richness (>80%) of the total 494 taxa found from 49,158 algal units counted (cells, colonies, coenobia, and filaments). Smaller algae were more abundant in downstream floodplains than in upstream channels and lagoons. Motile and siliceous algae were much more abundant than non-motile, nitrogen fixing, and phagotrophic algae. The frequency of these traits was associated more with flooding frequency than habitat type. The highest algal richness and diversity were found downstream, where shallow floodplain ecosystems with seasonally fluctuating water depths offer greater habitat heterogeneity, and macronutrients are resuspended. The increasing threats from upstream water abstraction plans, fracking, and climate change require enhanced protection and monitoring of the Okavango Delta's natural annual flood-pulse to maintain the high species and functional diversity of this unique wetland's microalgae. This study provides key baseline data and information on algal assemblages at the base of aquatic food webs in a remote, near-pristine Ramsar and UNESCO World Heritage site; future comparisons and assessment of impact of the threats above mentioned can be made using our baseline. It is key to investigate biodiversity in near-pristine and pristine ecosystems because they provide a benchmark of how Nature works when undisturbed or only partially disturbed by human impacts.

Dissolved Organic Matter and Sulfide Increase CH_4 Uptake by a Psychrophilic Lake Methanotroph Isolate, *Methylobacter* Sp. S3L5C

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Aerobic methane-oxidizing bacteria, known as methanotrophs, dominate boreal freshwater lakes and wetlands and play a crucial role in mitigating natural CH_4 emissions. In these environments, members of the methanotrophic order *Methylococcales*—particularly the genus *Methylobacter*—are widely recognized as key contributors to methane oxidation. (Meta)genomic data suggests that these methanotrophs not only consume CH_4 but may also use dissolved organic matter (DOM) and reduced sulfur compounds (e.g., sulfide) present in these environments as an electron source. In this study, we investigated the effect of DOM and sulfide on the metabolism of a psychrophilic *Methylobacter* sp. S3L5C, a representative of boreal lake habitat methanotrophs. The cultivation was conducted in various conditions, with freshwater DOM (60 mg L^{-1}) applied either alone or in combination with sulfide (0.05 mM) addition at two different CH_4 levels (1% and 20% v/v). The growth (OD_{600}), CH_4 and O_2 consumption, CO_2 production, and gene expression (mRNA) patterns of S3L5C were analyzed. At 20% CH_4 (v/v) cultivation, DOM addition enhanced CH_4 consumption, CO_2 production and growth of S3L5C, while addition of sulfide+DOM led to further increase in these variables. The addition of sulfide+DOM also enhanced CH_4 consumption at 1% CH_4 (v/v) cultivation. The effect of DOM on the S3L5C´s metabolism was accompanied by enhanced expression of the *cyc2* gene which has been suggested to mediate the extracellular electron transfer from DOM. Furthermore, the addition of sulfide+DOM enhanced the expression of the genes involving dissimilatory sulfide and thiosulfate oxidation (*sqr* and *soxB*), respectively. Our findings and previous metagenomic data indicate that the capacity to utilize DOM and reduced sulfur compounds is an adaptive trait that enhances methanotrophic activity in boreal and subarctic freshwater lakes and wetlands.

Warming and Eutrophication Interactively Affect the Autotrophic Picoplankton of Shallow Lakes – a Mesocosm Experiment

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Global climate change is challenging the stability of shallow lake ecosystems in complex ways, as rising temperatures are accompanied by changes in wind patterns and precipitation, which, in turn, lead to altered lake and catchment nutrient dynamics. The interactive effects of warming and altered nutrient dynamics on picoautotrophs (picoplankton) – the smallest fraction of phytoplankton – were studied in a field mesocosm experiment at three different temperature regimes and two nutrient regimes. Mean picoplankton biomass was approximately three to four times higher under high nutrient conditions, regardless of the temperature regime. In contrast, the biomass of larger, conventionally sized phytoplankton (> 0.7 µm) increased by an order of magnitude under high nutrient conditions at all but the highest temperature regime, where it showed only about a two-fold increase. Thus, picoplankton was favoured at the highest temperature and nutrient enrichment. Additionally, picoplankton community composition was affected by both nutrient and temperature regimes, with nutrient enrichment having the larger effect. These results underscore the interactions between climate-induced warming and eutrophication and demonstrate non-linear associations between phytoplankton communities and rising temperatures. While the proportion of picoplankton is expected to decrease under high nutrient loading and moderate warming, further temperature increases may make shallow ecosystems prone to regime shifts. The resulting warm, clear-water state can be characterized by a relatively high proportion of picoplankton, regardless of nutrient loading.

Non-Invasive Swab Technics for Ecotoxicological Responses of Amphibians Species to Evaluate Integrity of Nature Based Solution from Pesticide Exposition

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Artificial wetlands intercepting drained water showed efficiency to remove pesticides from agricultural lands. In parallel, artificial wetlands, considered as nature based solution, contribute to biodiversity as refuge but also sometimes as trap. Thus the question of integrity of this nature based solution is raised.

Amphibians are particularly vulnerable to pesticide exposures according to numerous laboratory and field studies. Enzymatic activities in biological tissues and body condition are usually proposed as relevant biomarkers for studying the effects of pesticides on these organisms, especially in agricultural context. Nevertheless, measuring enzymatic activities on animals often requires invasive sampling methods, such as blood sampling. Developing non-invasive approaches is crucial to the ethical principles that aim to minimize the impact on individuals. We aimed to test a non-invasive sampling approach, namely buccal swabbing, to investigate the effects of pesticides on the enzymatic activities of two native amphibian species, the common toad (*Bufo bufo*) and the green frog (*Pelophylax sp.*), in six ponds distributed along a pesticide contamination gradient including artificial wetland of Rampillon in the frame of Alfawetlands HORIZON project (www.alfawetlands.eu). We also performed morphometric measurements to determine the body condition of the swabbed individuals. Our results show that buccal swabbing effectively allows quantifying the activities of 6 enzymes present in the saliva of wild amphibians and involved in neurological, non-specific immunity, and nutrition processes, supporting the relevance of this approach to assess their enzymatic responses *in situ*. Enzymatic levels of acetylcholinesterase, β-galactosidase, β-glucosidase, of cytotoxic biomarkers, such as glutathione S-transferase, and peroxidases, were either significantly correlated with pesticide concentrations, or responsive to synchronic-antagonistic effects of pesticide fluxes occurring in an agricultural artificial, suggesting that buccal swabbing in amphibians is applicable in the field for this purpose, and that agricultural artificial wetland could have the potential to affect aquatic fauna.

Unravelling the True Floristic Diversity and Extent of Distribution of Saltmarsh Vegetation in Sri Lanka

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Among blue carbon ecosystems, saltmarshes are the least studied. Many countries including Sri Lanka are yet to determine the diversity, true extent and types of saltmarshes. This study presents the working progress of an ongoing assessment in the tropical island of Sri Lanka, aiming to develop a standardized classification for saltmarsh ecosystems. The research focuses on delineating their boundaries and determine the island-wide presence. A ground truthing has now covered northwestern, northern and some areas of the eastern coastline where vegetation community structure is established through Braun and Blanquet method and belt transects and extent through GPS-backed polygon preparation. To date, this research has confirmed 15, 303 ha of saltmarsh. The current study identified eight distinct vegetation communities; *Suaeda* communities mixed with *Tecticornia indica* and grass, *Suaeda* communities mixed with matured mangroves, *Suaeda* communities mixed with dwarf mangroves, *Suaeda* communities mixed with scattered shrub vegetation, *Tecticornia indica* dominant communities, *Salicornia brachiata* dominant communities, grass and sedge dominant communities and saltmarshes mixed with dry deciduous forests. Grass and forb dominant depressions with seasonal vegetation were seen across all types of saltmarshes where detailed studies are required to identify changes to vegetation with reclining water levels. The identified species comprise 195 species which belong to 61 families. This study identified the spread of saltmarsh to formerly mangrove ecosystems when they are converted to shrimp farms, and later abandoned, especially along the northwestern coastline. It highlights the ecotones formed by saltmarsh with mangroves and other coastal vegetation and calls for global-level agreements on their vegetation classification. Findings confirm tropical saltmarshes are complex and diverse in vegetation community character, which requires clear definitions and vegetation zonation to delineate their extent. The research emphasizes the need for a comprehensive, regionally accepted saltmarsh ecosystems classification for mapping and defining their extent.

N_2O Fluxes Explained by Monthly Dynamics of Soil Microbiome in Drained Peatland Forest

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Drained peatland forests are significant sources of nitrous oxide (N_2O), a potent greenhouse gas. This study analysed temporal and spatial variability in soil physico-chemical properties and microbial processes in nitrogen cycling and N_2O emissions in drained peatland forest. Here we show that the soil physico-chemical variables exhibited distinct temporal patterns for dynamic soil parameters such as temperature, water-related properties, ionic compounds of nitrogen, and N_2 emissions, while spatial patterns were evident for more stable soil chemical parameters. Soil gene copy numbers demonstrated both temporal and spatial patterns, with higher abundances under moist or warm conditions and lower abundances under dry or cold conditions. Peak N_2O emissions occurred during spring freeze-thaw period and water table fluctuations, when transient aerobic and anaerobic conditions activated nitrification and prokaryotic and fungal denitrification, shown by functional genes. High N_2O emissions were caused equally by temporal and spatial factors. Rewetting of peatland forests can mitigate these high N_2O emissions. Results of this study help to enhance N_2O flux models and to bolster sustainable peatland management strategies.

Complex Interactions Between Environmental Factors Explain Changes in Zoobenthos Biomass and Abundance in a Large Shallow Lake

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We investigated predictors of abundance and biomass of zoobenthos taxa in the hemiboreal eutrophic shallow Lake Võrtsjärv (Estonia). We worked with 45-year long time series from monitoring database at two timescales: yearly and monthly. We employed machine-learning algorithms such as boosted regression trees, and a Bayesian generalized linear model for generating estimates of several metrics of zoobenthos. We found that interannual differences in zoobenthos abundance and biomass were caused by complex interactions between environmental factors such as wind speed and total phosphorus, the biomass of benthivorous fish, and the availability of phytoplankton. Wind speed and, to a lesser extent, water temperature were the most important predictors of the monthly variations of zoobenthos biomass and abundance. Wind speed had a positive influence on the abundance and biomass of non-biting midges (chironomids) and oligochaetes, whereas it had a negative effect on aquatic mollusks and other taxa of benthic invertebrates. Our results highlight how the influence of environmental variables vary according to the timescale and how climate change such as the reduction of wind speed (atmospheric stilling) might affect the recruitment of zoobenthos who constitute the main food item of benthivorous fish in several shallow lakes.

Spatial and Temporal Changes in Forest Dynamics of Maludam Peat Swamp Forest

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Information on tree species distribution, biomass recovery, and structural characteristics after logging in the Maludam Peat Swamp Forest (PSF) is vital for assessing the forest's recovery, evaluating the impacts of logging, and guiding conservation, restoration, and peatland management efforts. This study investigated the tree species distribution, forest structure, and above-ground (AGB) and below-ground biomass (BGB) across different phasic communities (PCs) in Maludam PSF. Sixteen plots (30 m × 40 m) were established in four different PCs; Mixed Peat Swamp (MPS), Alan Batu (ABt), Alan Bunga (ABg), and Padang Alan (PA). Trees with a diameter at breast height (DBH) of ≥ 5 cm were identified and recorded. A total of 69 species from 58 genera and 35 families were documented. Species richness and diversity varied across PCs, with *Litsea* spp. dominating MPS (IVI = 39.5%) and *Shorea albida* dominating ABt (IVI = 32.6%), ABg (IVI = 96.5%), and PA (IVI = 94.8%). The dominance of Shorea albida in three PCs indicates ecological resilience and a competitive advantage in peat swamp conditions, while also indicating lower biodiversity and possible environmental stress or historical disturbances such as deforestation. The AGB estimates for MPS, ABt, ABg, and PA were 65.5, 69.4, 36.7 t C ha^{-1}, and 22.0 t C ha^{-1}, respectively while BGB estimates were 16.6, 17.1, 8.5 t C ha^{-1}, and 5.0 t C ha^{-1}, respectively. These values were significantly lower compared to undisturbed PSF, indicating the slow recovery of PSF after logging. These studies emphasise the critical need for effective restoration and conservation measures for logged-over PSF to safeguard its key functions in carbon storage, biodiversity preservation, water regulation, fire prevention, and support for local livelihoods.

Keywords: peat swamp forest, phasic communities, tree species, C stock

An Analysis of the Diversity, Abundance and Distribution of Mammals in Paul Da Gouxa Wetland (Portugal) for Management Purposes

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Portugal is one of the Southern European countries most affected by the conversion of wetlands into agricultural and grazing areas, leading to their loss and degradation, and negatively affecting existing biodiversity. Paul da Gouxa is a peat bog located in Alpiarça, Portugal, which has just recently been designated a Local Nature Reserve. To develop an adequate management plan, it is necessary to know the existing local biodiversity and their respective distribution. For this we assessed the specific diversity, population abundance and distribution of small and medium-sized mammals in the different habitats of Paul da Gouxa. A combination of techniques was used: camera trap for medium-sized mammals; live-trapping (winter and spring seasons) and hair tubes for small mammals. A total of 10 sampling sites were analyzed, in both natural and humanized/agricultural habitats. The results obtained show that the habitats with the greatest specific diversity of medium-sized mammals were the Margin Wetland and the Restored habitats, with 6 species observed: Genetta genetta, Lutra lutra, Vulpes vulpes, Meles meles, Herpestes ichneumon, Martes foina and Sus scrofa. As for small mammals, 4 species were detected: Apodemus sylvaticus, Mus sp., Crocidura russula and Rattus norvegicus. The Non-Restored habitat had the highest specific richness. However, this was due to the presence of Ratus norvegicus, a species usually associated with degraded areas, as is also the case here due to the accumulation of litter from recreational fishing activities. The highest abundance of individuals was observed in the Non-Restored habitat, followed by the Restored habitat, the Horse Pasture and the Wetland habitats. Our results show that management options need to be carefully designed to maximize mammal biodiversity at the Paul da Gouxa Local Nature Reserve, marginal habitats playing an important role in the survival of these communities.

Natural Habitats of Medicinal Plants Traditionally Used by the Ainu, Indigenous People of Hokkaido, Japan

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The Kushiro Wetland in Hokkaido is the first wetland in Japan to be registered under the Ramsar Convention. However, deforestation and river strengthening in the area have led to increased sediment and nutrient inflow, causing the marsh to dry out over time. Among the plants traditionally used by the Ainu, indigenous people of Hokkaido, there are species that prefer riparian wetland forest environments. They are not only important for maintaining the wetland ecosystem but also serve as living evidence of Ainu history and culture. The purpose of this study is to clarify the environmental factors in which these plants grow, thereby identifying high-priority conservation areas and developing effective conservation measures. The study site is Teshikaga experimental forest of Tamagawa University, eastern Hokkaido. Two quadrats were set up on one boardwalk and three on another boardwalk. Soil conditions, including moisture content, temperature, electrical conductivity, and hardness, were measured, along with canopy openness. Additionally, plant species and their coverage were visually recorded while walking thorough the study area. Principal Component Analysis was performed on soil environment and openness, and plant species and their cover were compared. In relatively dry but closed areas, many colonies of *Pachysandra terminalis* and *Sasa nipponica* were identified. The cover of *Sasa nipponica* was higher in areas close to farmland adjacent to the study forest. In open, moisture-rich environments, the cover of *Dryopteris crassirhizoma* and *Matteuccia struthiopteris* increased, and *Sasa nipponica* was no longer found. As the area converted to farmland increases and the adjacent forests grow, it is possible that the vegetation will become uniform, with only drought-tolerant plants thriving on the forest floor. It is necessary to expand the survey area to investigate the natural habitat conditions of more plant species and to clarify the relationship between distance from farmland and moisture content.

Microbial Nitrogen Cycle Processes and Emissions in Tropical Peatlands: A Comparative Study of Natural and Degraded Ecosystems

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Peatlands in Southeast Asia have suffered extensive degradation due to land-use changes. Over the past two decades, approximately 25% of Malaysia's natural peatlands have been converted for large-scale agro-industrial projects, primarily driven by the rapid expansion of oil palm cultivation. The draining and conversion of tropical peat swamp forests have turned these ecosystems into significant sources of nitrogen (N), leading to increased greenhouse gas (GHG) emissions, including nitrous oxide (N_2O), as well as soil degradation and biodiversity loss. This study focuses on natural and converted tropical peatlands, aiming to investigate the effects of land-cover change on microbial N processes and gaseous N emissions. It also explores the potential of other ecosystem compartments to contribute to N_2O production, in addition to the soil. We measured soil N_2O fluxes and potential N_2 emissions, analyzed the abundances of N cycle functional genes, and conducted sequencing from ground and canopy soil, leaves and litter in tropical peatlands. These analyses, along with soil physico-chemical parameters, were conducted at two contrasting sites: an undrained peat swamp forest and an oil palm plantation in Sarawak, Malaysia.

Drained tropical peatland soil was the primary emitter of N_2O, whereas N_2O emissions from the soil in the natural peat swamp forest site were nearly negligible. The natural site showed a higher soil N_2O sink capacity, indicating that more of the available N_2O was further reduced to N_2, as the denitrification process is complete there compared to the drained site. Quantification of N cycle genes revealed that the soil in the natural site had a higher genetic potential for denitrification and DNRA processes compared to the drained peatland. Both the canopy soil and litter showed genetic potential for nitrogen cycling processes, and the leaves from both sites also demonstrated this capacity, highlighting the role these ecosystem compartments play in nitrogen cycling.

Session 5:
Tropical wetlands

30 June
16:45-18:20, Manninen Hall

Mangroves and Seascape Connectivity: Identifying the Next Steps for Research and Management

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Mangroves provide an impressive array of ecosystem goods and services and are a critical ecosystem in the connected seascape, supporting ecological functions well beyond their boundaries. The importance of connectivity between ecosystems is the focus of a rapidly growing interdisciplinary science, crossing multiple spatial and biological scales with relevance to both fundamental and applied questions of ecology and management. Consistent with this trend, there has been great progress in the field of mangrove connectivity. However, there is no clear consensus on what the most important remaining challenges are to guide research and management. Here, we identify eight critical connectivity themes for mangroves: thresholds and drivers, regional and global stresses, blue carbon, restoration, ecosystem services, marine spatial planning, nature-based solutions and community inclusion. Across these eight themes, we explore the current major gaps in connectivity science or management, and how these challenges might be overcome, integrating connectivity into our scientific understanding of the best approaches for achieving sustainable management of mangroves and of the seascapes in which they are embedded. We identify four broad solutions that would help with these combined scientific and management challenges: a) new forms of innovative funding that allow sustainable sources of revenues for seascape scale management; b) integrative policies that recognise interconnectivity between ecosystems and integrate local with national and international governance; c) multi-scale experiments and studies that support long term monitoring; d) participatory collaborative management. By identifying these major gaps and suggesting key solutions across a range of subject areas, we hope to contribute towards advancing the science and application of mangrove connectivity.

Variations of Soil Organic Carbon Across Different Land Use Types in Tropical Peatland

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Peatlands are significant carbon (C) sinks crucial in mitigating climate change. Their conversion for agroforestry involves land clearing, drainage, compaction, and fertilization, all affecting soil organic carbon (SOC) stability. While the effect of these changes is recognized, the specific influence of increasing temperature and liming on SOC remains unclear. This study aimed to evaluate the stability of SOC across land use types and different environmental conditions. Soil samples (0–25 cm) were collected from a peat swamp forest (PSF), an oil palm plantation (OPP), and a neighboring secondary forest (OPF). The composition of C groups was estimated from ^{13}C CP/PASS NMR spectra. SOC biodegradability was assessed via laboratory incubations by measuring CO_2 production in three treatments: Control (native pH, 25°C), Neutral pH (pH 7, 25°C), and Higher Temperature (native pH, 35°C). A seven-day photodegradation experiment was conducted at 650 W m^{-2} using OPF and OPP soils. Alkyl C was selectively preserved in PSF and OPP, while OPF contained a larger proportion of *O*-alkyl C. SOC mineralization rates in the Control treatment followed the order PSF > OPF > OPP. Aromatic C negatively correlated ($p < 0.05$) with SOC mineralization in the Control treatment, indicating its role in stabilizing peat SOC. SOC mineralization rates in OPF and OPP soils increased under Neutral pH, whereas PSF soil decreased. Higher Temperature increase SOC mineralization by 1–2 times across all soil samples, suggesting bacterial adaptation to changing conditions. Photodegradation led to 6–16% and 7–19% C loss in OPF and OPP soils, respectively. These findings indicate that land use conversion, combined with liming, could accelerate SOC loss in peatlands, irrespective of the initial structural properties of SOC.

Can't See the Rise for the Trees: Prevalence of Mangrove Progradation in Northern Australia

Kerrylee Rogers[1], Emma Asbridge[1], Chris Owers[2], Rogerio Goncalves[1], Sarah Hamylton[1], Jeffrey Kelleway[1], Richard Lucas[3], Colin Woodroffe[1]

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Changes to mangrove forests since the mid-Holocene, when eustatic sea-level rise (SLR) stabilised, have generally been related to natural geomorphological and ecological processes, and it is only recently that changes to mangrove forest distribution and condition could reasonably be attributed to anthropogenic pressures. While it may be reasonable to start attributing mangrove distribution changes to global mean SLR, the reality of doing so is limited by the relatively modest increase in global mean sea level since industrialisation and the effect of interrelated processes influencing tidal inundation. Projections of the influence of SLR on mangrove forests imply the seaward margin may retreat with extension of the landward margin. We used the archive of Landsat imagery from 1987-2023 to evaluate evidence for these changes. Shore-normal transects covering 1500 km of open coast of Northern Australia were established and the dense times series of Normalised Difference Vegetation Index and Normalised Difference Water Index were extracted to analyse changes that could be attributed to SLR. This coastline includes a range of geomorphologically complex features such as cheniers, tidal creeks and spits. We found widespread occurrence of progradation of the seaward margin but landward changes in mangrove extent were highly variable. Despite extensive dieback of mangroves in recent years, including events in the early 1990s and 2015-2016, partial or even full recovery of vegetation cover was evident in the years following. Observations of progradation or stability of the mangrove seaward margin over the past three decades are contrary to expectations under SLR, and ongoing monitoring is therefore required to clearly identify the effects of SLR along this coast. In contrast to highly populated coastlines where infrastructure and assets cause coastal squeeze, landward expansion of mangroves in northern Australia is anticipated across the widespread low-lying coastal plains, which offer accommodation space under a higher sea level.

Impact of Land Conversion on Soil Carbon Dioxide Emissions from Tropical Peatland

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Tropical peatlands store a large portion of the Earth's terrestrial organic carbon (C), serve as important pools in global greenhouse gas (GHG) balances, and significantly influence global warming. Despite their importance, the rapid conversion of these peatlands, especially into industrial plantations, has raised concerns about their C emission contributions. Previous studies have primarily compared soil CO_2 emissions between forests and agricultural lands, while specific land conversion process was often disregarded. Addressing this gap, our research focuses on the soil CO_2 emissions together with environmental properties, resulting from the conversion of a secondary peat swamp forest into an oil palm plantation in Sarawak, Malaysia. Soil CO_2 emissions measurements were conducted from November 2017 to December 2018 using closed chamber method. Our results indicate that the mean soil temperature, air temperature and relative humidity during measurement period were 30.1 ± 0.9 ^{o}C, 34.5 ± 1.6 ^{o}C and 61.8 ± 9.2 %, respectively. The study site recorded an annual precipitation of 2352 mm year^{-1}. The water table depth fluctuations with a mean of -90.8 ± 13.9 cm, had a significant impact on soil moisture dynamics, which exhibited a mean value of 0.55 ± 0.04 m^3 m^{-3}.The mean soil CO_2 emissions was 242.0 ± 53.5 mg C m^{-2} h^{-1}, higher than those reported in an undrained tropical peat swamp forest. However, this increase is potentially offset by enhanced C sequestration through photosynthesis as the oil palm matures. Soil CO_2 emission showed a negative correlation with water table depth ($p < 0.05$) and soil moisture ($p < 0.05$). These results highlight the importance of managing groundwater levels to reduce CO_2 emissions from land conversion while enhancing our understanding of the dynamic relationship between land use change and CO_2 emissions in tropical peatlands, providing crucial insights for sustainable management practices.

Sustainable Management of Peatland Through Malaysia's National Action Plan for Peatlands

Samsudin Musa, Roslan Rani, Noradli Parsada

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The peat landscape, including the peat swamp forests of Malaysia, is a truly unique and fragile ecosystem that plays a crucial role in maintaining environmental balance and conserving the country's natural heritage. They provide a variety of benefits in the form of forestry and fisheries products, energy, flood mitigation, water supply and groundwater recharge. These vital ecosystems, covering 2.56 million hectares or 7.75% of the nation's land area, are integral to our environmental well-being and socio-economic development Given the critical importance of these landscapes, it is essential that they are protected and managed sustainably. Unregulated development, land conversion, and peatland degradation can lead to severe environmental consequences, including loss of biodiversity, increased carbon emissions, and worsening climate impacts. Therefore, a comprehensive and integrated management plan is needed to balance conservation efforts with sustainable use.

Malaysia has developed a National Action Plan for Peatlands outlines 12 focal areas with specific strategic actions. It focuses on restoring damaged peatlands through rewetting, replanting, and rehabilitation efforts while supporting local communities through ecotourism and sustainable agriculture. It also aims to strengthen policies and coordination between federal and state governments to ensure effective governance, alongside boosting public awareness and stakeholder involvement through education and outreach initiatives. The strategic focal area designed to synergize ecological integrity with socioeconomic resilience. Inventory, Mapping, and Assessment form the foundational pillar, enabling data-driven decision-making by cataloguing peatland extent, degradation status, and ecosystem services.. Integrated Peatland Management harmonizes sectoral policies, supported by National Policies and Legislation enforces regulatory coherence and accountability. Community Livelihoods ensure inclusive development by integrating local populations into sustainable practices, complemented by Sustainable Financing mechanisms.

By implementing this plan, Malaysia aims to mitigate climate change, preserve biodiversity, and support the livelihoods of communities, contributing to regional and global environmental goal

Ecosystem Connectivity of Tropical Coastal Wetlands and Its Effects on Blue Carbon Storage

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Ecosystem connectivity refers to the degree of interaction between natural environments which facilitate the exchange of energy, materials and organisms among ecosystems. Ecological principles related to connectivity have largely developed in the context of terrestrial landscape ecology; but less so in seascapes involving coastal wetlands. As these wetlands intersect land and sea, they provide both terrestrial and marine ecosystem services, including the important service of carbon sequestration. In tropical archipelagos such as Indonesia, mangroves and seagrass meadows constitute the main "blue carbon" ecosystems, i.e., vegetated coastal wetlands that sequester and store large amounts of carbon, therefore playing a key role in the mitigation of global climate change. It has been estimated that Indonesia's mangroves and seagrass meadows store 3.4 Pg of carbon, or approximately 17% of the world's blue carbon. In this paper we review the current state of research on the connectivity of mangroves, seagrass meadows and coral reefs, and discuss results from our studies on the relationship between ecosystem connectivity and carbon stocks in the coastal areas of several islands in Indonesia. For example, results from Seribu Islands Marine National Park indicate that the presence of mangroves may affect sediment carbon stocks in seagrass meadows. Seagrass meadows growing adjacent or in proximity to mangroves contained significantly higher sediment carbon stocks compared to seagrass meadows around islands in which mangroves are absent. In our research site of Saparua island in eastern Indonesia, we are studying the extent to which connectivity between coastal ecosystems affects carbon stocks, as well as the relative proportion of autochthonous and allochthonous carbon sources in seagrass meadows using carbon isotope analysis. A better understanding of the ecological processes that affect carbon storage in connected ecosystems provides valuable insight into the effective management of blue carbon ecosystems.

Session 6:
Use of wetland ecosystems

30 June
14:45-16:05, Manninen Hall

1 July
15:00-16:00, Manninen Hall

Method Harmonization in Large-Scale Paludiculture Pilot Projects: Soil Moisture and Trafficability Measurement in the PaludiNet

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The PaludiCentral as part of several large-scale paludiculture projects (PaludiNet) aims to integrate research, monitoring and practical management to support and promote peat-preserving use of wet peatlands. To achieve this, uniformly and accurately collected data on water levels, soil properties, nutrient contents and other parameters across various organic soil types are essential. Two important aspects among many are approaches assessing load-bearing capacity for machine trafficability on wet soils and evaluation of soil moisture sensors.

Load-bearing capacities of organic soils depend on several factors, including soil moisture, root density, and bulk density, but the comparability of measurements is often questioned. In a field trial, we compared measurements of seven participants using shearing vanes (shear force) and penetrometers (penetration resistance). The results highlighted depth as the most important explanatory variable for penetration resistance, with user contributing much less to the variation overall. However, significant differences between users were found for both devices, emphasizing the need for standardized documentation of measurements.

Soil moisture does not only affect trafficability but also biogeochemical processes such as greenhouse gas exchange and nutrient cycling. Precise measurement of soil moisture is essential for understanding these processes and supporting sustainable paludiculture management. Electromagnetic sensors provide non-destructive, high temporal resolution soil moisture measurements by determining the relative dielectric permittivity (ε) and from this calculating volumetric water content (VWC) using soil-specific calibrations. Given the exponential relationship between ε and VWC, accurate ε-measurements are crucial, especially in organic soils where VWC can exceed 80%. We evaluated 15 commercial soil moisture sensors under laboratory conditions using reference solutions with defined ε-values and varying electrical conductivities. A third of the sensors tested measured reliably and accurately between 40<ε<80, making them suitable for organic soils. A further third were of limited use, while the remaining sensors were unsuitable for reliable measurements in organic soils.

Unsaturated Vertical Flow Constructed Wetlands with Granular Ferric Hydroxides and Manganese Oxides for Enhanced Organic Pollutants Removal from Greywater

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Greywater contains organic pollutants that may limit its safe reuse. A concern arises since greywater typically has lower organic bioavailable carbon concentration than municipal wastewater, limiting microorganisms‘ capacity to metabolize organic compounds. Research on their removal via constructed wetlands (CWs) is gaining attention, but CWs often require intensification to remove a broad range of compounds, especially during low-temperature periods. Reactive materials in CWs, such as granular ferric hydroxides (GFH) and manganese oxides (MnOx), are believed to serve not only as sorbents but also as oxidants under certain conditions and interact with plants and microbial communities. Our study aimed to observe the removal of 25 target organic compounds in unsaturated vertical flow CWs supplemented with GFH and MnOx and to assess their impact on microbial communities. The CWs were set up outdoors in PVC columns (Ø=20 cm, h=80 cm). The upper bed was filled with GFH, MnOx, or sand, and the lower with only sand. Both layers were 30 cm high, and separated by geotextile. The columns were either planted with *Iris pseudacorus* or left unplanted. Synthetic greywater, spiked with 25 compounds (average concentration 29 µg/L), was used to feed the columns. Columns with GFH beds showed higher removal efficiency, with an overall enhancement of 28% compared to the sand beds. This could be attributed to GFH's higher surface area and greater prokaryotic and fungal abundance in GFH beds. Cyclamate, sulfamethoxazole, bisphenol-S, ketoprofen, gemfibrozil, and acesulfame were removed around 20–70% more efficiently in GFH than in MnOx beds. Additionally, the relative abundance of some Mn- or Fe-oxidizing genes (*mnxG*, *mcoA*, and *mtoA*) in prokaryotic communities was higher in GFH and MnOx beds than in sand beds. Meanwhile, the plant effect was only apparent in MnOx beds, with an overall impact of 7%.

GHG Emissions and Soil Functional Gene Activity in an Innovative Nature-Based Wastewater Treatment System Within a Riparian Zone

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We investigated the GHG emissions, the factors controlling them and soil microbial functional gene activity in an innovative nature-based wastewater treatment within a riparian zone. The system consisted of the subsurface flow application of secondary-treated wastewater under field conditions. From April to October 2023, we alternated one week of wastewater supply with one week of drainage (wet/dry conditions) and conducted 5 samplings under each condition. For each sampling event, we assessed the N_2O, CO_2 and CH_4 soil emissions together with soil properties (temperature, water content, pH, N and C). Additionally, we assessed the activity (mRNA expression) of key genes involved in these processess: nosZ, nirK, amoAOA, amoAOB, mcrA and pmoA. We observed that N_2O emissions increased with a shallower water table and higher soil temperature and moisture, while CO_2 emissions decreased under wetter conditions. The soil remained a CH_4 sink throughout the experiment, although some plots with higher soil moisture exhibited positive emissions. Once the system was operating, flow intermittency did not cause significant differences in GHG fluxes between conditions. In wet conditions, for N_2O, we found significant positive correlations with amoAOA as well as with the nitrifiers/denitrifiers ratio, suggesting that N_2O production was more strongly influenced by nitrification. We found negative correlation between N_2O and nosZ/nirK ratio, which in addition to high nosZ/nirK ratio values, indicated that wetter conditions favored complete denitrification. For CH_4, we found positive correlations with mcrA, and methanogens/methanotrophs ratio. Furthermore, the positive correlation between mcrA and pmoA, as well as the mcrA/pmoA ratio indicated that both processes are stimulated by the treatment. The biogeochemical heterogeneity of riparian soils, in conjunction with flow intermittency and wastewater nutrient supply, supported both GHG production and consumption. Therefore, this nature-based wastewater treatment did not lead to a relevant increase in GHG emissions.

Facilitating Large-Scale Paludiculture in the Framework of the "PaludiNet" in Germany: Challenges, Network and First Results

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Although drained soils represent only 7% of agricultural land in Germany, they contribute to 41% of total agricultural greenhouse gas (GHG) emissions, with 80% of these emissions coming from agricultural used peatlands. Transitioning from drainage-based to wet peatland utilization offers substantial benefits, including reduced GHG emissions, halted peat degradation, improved water retention, and enhanced biodiversity. Moreover, so-called paludiculture can be used to produce peat-preserving biomass on wet soils, including horticultural substrates, building materials and bioplastics. However, the widespread adoption faces many obstacles, including complex approval procedures, high costs, limited expertise and the lack of established value chains for the biomass produced.

To address these challenges and facilitate the future transition to paludiculture, the German government is funding ten long-term projects to implement paludiculture on large scale. In total around 5500 ha project sites are distributed across different peatland regions and vary in terms of peatland type and site conditions, land ownership and area sizes, former land use and type of paludiculture. Their common goal is to demonstrate the entire process from planning and rewetting to the establishment, management, processing, and marketing of paludiculture products on a practical scale.

Within the projects, scientific studies are carried out on the effects of paludiculture on greenhouse gas emissions, nutrient fluxes, biodiversity and other ecological parameters, as well as on economic and socio-economic issues. To achieve nationally representative results, these studies must use comparable methods and comprehensively analyze the data. Therefore, the "PaludiCentral" as coordinating project has established the "PaludiNet", a collaborative network of the ten founded projects, in which thematic working groups discuss, test, and define methods, share results, and plan syntheses.

In our contribution, we explain how we tackle the challenges of implementing paludiculture on a large scale, illustrate the cooperation within the "PaludiNet" and present first results from the cross-project network.

Long-Term Assessment of In-Stream Free-Water Surface Treatment Wetland Performance in Agricultural Diffuse Pollution Mitigation

Jürgen Sarjas[1], Margit Kõiv-Vainik[1], Ilona Tamm[1], Kuno Kasak[1,2]

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Waterbodies downstream of farmed lands are at risk of eutrophication, mainly because of the nutrients leaching from agricultural fields. Nature-based water protection measures such as treatment wetlands (TW) are highly effective in reducing diffuse agricultural pollution and the risk of eutrophication. We present a long-term (7-year period) overview of the performance of a well-established in-stream free-water surface (FWS) TW system built to reduce diffuse agriculture pollution in a temperate climate zone in southern Estonia. The TW system consists of two subsequent FWS TWs with a catchment area of 2.2 km^2. The TWs are mainly vegetated with cattail (*Typha latifolia*) and common reed (*Phragmites australis*). Nearly full vegetation cover was attained in both wetlands by 2023, with the first wetland benefiting from the planting of cattails. The second wetland was left to develop vegetation naturally. Slightly higher diversity was noted in the naturally developed vascular plant community on the second wetland. Twice a month monitoring of water parameters was conducted from 2017 to 2023. The results for the entire study period show positive trends in removal efficiency for total nitrogen, total phosphorus, and total organic carbon with high seasonal variability, showing significantly higher efficiency during the vegetation periods. The retention rates of nitrogen, phosphorus, and organic carbon reached 11.33, 0.64, and 17.05 kg ha^{-1} d^{-1}, respectively. Our study provides insights into the temporal development of treatment efficiency, retention rate, and plant community of an in-stream FWS TW system in temperate climate zone and gives recommendations on how to improve in-stream TW design and management.

Free-Water Surface Treatment Wetland Performance Enhancement by Sediment and Biomass Removal and Valorisation

Margit Kõiv-Vainik, Lii Lopp, Jürgen Sarjas, Isaac Okiti, Ivika Ostonen, Mihkel Pindus, Kuno Kasak

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Treatment of wetland performance relies on several physical, chemical and biological processes. We must adequately manage treatment wetlands to support all these processes and improve wetland performance. The most common management methods are periodical above-water plant biomass harvesting and removal of accumulated sediments. To be consistent with the objectives of a circular economy and to meet sustainable development goals, it is essential to valorise the large quantities of harvested plant biomass and excavated sediments. Two studies were performed in southern Estonia on in-stream FWS TW mitigating agricultural diffuse pollution to meet these pollution mitigation and sustainable economy goals.

The first study determined the amount of nutrients removed with winter harvesting of above-ice biomass compared with below-ground storage. This information is essential for the performance evaluation and determining the potential valorisation possibilities for removed biomass. Our results showed that winter harvesting of *Typha latifolia* removed 50% of plant biomass, and 30% of N and P accumulated in the macrophytes. This removed biomass had a C/N ratio of 40, which makes it valuable as a potential feedstock for ecological building materials and charcoal production.

The second study assessed the impact of FWS TW sediment on agricultural soil fertility and crop yield during a large-scale field experiment. The sediment effect was compared with no amendment, digestate and N:P:K mineral fertilizer. During the extremely dry spring of 2023, the sediment amendment significantly increased soil moisture content (median 38% compared to 14% on other plots), leading to earlier sprouting and grain ripening of summer wheat. Furthermore, with sediment, a significantly higher yield was gained (median of 8.5 tonnes/ha). These studies confirmed that periodical biomass and sediment removal are beneficial FWS TW management methods, and both materials have value for the circular economy.

Improving Winter Performance of Constructed Wetlands: Microbial Resilience and Management Strategies

Rumiao Wang

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Constructed wetlands (CWs) are widely used for wastewater treatment, particularly for nitrogen removal, by leveraging plant-microbe interactions and natural biogeochemical processes. However, in cold climates, microbial activity declines significantly in winter, leading to reduced nitrogen removal efficiency. Low temperatures suppress enzyme activity, alter microbial interactions, and disrupt key nitrogen-cycling pathways, posing a major challenge for CW performance. Developing strategies to maintain microbial function and denitrification efficiency under cold stress is essential for optimizing CW operations in temperate and boreal regions.

This study explores the role of water-level management in stabilizing microbial communities and maintaining denitrification during winter. By comparing high-water-level (ice-insulated) and low-water-level systems, we found that elevated water levels effectively mitigate thermal fluctuations, preserving denitrifying enzyme activity and microbial diversity. While overall microbial composition remained stable, denitrifier interaction networks shifted significantly: cooperative associations strengthened within groups sharing the same nitrogen-reducing gene type (nirS or nirK), while competition increased between groups with distinct gene types.

Key denitrifying microbes, such as Bradyrhizobium and Pseudomonads, exhibited resilience in sustaining nitrogen cycling under cold stress. Enzyme activity analysis revealed contrasting responses across biogeochemical processes: phosphorus-related enzymes demonstrated cold tolerance, whereas nitrogen-cycle enzymes were highly temperature-sensitive. A critical temperature threshold (~5°C) was identified, above which microbial functions remained stable.

These findings suggest practical strategies for optimizing CWs in cold climates: (1) Maintaining higher water levels to leverage natural ice insulation, (2) Managing system temperatures near identified thermal thresholds, and (3) Enhancing cold-adapted microbial interactions. By integrating these approaches, CWs can achieve improved winter wastewater treatment efficiency, ensuring more stable nitrogen removal and long-term ecological sustainability.

Supporting Peatland Policy with Science and Innovation: The Dutch Approach

Joost Keuskamp[1,2,3], Gilles Erkens[4,1,5], NOBV Team[6], VIPNL Team[6]

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In The Netherlands, approximately 85% of peatlands is under agricultural use for dairy farming. These drained peatlands contribute significantly to national greenhouse gas emissions. In 2019, the Dutch government aimed to reduce emissions by 1 megaton CO_2-equivalents annually by 2030, requiring collaboration between science, innovation, and policy.

Two main programmes drive this effort: the Netherlands Research Programme on Greenhouse Gas Dynamics in Peatlands and Organic Soils (NOBV) and the innovation programme VIP-NL. NOBV focuses on developing a robust national monitoring system, uncovering the mechanisms of peat oxidation, and quantifying the effectiveness of mitigation measures. VIP-NL complements this work by assessing the socio-economic and practical implications of proposed measures, including their effects on farming systems, biodiversity, income, and implementation feasibility.

The presentation covers these programmes' structures and outcomes, highlighting the importance of mechanistic understanding for effective strategies. Case studies address dairy farming systems and alternative land uses, exploring emission reduction trade-offs with agricultural productivity and water management. Future sustainable peatland management pathways are also discussed for the Netherlands by 2050.

Session 7:
Wetland restoration

30 June
14:45-16:05, Moora Hall

1 July
15:00-16:15, Moora Hall
17:00-18:15, Moora Hall

3 July
11:15-12:30, Moora Hall

Nitrogen and Phosphorus Loss and Removal Before and After Rewetting of a Pump-Drained Agricultural Wetland

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In the summer of 2023, the Danish Nature Agency completed a restoration of the drained wetland area Gammelgaard Sø, situated in Eastern Jutland Denmark. The wetland with an area of 44 ha was pump drained from 1957 to summer 2023. Most of the area consists of organic soil with a carbon content higher than 12 %, and due to soil subsidence growing of cereals was ceased 20 years ago and instead land use was permanent grass and cattle grazing.

The study area has been monitored from November 2019 and onwards to establish yearly water balances and mass balances for nitrogen (N), phosphorus (P), and total organic carbon. The amount of N and P removed by harvesting the biomass has been measured during the 4-year management period before rewetting. The rewetting measures involved shutting down the pump station, filling in canals and ditches. Monitoring of inlet and outlet of water and nutrients was continued upon recovering the Wetland.

In the pre restoration period 2020, 2021, 2022 and 2023 (restoration started 1. July 2023) the yearly loss of TP in water pumped out was 1.0, 1.6, 1.4 and 1.8 P ha^{-1} $year^{-1}$, while the loss of TN amounted to 24, 48, 25 and 26 kg TN ha^{-1} $year^{-1}$. Harvesting took place in August 2021, in June and August 2022 and June 2023. The P removal of plant biomass through each harvesting ranged between 6.5-9.3 kg P ha^{-1}. The depletion in the redox-sensitive P pool of about 50% from 2020 to 2023 could primarily be attributed to plant harvesting.

The mass balances after restoration revealed that the wetland restoration resulted in nitrogen retention of 100 kg N ha^{-1} $year^{-1}$ (53 %) and a reduction in TP 0.7 kg P ha^{-1} $year^{-1}$ (-15 %) which mainly was due to loss of particulate P and dissolved non-reactive P.

Ecological Health in a Transboundary Lake

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The increasing eutrophication and algae bloom in global lakes have caused a range of symptoms that threaten ecosystem health and safety, such as biodiversity loss, habitat function decline, and harmful algae toxin increase, etc., becoming critical issues to be solved urgently. Unfortunately, the functioning of lake ecosystems is anticipated to deteriorate with ongoing global warming. Xingkai Lake is a Sino-Russian boundary lake. The increasing deterioration of water quality in Xingkai Lake has been observed for the past five decades, due to agricultural intensification and rapid wetland shrinkage and fragmentation. Here, we review the past development process of Xingkai Lake, sort out its ecological health issues, and look forward to the future challenges. This study deepens our knowledge of ecological health assessment in transboundary lakes and provides a scientific basis for the sustainable development of Lake Xingkai.

Restoration of Great-Fen Sedge (*Cladium Mariscus*) Habitat: Considering Phenotypic Plasticity

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Great fen-sedge *(Cladium mariscus*) habitats are priority habitats targeted by restoration programs and host to a rich faunal biodiversity. Facing several threats, like droughts, eutrophication, encroachment and land use, this habitat is restored by the Life Anthropofens project. The restoration success relies on several factors, among others the initial state of the habitat, the ecosystem functioning, adequate and targetable objectives, as well as long-term management. This study aims at understanding how restoration measures act on the plant community as well as the Great fen-sedge population.

We monitored Great fen-sedge vegetation on four alkaline fens in Northern France to characterize the community and distinguished two phenotypes and their changes after restoration.

On the sites hosting low Great fen-sedge densities (Villiers and Marchiennes), the allocation of resources in sexual reproduction and the higher plant diversity suggest that the population of Great fen-sedge on these sites has still not reached a mature stage and seems to stay in the recruitment stage. Environmental disturbances (mowing or trampling) create spaces that Great fen-sedge quickly recolonize by recruitment but also leave the possibility for other species to settle. Conversely, on the other sites (Sacy and Souche), the high density of individuals, vegetation height and litter thickness observed in habitats not subject to such disturbances, make recruitment almost impossible, and the Great fen-sedge allocate resources linked to survival rather than reproduction. Both vegetation facies suggest different strategies, one relying on dispersion and colonization, the other one relying on survival and competition. Shrub removal, without impacting the vegetation and the litter, promote the dense facies, whereas mowing and exportation promote a sparser but more diverse habitat and improve trophic conditions. Extending the monitoring in the future should give further conclusions about the hydrology restoration and long term habitat conservation.

Peat Depth Strongly Influences the Active and Passive Rehabilitation of Native Woodland on an Industrially Harvested Peatland in Ireland

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Restoration and rehabilitation of degraded peatlands is urgently required to mitigate carbon emissions and enhance biodiversity. These initiatives are often shaped by landscape configuration and diverse environmental factors. For example, in former industrially harvested peatlands in Ireland, restoration of sphagnum-dominated raised bog via rewetting may not be feasible in all cases, including drier and elevated areas. Thus, the creation of native woodlands through active or passive rehabilitation is an alternative approach. In this study, we established seeded and fertilized (active rehabilitation) and non-seeded, non-fertilized (passive rehabilitation) plots of birch (*Betula pubescens*) on bare peat in a degraded peatland site with variable peat depth, elevation, and openness. We assessed the survival, growth, and photosynthetic performance of tree seedlings after three years while also examining the establishment of native vegetation communities across all plots. For shallow peat plots (<10cm), preliminary results indicate higher density and growth of birch seedlings in seeded plots compared to unseeded plots. In contrast, for moderately deep peat plots (50-100cm), birch seedlings rapidly recolonized bare peat areas, irrespective of whether they were seeded and fertilized or not. Additionally, highly sheltered moderately deep peat sites exhibited a markedly greater overall vegetation recovery, in terms of vegetation cover and species richness, in both seeded and non-seeded plots when compared to exposed shallow and deep peat sites (>150cm). Therefore, site conditions are pivotal in selecting site rehabilitation methods. The integration of both active and passive restoration strategies is crucial for the recovery of post-extraction peatland sites. The findings of this study can inform peatland rehabilitation initiatives and their impact on ecosystem service delivery.

Interannual Variability and Uncertainty in Post-Restoration Wetland Greenhouse Gas Budgets

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Wetlands can sequester significant amounts of soil carbon over the long term due to high primary productivity and slow decomposition, particularly in climates with long growing seasons. Restoring wetlands is a promising nature-based climate solution to remove CO_2 from the atmosphere and mitigate climate change. However, restoration outcomes take years to decades to fully evaluate, making it challenging to predict future carbon dynamics, which are driven by climatic conditions and site-specific factors. Making multi-site comparisons is crucial for robust projections and regional up-scaling. Here, we present 45 site-years of continuous carbon flux measurements using the eddy covariance method from six restored freshwater to brackish and tidal wetlands in the California Delta. The restored wetlands, ranging in age from 3 to 25 years, provide unprecedented insights into how different restoration methods and design criteria influence carbon outcomes. Additionally, this long-term dataset enhances our understanding of interannual variability in both CO_2 uptake and CH_4 release, the latter being a key determinant of when a restored wetland becomes a net greenhouse gas sink. Our results show that most restored sites quickly become CO_2 sinks and near-neutral in terms of N_2O, while high CH_4 emissions delay climate benefits. Interannual variability plays a crucial role in determining the switchover time from source to sink. The first five years exhibit significant fluctuations, with switchover times reaching up to several hundred years in some cases. However, as wetlands mature, CH_4 emissions stabilize, and continuous CO_2 uptake reduces switchover time significantly. In addition, restoration outcomes are influenced by resrtoration approach and design. These findings have important implications for wetland restoration, policy, and management, highlighting the need for long-term monitoring and strategic planning to optimize climate benefits.

Riparian Zone Restoration in Latvia: Insights from Hydrological, Ecological and Wildlife Monitoring

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Forested riparian zones play a crucial role in maintaining ecosystem health by acting as buffers that protect water quality, stabilize banks and reduce erosion. These areas enhance biodiversity by providing habitats and migration corridors for numerous species. Additionally, they contribute to hydrological regulation by moderating water flow, preventing floods and aiding groundwater recharge. Their ecological functions, coupled with their recreational and aesthetic value, highlight the importance of conservation and sustainable management.

This study investigates a 1.4-kilometer section of the Tora River in north-central Latvia. The river is bordered by a 50-meter-wide riparian protection zone. Historically, forest management practices in this area have focused primarily on timber production, leading to even-aged spruce stands dominating the landscape.

To enhance water quality, support biodiversity, improve accessibility, and foster public engagement, a series of green and blue infrastructure initiatives were introduced in late 2023 and early 2024. These interventions included thinning dense spruce growth to promote broadleaf species, constructing a peak flow control structure to regulate drainage system runoff before it enters the river, and establishing a nature trail with educational displays on riparian processes and restoration efforts.

Long-term environmental monitoring, initiated prior to these measures, will continue to assess their impact. This monitoring includes tracking hydrological, chemical, and ecological parameters across the territory, such as groundwater levels and litter composition. In addition, wildlife cameras positioned in clear-cut areas, inside the forest and near the water provide insights into species distribution, their habits, seasonal and 24-hour activity patterns. Over a two-year period, camera data shows that clear-cut areas are primarily visited by deer and moose foraging for food, whereas a greater variety of species frequent forested areas and water sources, utilizing the stream as a movement corridor and drinking site. These results underscore the importance of maintaining riparian connectivity to support diverse wildlife populations.

Supporting Conservation of Inland Aquatic Vegetation with a New Global Evidence Synthesis

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Scientific evidence can inform conservation decisions and guide conservationists towards more effective, and cost-effective, actions. It is important that this evidence is accessible to those who need it. The Conservation Evidence database (www.conservationevidence.com) provides open-access evidence syntheses on the effects of conservation interventions, intended to support decision-making in conservation policy and practice.

This presentation will give an overview of our recent addition to the Conservation Evidence database: a global synthesis of evidence for the effects of interventions to conserve vegetation in inland aquatic habitats.

Aquatic vegetation contributes to good water quality, stabilises substrates, provides habitat and plays a key role in nutrient cycling. However, it faces a multitude of threats including pollution, invasive alien species, harvesting, modified water management and climate change.

Assisted by an international advisory board, we identified over 180 interventions that could be used to conserve vegetation (from macrophytes to phytoplankton) in aquatic habitats (from rivers to lakes, ponds, reservoirs and canals). Based on systematic literature searches in multiple languages, and recommendations from the advisory board, we collated and summarised over 300 publications quantifying the effects of these interventions.

There is a relative abundance of evidence in Europe or North America and for interventions to manage pollution, manage problematic species, or generally restore/create habitats. Specific interventions with a large evidence base include adding chemicals such as lime to reduce acidity, and managing food webs via fish populations (also known as biomanipulation). We found less evidence from Africa and Latin America, and for interventions addressing impacts of human disturbance and climate change. Many interventions have context-dependent effects. Contextual details within each narrative study summary, such as locations and implementation methods, help readers to judge relevance and likely effects in their situation. We encourage further testing of interventions to fill the identified geographic, conceptual and contextual knowledge gaps.

Decadal-Scale Changes in Ecosystem Functions in Restored Salt Marshes: Implications for Resilience and Trophic Support

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In coastal wetland restoration projects, permit-mandated monitoring plans rarely cover time spans relevant to critical ecosystem functions such as food web support and carbon sequestration. We compared metrics of ecosystem function in salt marsh islands created in 2004 and 2012 to reference areas in Galveston Bay (Texas, USA). The restored sites resembled reference areas in terms of emergent plant cover (primarily *Spartina alterniflora*), but did not provide a full range of comparable functions. Carbon sequestration potential in the older restored sites, as estimated by root biomass and soil organic content, approached that of the reference sites. However, trophic support for coastal food webs differed among sites; restored sites had up to 4x more infauna but half as much benthic microalgae. The older restored sites showed evidence of substantial subsidence and loss of higher elevation habitat, indicating that restored sites, unlike reference areas, do not have a high elevation refuge for retreat in response to sea level rise. Overall, when considering metrics of ecosystem function, the restored sites are providing a unique set of values to the coastal ecosystem, but these functions may not persist over time under pressure from sea level rise. This analysis suggests that the strategy of placing dredge material to create low elevation marsh habitat creates sites that may not persist for more than a few decades. Long-term monitoring plans will help assess vulnerability and identify priority areas for adaptive management or intervention to sustain the provision of ecosystem functions.

Contributions of Restoring Drained Organic Soils in Agricultural Use to Climate Change Mitigation Under EU Policy Frameworks

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Organic soils in agricultural use across EU27 member states account for a small portion of the total land area; however, they contribute approximately 7% of the EU27's total greenhouse gas emissions, positioning the EU as the second-largest emitter of greenhouse gases from drained organic soils. Consequently, rewetting drained organic soils is critical for achieving climate change mitigation targets. In 2024, the European Union adopted the Natural Restoration Regulation (NRR), which sets legally binding targets for the restoration of degraded ecosystems in Member States. This regulation recognizes the importance of drained organic soils in agricultural use and establishes restoration goals. Although various restoration measures are available to meet these targets, the NRR does not provide detailed guidance on their implementation. In this study, we use an economic land-use model incorporating multiple restoration strategies to evaluate the climate benefits of restoring drained organic soils used for agriculture. Our findings highlight the dynamics of various restoration measures in achieving restoration and the minimum rewetting targets set by the NRR. We show that while full rewetting provides the greatest emission reductions compared to intermediate restoration measures, it also leads to land being taken out of agricultural production, whereas intermediate restoration measures permit continued agricultural use of the land. Additionally, we evaluate the impacts of paludiculture on the restoration under different GHG prices. Our results indicate that, compared to the scenario without paludiculture application, the economic benefits from paludiculture strongly promotes full rewetting, leading to significant climate benefits. In scenarios with high GHG prices where the area of full rewetting remains similar, intermediate restoration measures play a crucial role in further mitigating emissions from drained organic soils. Overall, our findings suggest that the total climate benefit of restoration is a cumulative effect of all restoration measures, emphasizing the importance of implementing a combination of strategies.

Mimicking Natural Recovery Processes Promotes Flood Driven Phragmites Australis Establishment and Overall Mangrove Recruitment

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Estuarine macrophytes provide an important role in the suppression of disturbed upland sediments and often benefit from flooding events. We monitored changes in hydrophyte recruitment and sediment deposition around an innovative structure designed to emulate natural recovery processes while attenuating multidirectional flows. Sampling occurred over two years, including prior to, during and after a major flood event in a subtropical region on the east coast of Australia. Over a 500m long restoration site, sediment and mangroves established on both sides of the façade soon after construction, however floods promoted Phragmites invasion and ongoing competition into the disturbed environment post perturbation.

We found mangrove propagules naturally recruited within five 9m long x 1m wide transects prior to the flood but only 7.5% survived this event (from 406,900 to 31,900 mangroves over 500m). Mangrove recruitment continued post flood however Phragmites invasion increased heavily within 13 months (from 30,500 to 302,400 Phragmites over 500m). Overall, macrophytes showed a preference for the embayment floor area (-10 to +30cm ASL) over the bank edge (-60 to -10cm ASL) or slope zone (+30 to +90cm ASL).

By the end of sampling period and despite increasing competition from Phragmites for space, the average density of mangroves ranged from 4.3-8.2 trees per 1m^2, well above a mature mangrove forest. Prior to the flood, mean soil height increased 13.88 mm over 6 months (41.6 m^3 over 500 m) but amplified to 38.98 mm (116.9 m^3) after the flood. The total sediment storage over the two-year period was 71.7 mm (213.2 m^3), in conjunction with increasing macrophyte counts. Greatest increases in soil heights were within 1.5m of the facade.

Following major disturbances and as a response to fluctuations in sediment supply and flood intensity, pioneering macrophyte communities may change in composition, density and health while still maintaining critical ecosystem services.

Freshwater Habitat Restoration in Natura 2000 Network

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Freshwater biodiversity is experiencing a significant decline, not only in Europe but also globally. The Natura 2000 network plays a crucial role in both the EU's Biodiversity Strategy and the recently adopted Nature Restoration Law. This law aims to restore at least 20% of the EU's land and marine areas by 2030, with a strong emphasis on habitat restoration within the Natura 2000 network. To address the freshwater biodiversity crisis, setting clear and targeted habitat restoration goals within the network is essential.

In this study, we analyzed data on protected standing and running freshwater habitats (habitat codes 31xx and 32xx) within the Natura 2000 sites by selecting the most abundant habitats in each terrestrial biogeographic region. Next, we selected Natura 2000 sites where the conservation status of the habitats is excellent and explored context-dependent variables that could influence habitat conservation status, such as land use, lateral and longitudinal connectivity, ecological status, and edge density. Based on this, we identified key factors and thresholds for these variables to derive a restoration potential to guide prioritization within member states and inform about the restoration efforts needed across the Natura 2000 network.

Restore Floodplains as Sponge Landscapes by Dike Relocation in the Elbe Catchment

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Extreme weather events such as floods and droughts are increasing due to climate change, while the natural sponge function of the landscape has been lost. To meet these challenges, nature-based solutions like dike relocation are becoming increasingly important. Restored floodplains help to store water during dry periods and mitigate flood peaks.

In the last centuries, the river Elbe in Germany lost 80 % of its retention areas due to dyke constructions for flood prevention. This led to severe damage or destruction of many essential wetland habitats. Furthermore, dike raisings have proved to be insufficient to ensure protection. The creation of new retention areas by dike relocation is a major task in European river basin management. Also in the Middle Elbe stakeholders have attended to this challenge and around 14 dike relocation projects (2,600 ha of retention surfaces) are realized in the last 20 years, more than 3000 ha are in a planning phase.

The talk gives an overview of successfully implemented dyke relocations along the River Elbe and describes selected positive impacts on ecosystem functions and services.

One example is the Roßlauer Oberluch as one of the first large dike relocation project along the River Elbe which was implemented in 2006. To study exemplarily effects of floodplain restoration on biodiversity and ecosystem status, a specific floodplain research platform was established by the UFZ as part of the TERENO observatory programme. In particular, the stratified, randomised study design with interdisciplinary study plots, sets the scientific basis to all participating disciplines. It enables repeated surveys of the same plots for biotic (molluscs, insects, vegetation) and abiotic (soil, nutrients, pollutants, hydrology) factors. First flooding of the restoration area by the Elbe occurred in spring 2009. Results of the effects on biodiversity are visible.

Remove the Degraded Peat Before Rewetting but Where to Put It?

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It is widely accepted that rewetting peatlands is a crucial strategy to address global challenges such as eutrophication, biodiversity loss, and rising greenhouse gas emissions. However, long-term drainage and agricultural use have significantly altered soil characteristics, and these changes may hinder the restoration of lost ecosystem functions for several decades. Given the substantial financial investments and urgent societal needs, it is essential to make informed decisions about the restoration techniques employed in degraded peatlands, especially in agricultural landscapes. This will help avoid negative consequences and maximize the benefits to society.

There is evidence suggesting that removing the upper layers of degraded peat, typically less than 30 cm thick, before rewetting can reduce nutrient export, limit nutrient availability, and facilitate both active reintroduction and passive recolonization by oligotrophic plants. Laboratory and field experiments also indicate that methane emissions can be significantly reduced—by one to two orders of magnitude—through this approach.

Removing degraded peat before rewetting appears to be an effective short-term restoration measure to return the peatland to a more natural state. While this approach shows promise, it is not without uncertainties, and the critical question remains: what should be done with the degraded peat? It cannot be eaten, it should not be burned, but options like closing a ditch or mixing it with mineral soils exist. Ultimately, the most pressing questions are the pros and cons of these approaches and their carbon footprint.

Preliminary answers to these pressing questions will be derived from a mesocosm field experiment, equipped with a skyline GHG measurement system, porewater samplers, and probes that continuously measure redox potential, soil moisture, and the water table. The early conclusion is that topsoil removal (TSR) can be highly beneficial—but it depends on the context.

Identifying Restoration Demand in Nanxi Watershed (China) Using Adapted Water Framework Directive Indicators to Promote River Continuity and Ecosystem Health

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In the frame of China Europe Water Platform we developed a novel aproach using comprehensive data-sets of the Nanxi river basin to produced an analysis on its ecological status in order to identify restoration demand. The methodology combined different GIS derived data and survey data to generate an internal overall assessment of the ecological status of the Nanxi River, that was then used to identify restoration demand. The work developed adapted part of Water Framework Directive (WFD) and involved Water Quality, Morphological Alteration and Water Quantity indicators. Different kind of pressure variables were used to conduct a complete evaluation of these criteria. For some of the variables the data, which is often the result of comprehensive field surveys, was missing or incomplete, in this case the data was derived from other sources. Water quality parameters showed in general better tendencies than hydromorphological aspects and issues of water quantity. The restoration aspects were divided into the three subtopics of the ecological status classification. The results of the hydromorphological pressure indicators show that river diverse array of river impoundments, hydropeaking, organic deposition, armouring or clogging and bank protection perturbant characteristics were present in extensive areas of the watershed. The prevailing water quality, hydromorphological conditions, water quantity and restoration demand in the Nanxi river basin strongly require restoration measures and changes in river management to counteract the effects of present degradation and habitat loss. To achieve this we propose a set of measures, that we consider need to be adressed cumulatively so that problems related to restoration demand are solved.

Assessment of Greenhouse Gas Fluxes and Carbon Dynamics at an Abandoned Peat Extraction Site in Lavassaare, Estonia

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Peatlands, in their natural condition, act as carbon sinks by sequestering significant amounts of carbon in the long term. However, when peatlands are drained for other purposes, such as peat mining, agricultural use, or forestry activities, they become significant sources of greenhouse gases (GHG). In Estonia, there are large areas where peat extraction activities ended decades ago, and no significant restoration work has been carried out. All of these areas are serious sources of GHG and have the potential to transform from significant sources of carbon emissions into carbon sinks if they are converted into wetlands. This study was carried out at Lavassaare, an abandoned peat extraction site in Estonia, to determine the current status of GHG fluxes, investigate the key drivers in the carbon cycle, and provide a baseline assessment of the ecosystem's carbon cycle before possible restoration. As a result of two years of observations (January 2023-December 2024), it determined that the area was a carbon source of 84 ± 129 g CO_2-C m^{-2} y^{-1} in 2023 and 19 ± 53.2 g CO_2-C m^{-2} y^{-1} in 2024. At the same time, methane (CH_4) emission was measured as 1.28 ± 0.64 g CH_4-C m^{-2} y^{-1} in 2023 and 1.94 ± 0.69 g CH_4-C m^{-2} y^{-1} in 2024. Seasonal analyses indicate maximum carbon uptake in summer, with the lowest net ecosystem exchange (NEE) of -0.042 kg C m^{-2} $month^{-1}$in June 2024. In winter, the highest NEE value was recorded in December 2024 0.023 kg C m^{-2} $month^{-1}$. CH_4 fluxes reached a maximum in summer and a minimum in winter. Closed chamber measurements showed the highest CH_4 emission in summer in areas dominated by *Phragmites australis* species. In addition, N_2O emissions were maximum in *Phragmites australis* areas, moderate in *Epilobium angustifolium* areas, and low in bare peat areas.

CO_2, CH_4, N_2O Exchange in Re-Wetted Forestry-Drained, and Natural Peatlands in Estonia

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Natural peatlands are significant reservoirs and sequesters carbon (C). Drainage of these peatlands for forestry destabilises the C storage by accelerating peat decomposition, and alters the soil gas exchange of N_2O and CH_4. Re-wetting of drained peatlands aims to preserve their C reservoir and restore the peat accumulating conditions. Quantifying ecosystem gas balances after re-wetting is needed to assess the effectiveness of peatland restoration as a climate change mitigation strategy, but it necessitates long-term monitoring of the greenhouse gas fluxes. However, research only limitedly covers restored peatlands in their full diversity; data is insufficient especially from periods beyond the first years after re-wetting.

We applied a field measurement-based modelling approach to determine the annual CO_2, CH_4 and N_2O balances for Kuresoo and Valgeraba bogs in Estonia, comparing forestry-drained sites re-wetted five years ago to their natural reference sites. We examined data from manual measurements of greenhouse gas fluxes from the soil from November 2023 to October 2024, accompanied by data from continuous measurements of soil water content, soil water table level, soil and air temperatures, and photosynthetically active radiation. The CH_4 and N_2O fluxes, and the net ecosystem exchange (NEE) outside the growing season, were determined from the series of gas samples from static, opaque chambers analysed by gas chromatography. NEE during the growing season was derived from gas flux measurements with a transparent dynamic chamber and a portable CO_2 gas analyser. The annual balances of the measured gases are compiled using linear interpolation, or modelling based on their dependencies with the environmental parameters.

Drivers of Porewater Quality in Rewetted Peatlands: Linking Vegetation, Soil Properties, and Hydrology

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Peatland rewetting is widely recognized as an effective nature-based solution for restoring ecosystem functions, including carbon sequestration, flow regulation, and improved downstream water quality. However, assessing the success of rewetting remains challenging due to the diversity of peatland types, variability in ecological responses, and time lags in hydrological and biogeochemical recovery. One key aspect of rewetting outcomes is water quality, both in porewater and outflowing water, which is influenced by multiple ecological factors, including vegetation community composition, soil properties, hydrological processes, and catchment morphology. Understanding these relationships is essential for developing reliable indicators of restoration success. To address this, we conducted fieldwork at 19 rewetted afforested peatland sites and a paired drained reference site across Sweden and Finland. We measured porewater and ditch water quality (DOC, DON, nutrient concentrations, SUVA, pH), vegetation functional communities, water table depth, soil properties (C/N ratios, bulk density), and catchment properties (discharge area, elevation, latitude). While ongoing data analysis will reveal trends and relationships, we anticipate identifying key indicators of restoration success, providing valuable insights for both researchers and landowners. This talk will present emerging findings and discuss their potential application in the development of monitoring restoration frameworks.

A Biogeochemical Perspective of Peatland Restoration

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Peatlands are vital carbon sinks, but large-scale degradation has affected their ability to sequester carbon. Peatland ecosystem health is currently being restored to reverse carbon losses or potentially increase carbon accrual, but the time required to restore a damaged site is unclear. This study used a space-for-time substitution approach to study peatland sites in close vicinity that were at different stages of restoration: newly restored, mid-restoration and long-restoration sites were compared with a damaged and a benchmark near-natural peatland. Restoration was performed primarily through blocking existing drains to raise the water table. Indicators of peat health, including moisture content and oxygen levels, were measured across 50-cm depth, demonstrating increased moisture and decreased oxygen along the restoration gradient. The restoration efforts were also visible through vegetation survey and associated chemical isotopic signatures, with a clear shift from more heterogeneous landscapes to graminoid dominance. A clear shift of microbial communities and associated functions was observed along the restoration gradient through metagenomic approach. Finally, the dissolved organic matter and chemical composition of the peat samples (analysed through FTIR) also supported evidence of peatland restoration. Finally, the carbon isotopic composition was determined by CF-IRMS, showing an enrichment of $\delta^{13}C$ in the upper layers of near-natural and long-restored sites, while damaged and recently restored sites exhibit more depleted $\delta^{13}C$ values across all depths, offering deeper insights into the biogeochemical processes occurring during restoration. Our findings demonstrate the importance of a multidisciplinary approach in assessing peatland restoration. By integrating botanical, geochemical, and microbial analyses, this study provides a comprehensive understanding of the trajectories of change in restored peatlands and their implications for carbon cycling processes, contributing to the broader goal of achieving net-zero carbon emissions.

Restore, Rehabilitate, or Refrain? Ecosystem Service Provision in Accidental, Created, and Restored Wetlands

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Salt marshes provide valuable ecosystem services, including carbon storage, water quality improvement, and recreation opportunities, but these ecosystems have suffered extensive losses due to urban development. The desire to mitigate environmental stressors like water pollution and biodiversity loss and create greenspace for urban residents has prompted renewed interest in creating or restoring marsh ecosystems in coastal cities like New York City (NYC), USA. However, marsh restoration programs typically hold some key assumptions that merit further scrutiny. One such assumption is that restoration and management of plant community composition (planting native species and removing invasive species) will facilitate ecosystem functions like biogeochemical cycling, and in turn ecosystem services like carbon storage and nutrient removal. Much scientific literature has documented, however, that plant community composition does not reliably predict wetland ecosystem function, and restored or created wetlands are rarely compared to wetlands with unmanaged, self-organized plant communities in the urban environment. In this study, we examined plant community composition and key functions (carbon storage, nitrogen cycling) in five tidal salt marshes in NYC that differed in origin (created, restored, and "accidentally" formed marshes without intentional restoration or management). We found that while created and restored marshes under active plant community management supported more biodiverse and native plant species assemblages, they did not differ significantly from accidental marshes in aboveground biomass, soil organic matter, or nitrogen removal potential. Further, social surveys demonstrated that local residents found both restored and accidental marshes aesthetically pleasing and valued them for habitat provision and recreation opportunities. Our findings point to a need for clear delineation of wetland restoration goals that are aligned with desired ecosystem services. While restoring native vegetation remains a primary goal of wetland restoration, we cannot assume that restoring and maintaining native vegetation necessarily facilitates desirable ecosystem functions and regulating and cultural ecosystem services.

Assessing the Water Regulatory Capacity of Raised Bogs in Estonian Using a Triplet-Design Approach

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In recent decades, Europe has endured increasingly severe flooding and drought events, resulting in extensive economic damage, loss of lives, and environmental impacts. Peatlands have the capacity to regulate water flow within the landscape and mitigate the effects of extreme weather events. However, degradation due to drainage and land-use changes has significantly reduced their "sponge" function, boosted even more by the straightening of rivers. In response, the SpongeBoost project (funded by Horizon Europe program) was initiated, bringing together partners from across Europe, spanning from the Azores to Estonia. As part of the project, we employ a triplet design—comparing near-natural, degraded, and restored peatland sites—to assess the effectiveness of restoration in enhancing water retention and ecological integrity in Estonian peatlands.

Two regions in Estonia have been selected for the triplet-design research: one in southeastern Estonia, consisting of Labassaarõ, Ess-soo, and Kungjärve bogs, and another in central-eastern Estonia, comprising Männikjärve, Laiuse, and Vaimastvere bogs. A monitoring network has been established in these sites to collect high-resolution water level and discharge data. Water level data is recorded using automatic pressure transducers in monitoring wells, while discharge is measured using rating curves or triangular-notch weirs. Additionally, one of the objectives is to leverage multi-temporal satellite imagery and multispectral drone data to evaluate how restoration interventions influence surface wetness and resilience to extreme weather events.

The results of this study contribute to the broader SpongeBoost framework, which aims to scale up nature-based solutions for climate adaptation. Our findings will identify best monitoring practices and reinforce the importance of long-term monitoring of targeted peatland restoration actions, emphasizing their role in mitigating floods and droughts in a changing climate. Evaluating restoration processes is crucial for informing adaptive management strategies at the national level.

Session 8:
Wetlands monitoring

30 June
11:15-12:50, Moora Hall
16:45-17:45, Moora Hall

1 July
11:30-13:00, Moora Hall

SAR Coherence and Backscatter Time Series for Monitoring Restored, Rewetted, Abandoned and Natural Peatlands

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Peatlands, vital for biodiversity and carbon storage, are threatened by human activities such as peat extraction, drainage for agriculture, and climate change. Monitoring peatland restoration and rewetting is crucial for biodiversity conservation and achieving greenhouse gas reduction goals. Peatlands of different statuses (natural, abandoned extraction, restored, rewetted) exhibit distinct vegetation, soil, and ecohydrological characteristics. This research uses time series SAR backscatter and coherence to study natural and restored peatlands across Canada. Soil moisture data were collected from seven natural peatland sites in Canada, spanning Sentinel-1's data period (spring 2017 to respective soil moisture end dates). Though no soil moisture data is available for restored and rewetted sites, their spatial locations were identified for over 200 restoration sites using techniques like the Moss Layer Transfer Technique (MLTT) and ditch blocking. Natural peatlands, abandoned extraction sites, and active extraction sites were also included in the study.

Soil moisture and backscatter correlations were analyzed using Seasonal and Trend Decomposition using Loess (STL), which isolates non-seasonal changes. Results showed similar trends in backscatter and soil moisture but significant differences between peatlands with varying surface conditions. Interferometric coherence, which measures pixel similarity, was also analyzed. Despite vegetation in some peatlands, many sites showed high coherence, aiding in peatland mapping and studying changes in surface height and soil moisture. Coherence data from natural, restored, and disturbed sites (2017–2024) revealed the lowest coherence in rewetted sites, with high variability, suggesting uneven water regimes and increased upland vegetation. Coherence differences were most evident in summer, with natural and MLTT peatlands showing higher coherence than rewetted or abandoned sites. The analysis found no significant coherence differences based on time since restoration, possibly due to increased upland vegetation. These findings highlight the potential of SAR backscatter and coherence for monitoring ecohydrological changes in peatlands under different management practices.

Topographic Variations Corresponding to Vegetation Patterns, Verified by Use of Airborne Drone in a Mountain Peatland in Hokkaido, Japan

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Cold region peatlands exhibit heterogeneous vegetation patterns at fine spatial scales. Topography plays a crucial role in regulating these patterns by creating uneven hydrological conditions to which wetland plants are sensitive. However, few studies have quantitatively examined how topographic conditions influence vegetation across an entire peatland. In this study, we developed a model to represent the relationship between detailed topography captured by an airborne drone and vegetation in a mountain peatland. The study area (0.15 km^2) is located in Hokkaido, northern Japan, at approximately 870 m above sea level. The site features diverse vegetation, including Sphagnum moss, sedges, reeds, shrubs, and a community disturbed by deer and human trampling. We generated a high-resolution (10 cm) digital terrain model (DTM) of the peatland using aerial imagery obtained from an airborne drone and derived 18 topographic variables. Based on vegetation survey data, we identified nine plant communities and recorded vegetation types at 1,273 locations across the peatland using GNSS positioning. We constructed a random forest model to classify vegetation types from topographic variables and assess predictive performance. The variables that significantly improved model accuracy, in order of importance, were distance from surface water, altitude, relative height to surroundings, terrain ruggedness, distance from the forest edge, slope, and wetness index. The model's predictive accuracy varied by vegetation type, ranging from 34% (disturbed community) to 88% (reed), with an overall accuracy of 67%. Significant differences were observed among many vegetation types for the most influential variables. The predicted vegetation map revealed distinct distributions of Sphagnum species along the altitude gradient and localized distributions of reed and shrub communities. These findings indicate a topographic niche for each vegetation type and underscore the importance of incorporating multiple topographic elements when modeling peatland vegetation.

Monitoring the Spatio-Temporal Patterns of Vegetation Water Stress Conditions in Čepkeliai Peatland

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Peatlands, characterized by their water surplus, exhibit high sensitivity to climate change, which drives shifts in ecohydrological conditions, particularly during drought periods. In raised bogs, where atmospheric precipitation represents the exclusive water input, it is essential for preserving hydrological equilibrium and supporting peatland vegetation. Integrating in situ measurements with remote sensing techniques provides a practical approach for assessing water stress patterns across extensive areas, as evidenced by the phenological responses of these ecosystems. The study was conducted in the Čepkeliai raised bog, a semi-pristine peatland in south-eastern Lithuania. The main aim of this research was to find spatio-temporal patterns of peatland vegetation stress conditions, according to precipitation, expressed by Standartized Precipitation Index (SPI), Water Table (WT) derived from field measurements and Vegetation Condition Index (VCI) observations from satellite data. Terra MODIS satellite data of the growing season were used for 12 years (2012-2023) to monitor the long-term vegetation conditions and identify spatio-temporal vegetation water stress patterns.

The study findings indicate that WT, a key determinant of vegetation health, is strongly associated with 30-day precipitation, particularly in June. SPI at multiple timescales significantly correlated with VCI. Notably, strong positive correlations between VCI and WT were observed in June and September, highlighting the critical importance of these periods for monitoring vegetation water stress in raised bog ecosystems. Considering the temporal variation of WT, 30-day precipitation and SPI, June and September of 2015, 2016, 2018, and 2019 emerged as the months with the most pronounced dry conditions across the 2012-2023 period. The spatial distribution of VCI values during these years revealed areas most susceptible to water stress within the raised bog: moderate and severe drought areas were distinguished in the western part of the raised bog in June. Extremely drought areas occur in the western part of the raised bog in September.

Using L-Band SAR Data to Assess the Wetness of Peatlands

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In peatlands the water table depth has been observed using Synthetic Aperture Radar (SAR) to monitor the health of the bogs. Using this satellite data the water table depth and wetness of bogs can be remotely monitored to assess their condition, particularly to advise future restoration work and evaluate the results of restoration. Previous work using C-band SAR data has observed the water table depth and soil moisture using the backscatter intensity of dual-pol data. Our work assesses the capability of using L-band data (a longer wavelength from C-band) to penetrate deeper into the peat compared to C-band and assess the water table depth and wetness of bogs.

Using data from ALOS-2, we monitored the water table depth and wetness of bogs in Scotland and Sweden. Multiple known decompositions, including the Cloude-Pottier, Yamaguchi and Touzi decompositions, were tested on identifying the absolute wetness and changes in the wetness of the bogs. Additionally, change detection methods looking at the change matrix was used to assess the changes in the degree of wetness. The SAR data was compared to in-situ measurements from water loggers in Scotland and weather station data in Sweden. Overall, results showed that identifying changes in the wetness of bogs gave better results compared to measuring the absolute wetness. Specifically, the eigenvalues from the change matrix for dual- and quad-pol data demonstrated a strong correlation with changes in the wetness of the bogs (R^2 = 0.89 and 0.88 respectively). Additionally, it was assessed how the precipitation and temperature from a varying number of previous days from the satellite acquisition affected monitoring the wetness of the bogs. Using this L-band data show promise for future L-band SAR missions (NISAR) to assess the condition of peatlands and monitor the water table depth.

Investigating the Impact of Extreme Flood Events on Erosion Within Palmiet Wetlands in the Cape Floristic Region, South Africa

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Wetlands are important ecosystems in that they support biodiversity and provide society with essential ecosystem services. Palmiet wetlands, a type of valley-bottom wetland, are peatlands dominated by *Prionium serratum* that provide important flood attenuation services. This study investigated how nine palmiet wetlands distributed across the Cape Floristic Region of South Africa were affected by extreme floods in September 2023. The September 2023 floods lasted for three days (from 23 to 26 September) with some areas receiving up to 300 mm of rainfall in a day. Two methods, digitization and index analysis, were applied to map vegetation change in Sentinel-2 imagery for two timesteps: May and November 2023. For digitization, four classes were mapped: wetland vegetation, bare ground, river and invasive alien trees. For the index analysis, two indices were calculated: Normalized Difference Vegetation Index (NDVI), a measure of greenness, and Bare Soil Index (BSI), a measure of bare ground. Results showed that the area of bare ground within the wetland was found to have increased significantly following the floods ($w=18$, $p < 0.05$). In addition, both NDVI and BSI were significantly affected by the September 2023 flood, with bare soil significantly increasing ($t=-6.35$, $df=8$, $p < 0.01$) and NDVI significantly decreasing ($t=5.61$, $df=8$, $p < 0.01$) following the floods. Wetlands that were impacted by the September 2023 floods, such as the Onrus palmiet wetland, may have been undermined by alien tree invasion, impoundment and groundwater drawdown due to agriculture. It is possible that these drivers have reduced the resilience of these wetlands to the point that they are not able to withstand the shocks of extreme rainfall events, also decreasing their flood attenuation ability. To ensure the long-term resilience of these ecosystems, these wetlands urgently need protection, and clearing of invasive alien trees in and around these systems should be prioritized.

Radar Measurements Using WBSCAT for Supporting Multi-Frequency Snow Water Equivalent Retrieval and GEO- and LEO SAR Development

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Seasonal snow cover forms a volatile component of the terrestrial cryosphere, with large inter-annual variability in snow cover extent and duration. Approximately 1/6 of the population of the world relies on seasonal snow as the main source of freshwater both for human consumption and agriculture. The amount of freshwater stored in snow is often expressed as the Snow Water Equivalent (SWE). However, satellite sensors, in situ networks and Earth system models currently provide inadequate information on SWE, exhibiting large inconsistencies and biases between different approaches.

A promising method for monitoring SWE from space is based on repeat-pass interferometric SAR (d-InSAR). The approach has been demonstrated to provide SWE estimates using ground observations, airborne campaigns and space-borne SAR. Several upcoming satellite missions will dramatically increase the availability of suitable, low-frequency SAR observations which are optimal for the method; these missions include the NASA-ISRO Synthetic Aperture Radar (NISAR) and the Radar Observing System for Europe at L-band (ROSE-L). Moreover, Hydroterra+, a candidate mission for the European Space Agency's 12th Earth Explorer opportunity, proposes to use a SAR in geosynchronous orbit to observe the water cycle, including snow cover.

In order to study the opportunities presented by multi-frequency SAR observations, as well as the high temporal frequency provided by a mission such as Hydroterra+, the ESA WBSCAT ground-based radar system has been deployed in Sodankylä, Finland, to observe snow cover signatures for three winter seasons overlooking a boreal wetland. The wetland typically freezes over the winter, presenting a relatively smooth subnivean surface. Radar measurements are supported by instruments collecting ancillary data on snow depth, SWE, snow and ground temperature profiles, and weather conditions. The results indicate great potential based on the combination of multi-frequency observations from backscatter and interferometric phase. High temporal sampling matching HydroTerra+ capabilities is proven to enhance retrievals.

Finding Suitable Locations for In-Stream Wetland Creation/restoration: Comparing Suitability Analysis with Machine Learning Approach

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Wetlands are essential nature-based solutions (NbS) that support biodiversity, regulate water quality, retain nutrients, and sequester carbon. However, wetland loss due to agriculture and land-use changes necessitates strategic site selection for in-stream wetland restoration and creation. Identifying suitable locations requires robust spatial modelling that integrates key environmental variables. This study evaluates Random Forest (RF), a machine learning model, and the Analytical Hierarchy Process (AHP), an expert-driven decision-making method, for assessing in-stream wetland suitability in Estonia, where extensive wetlands have been drained.

Both methods incorporated slope, topographic wetness index (TWI), flow accumulation, soil organic carbon (SOC), and clay content. Geospatial datasets were processed at 10m and 50m resolutions to assess spatial scale impacts. Additionally, local and global datasets were analyzed to examine data origin effects. AHP used predefined weights, while RF was trained on existing in-stream wetlands and non-wetland land covers (forests, shrublands, grasslands, and arable land) to identify suitability patterns.

SHAP analysis in RF identified SOC and flow accumulation as key predictors, while AHP assigned higher weights to SOC (0.51) and slope (0.26). The highest RF hold-out accuracy (0.89) was at 50m local resolution. A validation framework using historical wetlands confirmed RF's superior predictive performance, with AUC values reaching 0.83 at 10m and 0.80 at 50m. In contrast, global RF models showed lower performance (AUC: 0.58–0.72), emphasizing the importance of high-resolution, locally calibrated data. AHP demonstrated greater stability across resolutions (AUC: 0.63–0.80) due to static weights.

RF adapted to spatial heterogeneity, while AHP applied structured decision-making in data-limited contexts, revealing a trade-off between classification accuracy and predictive differentiation. Confusion matrix analysis suggests false positives and negatives may indicate areas for future wetland development or degradation. Our findings support a hybrid approach where AHP serves as a screening tool while RF refines site selection, enhancing wetland restoration planning.

Environmental Contaminants and Their Influence on Ecological Risk and Microbial Dynamics in a Ramsar Wetland Sediments in Hong Kong

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This study explores the presence of heavy metals (HMs; including Cr, As, Pb, Cd, Mn, Ni, Cu, and Zn) and antibiotics (ABs: tetracyclines, quinolones, macrolides, sulphonamides), their associated ecological risks, and their effects on microbial populations in sediment from three distinct habitats—mudflat, mangrove, and *Gei Wai* (inter-tidal shrimp ponds)—within the Mai Po Ramsar wetland in China. Our data indicated that *Gei Wai* sediments were least polluted. PNEC analysis suggested that HMs presented a higher threat to microbial communities than antibiotics. The composition and functionality of microbial communities were assessed using 16S rRNA sequencing, and Proteobacteria was identified as the most abundant group and *Vibrio* as a common genus across all habitats. Mangrove sediments had the highest microbial diversity, followed by *Gei Wai* and mudflat. PICRUSt indicated dominant roles in carbohydrate and amino acid metabolism, with nitrogen metabolism particularly prominent in mangroves. This study underscores the dual impact of pollutants on ecological health and microbial ecosystems, highlighting the critical need for wastewater management to safeguard wetland environments.

A Deep Learning Approach to Wetland Fish Population Monitoring

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Wetland monitoring is designed to detect and assess the potential impacts of mining in the Alligator Rivers Region, northern Australia. Manual processing and analysis of large quantities of remotely sensed data (e.g. underwater video and aerial photos) is resource intensive. Artificial Intelligence (AI) methods for analysing such data promise improved efficiency but there is a paucity of research and frameworks for successfully transitioning and refining a wetland monitoring program to an automated or semi-automated system. The extent to which models can generalize across habitats is not well understood. Training AI on monitoring data needs to account for many unknown variables, including the number of annotations and labels required, varying among taxa, season and environments.

We developed automated identification and quantification of flora and fauna by generating large datasets of expertly annotated and labelled training data for training of AI methods.

We developed a novel framework using AI to identify and count individual fish species from the Alligator Rivers Region fish monitoring program. This included a training dataset of ~230k images and ~500k polygon annotations for 18 tropical freshwater fish taxa. The model was applied to a test dataset of video to measure abundance of each fish taxon (MaxN) in six (control and exposed) wetlands, Kakadu National Park. We found good efficacy in our AI method for deriving the abundance of multiple fish taxa in underwater video compared to trained human observers. Variability in fish detection was observed between habitat types, but that was reduced with cumulatively increasing habitat-specific training data. To the best of our knowledge, the training dataset developed is the largest generated for segmentation of tropical freshwater fish worldwide. It also has huge potential for expanding the volume of video data that can be analysed for an area and generate finer detailed ecological datasets.

Wetlands in Drylands Dynamics: Between Natural Variability and Climate Pressure

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In the context of climate change, wetlands in semi-arid environments face increasing pressures due to shifts in precipitation and temperature patterns. In Southern Africa, the remote sensing-based monitoring of these wetlands remains limited despite their crucial role as they are the primary water source for wildlife during the dry season and ecological niches for specific fauna and flora. Furthermore, the alternating presence of water between dry and wet seasons plays a key role in storing and emitting greenhouse gases. Therefore, assessing and quantifying changes in this wetlands hydroperiod is a significant challenge in understanding the functioning of these vulnerable ecosystems.

Our study focuses on an example of a dystrophic and endorheic savanna ecosystem: Hwange National Park in Zimbabwe, a protected area that experiences limited anthropogenic pressures. We developed a method to quantify surface water variability in these wetlands and classify them based on their degree of intermittence using Landsat satellite imagery from 1987 to 2022. To further characterize changes in these environments, we quantified the evolution of surface water, vegetation, and bare soil at various distances from the wetlands over the same period using a linear spectral unmixing method.

Our findings highlight a temporal lag between precipitation events and wetland refilling during the wet season. While the monthly frequency of wetland occurrence has not significantly changed since 1987, our spectral unmixing approach reveals a significant decline in wetland water surfaces, along with opposing dynamics between vegetation and bare soil. Additionally, this reduction in water presence is correlated with rising temperatures in the region. Our results underscore the importance of incorporating inter- and intra-annual hydrological dynamics into water resource management strategies in semi-arid environments, where water availability is a critical conservation issue.

Early Vegetation Regeneration in Riparian Wetlands Following an Extreme Flood: Spatial Variation Along the Entire River

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Two spatial frames have been adopted to explicate ecological processes: local scales that concentrate on specific processes in defined areas and broad scales that focus on overall patterns of extensive areas. In the summer of 2020, a 1-in-over 200-year rainfall event caused a record-breaking extreme flood along the Seomjingang River of southern Korea, devastating a substantial portion of vegetation. This study examines early regeneration patterns of riparian wetland vegetation following the flood along the entire main stem of the river. Detecting vegetation in greater detail, rather than relying on vegetation indices such as NDVI, can help capture the complexity of vegetation types in broad-scale studies. Using spectral bands and indices of Sentinel-2 images, we built a machine-learning model to classify the vegetation into herbs and woody plants. The regeneration rates of herbs and woody plants were calculated for each 1 km section by comparing the classification results.

Inequality and spatial autocorrelation analyses revealed spatial heterogeneity in the regeneration pattern. Woody plant regeneration proceeded at a slower rate along the river but showed spatially clustered patterns than that of herbs. In addition, pre-flood vegetation composition and post-flood vegetation cover were the key factors influencing the regeneration rates. The pre-flood vegetation composition of higher woody plants had dual effects: accelerating herb regeneration while inhibiting woody plants regeneration. In contrast, higher post-flood cover of woody plants facilitated the regeneration of both vegetation types, whereas higher post-flood herb cover only enhanced the regeneration of herbs. Identifying patterns with detailed vegetation information can help establish spatial priorities for managing riparian wetland ecosystems after extreme flooding. Management and conservation of riparian wetland ecosystems should consider vegetation type-dependent strategies and spatial heterogeneity in regeneration processes.

Spatial Scaling of Categorical Data, the Multi-Dimensional Grid-Point Scaling Algorithm

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Modeling the effects of vegetation changes on ecological processes in wetlands often requires the spatial scaling of categorical data. Since class definitions are scale-dependent, up-scaling categorical data must account for that dependence to represent the vegetation cover condition at the lower spatial resolution. However, most decision rules that aggregate categorical data do not produce scale-specific class definitions but label the larger grid cell with one of the original class labels from the higher-resolution data, which leads to a high loss of cover information. In contrast, the multi-dimensional grid-point (MDGP) scaling algorithm generates scale-specific class definitions based on frequently occurring relative abundances of classes at the higher resolution.

We evaluated the tradeoffs in class precision (how much original information is retained in a scaled grid cell) and class representativeness (the minimum proportion of the larger landscape that a scaled class must occupy to be maintained) on compositional information loss and class detection accuracy of scaled classes from multispectral Landsat data. We compared the performance of the conventional majority rule with the MDGP-scaling algorithm.

For two study areas in the Florida Everglades (USA) wetland, the MDGP-scaling retained between 3.8 and 27.9% more compositional information than the majority rule as class-label precision increased. Increasing class-label precision and information retention also increased overall spectral class detection accuracy from Landsat data by up to 8.6%. Rare class removal and increase in class-label similarity were controlled by the class representativeness threshold, also leading to higher detection accuracy as class representativeness increased.

When upscaling categorical data across natural landscapes, negotiating trade-offs in thematic precision, landscape-scale class representativeness, and increased information retention in the scaled map results in greater class-detection accuracy from lower-resolution, multispectral, remotely sensed data. MDGP scaling provides a framework for weighing trade-offs and making informed decisions on parameter selection.

A Call for Water – Investigating the Water Requirements for the Endangered Australasian Bittern (*Botaurus Poiciloptilus*)

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Water extraction for agriculture and human consumption, compounded by climate change-induced weather events, has disrupted the natural flow regimes of river and wetland systems globally. These changes critically impact species dependent on wetland ecosystems. This study focused on the Endangered waterbird, Australasian bittern (*Botaurus poiciloptilus*). In Australian regulated river systems, managed delivery of water (environmental water) is increasingly being delivered to maintain Australasian bittern habitat and trigger breeding. However, little is known about their response to varying hydrological conditions, particularly calling patterns in relation to environmental water and unregulated floodplain inundation. We investigated the vocalisation phenology of the Australasian bittern in five wetland complexes in Australia's Murray-Darling Basin from 2016–2022. Using continuous acoustic monitoring, we identified the onset, duration, and spatial and temporal variation in bittern calls. We also developed a predictive model using 11 environmental features that predicted calling behaviour with an accuracy of 93.5%. The highest ranked features related to water depth and watering duration. Site specific trends in bittern calling and a preference for austral summer conditions were also evident. Our results demonstrate that of the 10 detected calling events, four were associated with a combination of environmental water and unregulated flows, four with environmental water, and two with unregulated flows. We detected unexpected winter calling events which highlights the value of year-round monitoring. Our findings highlight the critical role of hydrological regimes to support Australasian bittern occupancy and breeding and suggests the potential for managing environmental water flows with other wetland species temporal vocalisation patterns.

A Multi-Scale Approach to Map Surface Soil Moisture in Boreal Baltic Coastal Meadows of Estonia

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Boreal Baltic coastal meadows, protected under the EU Habitats Directive (Annex I, 1992), are semi-natural ecosystems shaped by traditional land-use practices such as grazing and agriculture. These land-uses have preserved essential ecosystem services, including carbon storage, erosion control, flood regulation and habitat for wading birds.

However, these ecosystems are increasingly subject to climatic disturbances, such as prolonged summer droughts, storm surges linked to extreme weather events, and changes in land use, including agricultural intensification and abandonment. To monitor the complex dynamics influencing coastal meadows, estimations of biophysical variables from remotely sensed imagery, such as Surface Soil Moisture (SSM), which represents the water content in the top 5–10 cm of soil, is particularly important. SSM plays a crucial role in regulating key ecological processes, including microbial respiration, carbon cycling, and soil structure—processes vital for ecosystem resilience.

We use a multiscale synergy approach to study SSM, integrating UAV and Landsat. First, high-resolution UAV imagery is used to capture fine-scale spectral reflectances, which are then used to estimate the Temperature Vegetation Dryness Index (TVDI). This index is based on the relationship between the Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST). The TVDI is calibrated with in-situ volumetric water content percentage (VWC%) measurements to estimate SSM.

Second, we integrate the high-resolution UAV-derived SSM to Landsat imagery to model SSM at a broader scale, employing a XGBoost model. While the estimation of SSM at high spatial resolution retrieves different results depending on the study area, the predictive capabilities of the XGBoost model provides robust results with RMSE below 10%. This approach aims to develop a scalable and accurate methodology for SSM monitoring, improving our ability to map fine-scale moisture variations while scaling up to landscape-level assessments, assessing the effectiveness of conservation frameworks for a continued monitoring, complementing previous studies.

Managing Water Control in Atlantic Coastal Wetland Grasslands for Grazing and Amphibian Conservation

Lilia Mzali, Vincent Boutifard, Daphné Durant

INRAE, Saint-Laurent-de-la-Pree, France

The grasslands of the agricultural fresh water marshes of the French Atlantic coast are devoted to extensive suckler cattle farming, which provides a habitat for and preserves a fauna specific to wetlands. Managing water levels in the ditches of these clay marshes is a key factor in controlling the flooding of the grasslands, given the slight variations in topography and the associated gravitational transfers.

Controlling the flood is one of the major levers for biodiversity, whether in terms of plant communities or amphibian populations, while ensuring the grass quality and growth are staggered over the summer season, for the herds.

The development of low-cost, open-source GNSS buoys, coupled with a digital terrain model, allows real-time monitoring of water levels in the ditches and flooding in the grasslands. This monitoring, combined with a conceptual model of the expected flooding levels in the grasslands by season, ensures the functionality of the grassland habitats necessary for amphibians, while also guaranteeing sufficient forage production for the herd. This enable a protocol to be established for controlling the sluices that regulate water levels.

Thanks to this monitoring, we maintain water levels within a variation range of ±5 cm from a seasonal management guideline. This guideline ensures that 1 hectare of a target parcel remains flooded for 5 months of the year, thus creating a habitat that is favourable to amphibians. We achieve our goal of maintaining a population of 10 Parsley frogs on the farm, while producing grass for cattle, staggered over the summer period.

This monitoring is constantly being improved, thanks to technical adjustments to simplify sluice management, field campaigns to validate simulations of water level in the grasslands, and the adaptation of management guidelines based on the acquisition of new knowledge about the links between water management, biodiversity, and grass growth.

Monitoring for Management: A Modular, Ecosystem Function-Based Assessment Framework for Estuaries

Christine Whitcraft[1], Jan Walker[2], Eric Stein[2], Kevin O'Connor[3]

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Building an estuarine assessment program around a modular, function-based framework allows us to address several key challenges in large scale monitoring, such as comparability across heterogeneous environments, standardization among practitioners, and differing management needs. A function-based approach provides a way to accommodate different estuary types and assimilate data from diverse monitoring programs. The modular nature of the approach provides flexibility for implementing agencies to address both local and regional needs concurrently, thereby encouraging broad adoption. Here, I will discuss such an approach developed to assess the effectiveness of California's (USA) Estuarine Marine Protected Area Program (EMPA) with examples of standard protocols, standard data templates, and guidance on analysis, synthesis, and reporting. In addition, I will present sample data to demonstrate the utility of this approach for answering functional questions across a range of estuarine habitats. This framework provides an opportunity to assess general condition and trends of coastal wetlands that can be used as baselines for regional assessments, proposed restoration projects, and the development of bioassessment tools, as well as help the state assess its large investment in coastal wetland protection, enhancement, and restoration.

Session 9:
Peatlands

1 July
11:30-13:05, Manninen Hall

3 July
16:45-18:30, Manninen Hall

Tackling Barriers for the Restoration of Nutrient Poor Peatlands Drained for Forestry

Eeva-Stiina Tuittila[1], Brunella Palacios Ganoza1[1], Nina Kumpulainen[1], Noora Rämö[1], Teppo Hujala[1], Anu Laakkonen[1], Liisa Maanavilja[2], Jukka Turunen[2], Kari Minkkinen[3], Paavo Ojala[3], Lasse Aro[4], Anne Tolvanen[5], Päivi Merilä[5], Anna M. Laine[1]

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The United Nations Decade on Ecosystem Restoration urges to prevent, halt, and reverse the degradation of ecosystems worldwide to achieve the climate goals of the 2015 Paris Agreement. In Europe, almost half of peatland area is degraded due to drainage for agriculture, forestry, and peat extraction; in Finland the drainage area is even higher, around 60%. In the boreal conditions of Finland, most of the drainage has been done for forestry. Drainage was so active that up to 0.8 Mha of the drained peatlands were too nutrient poor to support tree growth. These low productive sites are a low hanging fruit for restoration, but science and know-how needed for large scale restoration is still sporadic.

Our study aimed to address the barriers for large scale restoration of the nutrient poor peatlands drained for forestry. In science our focus was on functional biodiversity (plants, testate amoebae), loss of carbon (peat respiration), greenhouse gas emissions (CO_2, CH_4, N_2O) and new soil organic matter formation (apparent carbon accumulation) and the factors controlling them. For the education of forest and excavator professionals, we focused on the site selection and effective restoration methods.

Restoration by dich blocking and tree removal had resulted in succession towards natural target (control sites) but not reached that. This directional development was observed for the communities of mosses, vascular plants, testate amoeba and their traits. Biogeochemistry had recovered faster than biological communities. Restoration had decreased the loss of carbon from peat into atmosphere at the level of undrained sites and methane emissions had similarly recovered to the level of undrained. New soil organic matter formation appeared to be faster than in the undrained sites but slowing down with time since restoration. For education, we organised restoration demonstrations and created a series of short videos and podcasts based on expert interviews.

Spatial and Temporal Patterns of Dissolved Organic Carbon Concentrations in Peatlands and Leaching into the Western Siberian River Network

Yulia Kharanzhevskaya

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Tomsk State University, Tomsk, Russian Federation

Leaching of dissolved organic carbon (DOC) from peatlands into the river network is an important component of the carbon budget. Climate model simulations for the next century predict near-doubling of West Siberian land surface areas with a mean annual air temperature warmer than 2 °C, suggesting up to 700% increases in stream DOC concentrations and up to 29–46% increases in DOC flux to the Arctic Ocean (Frey, 2005). This study investigated the spatiotemporal distribution and fluxes of DOC in northeastern part of the Great Vasyugan Mire (GVM) and headwater stream – Klyuch River during warm season of 2021–2024.

DOC content in GVM waters varied from 23.5 mg/L up to 92 mg/L and higher concentrations were noted at the boundary area with pine and birch dwarf-shrub *Sphagnum* community. Our data showed that increasing of DOC concentrations in waters of GVM are consistent with variations in the degree of peat decomposition and the carbon content in the active layer of the peat deposit. In the boundary area, the degree of peat decomposition increases up to 35-50% and the DOC content in the 0-100 cm peat layer rise to 50.9-51.2%. DOC content in Klyuch River headwater varied from 37.0 mg/L up to 128.6 mg/L. An increase in the DOC content in waters of the Klyuch River headwater in the swampy forest in comparison with GVM indicates the influence of waters coming from parts of the catchment occupied by swampy forest. In seasonal dynamics, higher concentrations of DOC were noted in the summer hot period (July-August), while the DOC release prevailed in April and May during the snowmelt period. The total DOC release with water of the Klyuch River in the swampy forest during the spring flood and summer-autumn low water period varies from 1.43 to 7.54 g/m^2.

Forest Management Impacts on Fine Root Input to Peat Carbon

Tuula Larmola[1], Petra Straková[2], Tomas Hajek[2], Tijana Martinovic[3], Päivi Mäkiranta[1], Timo Penttilä[1], Jyrki Jauhiainen[1], Raija Laiho[1], Petr Baldrian[3], Liisa Ukonmaanaho[1], Raisa Mäkipää[1]

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In peatland forests, most soil carbon may derive from roots and root-associated microorganisms rather than from the aboveground plant litter. Large uncertainties prevail in the quantity and quality of plant fine roots because it is very laborious to sort them from peat. We used modified ingrowth method and Fourier transform infrared (FTIR) spectroscopy to examine how forest management impacts fine root growth, depth and species distribution in two peatland forests: Ränskälänkorpi, Southern Finland (Holisoils project) and Kivalo in Northern Finland (ALFAwetlands project). Management options included rotation forestry with clear cuts vs. continuous cover forestry, i.e., selective cuttings. Woody roots dominated both under selective cutting and control plots in the south, whereas graminoid and herbaceous roots were more common in all management options in the north and in southern clear cuts. Most, up to 80-95 % of the fine roots grew in the top 20 cm of soil. The amount or depth distribution of fine roots did not differ among most management options. However, fine root biomass production tended to be smaller and more evenly distributed by depth at the clear-cut plots with soil preparation. Thus, continuous cover forestry did not compromise the soil carbon input as fine root quantity or quality in the first years after harvesting. The lower root litter inputs or shifts in decomposability from low in woody roots to higher in herbaceous roots may in part contribute to net carbon loss from clear cut soils. To further assess root biomass quality, we will compare FTIR based to DNA based species identification.

Bridging Scales in Peat Carbon Dynamics: Leveraging FTIR Spectroscopy for Ecosystem Modeling

Petra Straková[1], Tomáš Hájek[1], Tuula Larmola[2], Raija Laiho[2], Annamari Laurén[3], Kari Minkkinen[3], Paavo Ojanen[2], Jaan Pärn[4], Tomáš Picek[1], Zuzana Urbanová[1]

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Peatlands play a pivotal role in the global carbon cycle, acting as significant reservoirs of organic carbon while simultaneously influencing greenhouse gas (GHG) dynamics. However, our ability to predict carbon turnover across scales remains constrained by the challenges of integrating microscale biochemical processes with ecosystem-scale phenomena.

This project, at its initial stages, aims to integrate Fourier-Transform Infrared (FTIR) spectroscopy into peatland carbon models to address these challenges. By identifying FTIR spectral markers of organic matter decomposition, we plan to investigate the long-term effects of climate and land-use changes on peat carbon quality and GHG emissions. Leveraging preliminary field experiments, we will explore litter and peat decomposition dynamics under varied hydrological conditions and peatland types, linking microscale chemical transformations with large-scale carbon fluxes.

A key goal of this project is to establish a global FTIR spectral database to refine ecosystem models such as Yasso and SUSI. To achieve this, we welcome collaboration and invite researchers to share FTIR data or peat samples to enhance the scope and precision of these efforts. Together, we aim to develop high-precision tools for predicting GHG fluxes and advancing our understanding of peatland carbon dynamics.

Join us to explore how FTIR spectroscopy can transform peatland research, bridge critical gaps between scales, and foster collective progress toward climate change mitigation.

An Integrated Analysis of 'Eco-Geo-Hydro' Processes in a Peat Bog on Jeju Island, South Korea

Sungjae Woo, Daehyun Kim

Department of Geography, Seoul National University, Seoul, Korea, Republic of

Peat bogs are facing conservation challenges by ongoing climate change and terrestrialization. While most studies have focused on the effect of either ecological or hydrological factors, relatively few examined how ecological, geomorphological, and hydrological processes can jointly drive peat formation and terrestrialization.

We investigated a mountain bog ecosystem in Jeju Island, South Korea, to clarify how low decomposition rates of organic matter, vegetation succession, and the local hydrological cycle collectively influence terrestrialization. We conducted soil analyses, vegetation surveys, and tree-ring analyses to confirm Eco-Geo processes and hydrosere. To verify whether hydrosere led to a reduction in swamp area, we conducted satellite image analysis. By establishing an Eco-Geo-Hydro model, we predicted changes in wetland area and sedimentation rate of the bog.

Soil analyses revealed highly stable organic matter contents (50–65%) with no significant variation by depth (one-way ANOVA, $p = 0.229$). Considering the land-use history of the ecosystem, this indicates extremely low decomposition rates and continued peat accumulation. We posited that if elevation gain reduces flooding stress, it facilitates progressive hydrosere. Vegetation survey results documented a clear successional gradient from aquatic plants through terrestrial herbs and shrubs to trees. Tree-ring data in the surrounding *Cryptomeria japonica* stands showed age gradients corresponding to increasing distance from the swamp, demonstrating the classic hydrosere model. Satellite image analysis showed the swamp's area declined between 2011 and 2023, consistent with peat accretion and tree encroachment. Considering peat accumulation, hydrosere, and swamp contraction, an ecohydrological model predicted a sedimentation rate of 1 cm yr^{-1}.

The study identified potential processes of terrestrialization of a bog ecosystem to suggest that vegetation-driven peat accumulation plays a key role in accelerating terrestrialization in peat bogs. By integrating Eco-Geo-Hydro processes, this study provides insights for effective wetland conservation policies.

Raised Bog Vegetation Development After the Change of Site Hydrology

Mara Pakalne

University of Latvia, Riga, Latvia

Intact peatlands in Latvia, including raised bogs host a high biological diversity. They play a crucial role in climate change mitigation despite covering only about 3% of the Earth's land surface. Due to drainage, the characteristic site micro-topography - hummocks, hollows, lawns and pools disappear. Vegetation development after implementation peatland restoration activities was studied in Sudas-Zviedru Mire in the Gauja National Park in Latvia within the LIFE project 101074396 — LIFE21-CCM-LV-LIFE PeatCarbon "Peatland restoration for greenhouse gas emission reduction and carbon sequestration in the Baltic Sea region". The aim of the study was to follow vegetation response after restoration activities. Changes in plant cover and site hydrology, resulting from the elevated water table in drainage-influenced areas of raised bog, was analysed in permanent vegetation plots compared to daily water level data. Vegetation plots were established in 2015 within the LIFE Wetlands project and continued within LIFE PeatCarbon project in 2024. Vegetation studies show that restoration results in the succession of plant communities towards the targeted raised bog vegetation of wetter conditions. This was evident from the decreased abundance of species benefiting from drainage and the corresponding increase of species characteristic for wetter habitats. As there was a distinct rise of the water level, also the vegetation recovery was immediate followed by re-appearance of *Sphagnum cuspidatum, Rhynchospora alba*, accompanied by other species, like *Drosera rotundifolia, Andromeda polifolia*, etc. Most important is the development of *Sphagnum* communities as they play a crucial role in raised bog carbon accumulation and are dependent on water availability. The results of peatland restoration measures show that peatland restoration actions have a positive effect on peatlands. *Sphagnum* dominated communities are recognized as creators of conditions inevitable for peatland formation; hence this genus is essential for peatland formation initiation and to keep the environment with high carbon storage potential.

A Dendrochronological Study on the Effect of Water Level Changes on Scots Pine (*Pinus Sylvestris* L.) Increment in Estonian Peatlands

Kärt Erikson, Kristina Sohar, Alar Läänelaid, Ain Kull

University of Tartu, Tartu, Estonia

Peatlands in Estonia have been and still are under heavy human influence, mainly by drainage. The main reasons for draining peatlands have been forestry, agriculture and peat extraction. The drainage ditches affect mire hydrology and vegetation for decades.

In this study four peatlands with previous drainage impact were studied. Two of them had been influenced by forestry drainage and two by ditches for milled peat extraction. Tree-ring samples from growing pines were collected along transect following hydrological gradient and later analysed using dendrochronological methods. Since drainage is the main type of disturbance studied, relative increment methods were applied. In each peatland, samples were collected from six to seven study plots. Climatic effect on growth in different areas of the peatland were assessed.

The analysis shows that each peatland has distinct growth change peaks in specific periods corresponding to historic drainage records. In all studied peatlands, the average tree-ring growth is higher at distances closer to the drainage ditch. In general, our results show a strong drainage influence on tree growth up to 40 meters from the ditch. Beyond that, the effect gradually disappears. The climate analysis shows that a warmer May can have a positive effect on tree growth at all studied locations.

Overall, our results show that tree ring data gives us valuable insights into peatland history. The use of the transect method allows us to assess the impact of the water regime on the bog and to better distinguish between anthropogenic and climatic influences on the annual growth of tree rings. Based on this, more effective measures can be implemented for the protection of bogs.

Drying Induced Trends in Functional Traits of Ground Vegetation at Boreal Peatlands

Egle Köster[1], Anna M. Laine[1], Mika Aurela[2], Jill L. Bubier[3], Gustaf Granath[4], Elyn Humphreys[5], Sari Juutinen[2], Tuula Larmola[6], Annalea Lohila[2], Tim Moore[7], Mats Nilsson[8], Matthias Peichl[8], Tarmo Virtanen[9], Eeva-Stiina Tuittila[1]

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Climate warming associated increase in evapotranspiration is predicted to lead to drying of boreal peatlands. The vegetation of peatlands is expected to develop towards more arboreal and biomass production to increase. Our previous studies have shown significant changes in the vegetation caused by lower water tables at the experimental water level drawdown (WLD) site Lakkasuo, in Southern Finland. The extent of observed changes depended on the nutrient status and functional composition of the vegetation.

This study focuses on the drying induced changes in functional traits of field layer vegetation (vascular plants and *Sphagnum* mosses) at pristine boreal peatlands. We aim to assess whether changes in functional traits that are observed in WLD experiment are already ongoing in pristine peatlands. For that we compared vegetation trends in undrained pristine boreal peatlands with long-term records from Finland, Sweden and Canada to the findings from the Lakkasuo WLD sites. In addition to community composition data, we measured traits from each site, and calculated community weighted mean (CWM) and trait distribution for each sampled year.

At Lakkasuo, long-term WLD had a clear effect on the CWM of measured functional traits, *Sphagnum* mosses being similarly responsive as vascular plants. Peatland type altered the responses that were more pronounced in rich and poor fen than in a bog. At studied pristine peatlands, some of the traits followed the trends seen in WLD sites, while the others seemed to have no change or even opposite direction of change in the observed time series. Conclusively, our results show that there is no uniform ongoing change in boreal peatlands, and some sites are more responsive while the others are more resilient to the ongoing climate change.

Lakkasuo Peatland – an Outdoor Laboratory for Peatland Climate Change Research Since Year 2000

Anna M. Laine, Eeva-Stiina Tuittila

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Climate warming is proposed to impact peatland ecosystems most strongly through drying that results from an increased evapotranspiration. Signals of drying responses may be detected from palaecological records, but more direct answers, particularly considering ecosystem functions, require experimental research. As the responses may alter over time, long-term experiments are called for. Here we present Lakkasuo peatland - a home for an experimental outdoor laboratory for peatland climate change research since the year 2000.

Lakkasuo peatland experiment, located in southern Finland (61°47’N, 24°18’E) was established in 2000 and consists of Before-After-Control-Impact (BACI) design on three study sites representing different peatland types: nutrient rich fen, nutrient poor fen and ombrotrophic bog. Each site includes a control area and an experimental water level drawdown area. In addition, in 2008 a factorial experiment of water level drawdown and warming with open top chambers was established. Lakkasuo is part of the European AnaEE (Analysis and Experimentation on Ecosystems) infrastructure network.

The core measurements at Lakkasuo include regular vegetation composition surveys, GHG flux monitoring with chamber method and water table monitoring. Over the years the setup has, however, hosted a multitude of studies including impacts on decomposition, biomass production, plant traits and functional diversity, testate amoebae and their traits, just to start with.

The key finding is the site/peatland type specific response of most of the measured variables to water level drawdown. Generally, most variables show the strongest responses in the rich fen while bog appears to be most resilient. In addition, short- and long-term responses differ, indicating the need for such long-term experiments. In our presentation we will give an overview of results so far.

The Potential for Restoration of Smelter-Damaged Peatlands in Sudbury, Ontario Canada

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Peatlands can be degraded by pollution from mining and smelter operations, with severe impacts on *Sphagnum* mosses that are keystone species in peatlands. Little is known about successful restoration of smelter-damaged peatlands. In Sudbury, Ontario. that was the world's largest point source of SO_2 and particulate Ni and Cu emissions, ore roasting and smelting operations (1887-1972) denuded the regional landscape of vegetation. During 1986, fourteen years after the start of major pollution controls, Gignac and Beckett reported that poor fen peatlands in proximity of a Sudbury smelter contained flat, black and barren peat with sparse vegetation. In 2020-21, we investigated the present vegetative, biogeochemical, and microbial status of the same poor fens. Over the past 35 years *Sphagnum* moss, a keystone species, has re-established in poor fens as close as 4 km to smelters, whereas in 1986, *Sphagnum* was not observed until 12 km. Chemical analysis of the peat showed that total Ni and Cu concentrations in peat samples were substantially lower than in 1986. We found that peat microbial community structure was controlled by *Sphagnum* species and microtopography; by way of contrast, in Sphagnum prime influencers were metal contamination and pH. To test if potential active restoration efforts in Sudbury's peatlands are feasible we placed healthy *Sphagnum* and peat plugs of five species into a contaminated Sudbury peatland. Over five years, *S. fuscum* (a hummock species) and *S. fallax* (a lawn species) exhibited successful establishment (expansion and new growth). The transplant peat microbiome has shifted towards a community structure that mirrors the microbiome of the host peatland with even dominance between Acidobacteria and Proteobacteria. In the summer of 2024, a larger scale trial using three variations of the *Sphagnum* moss layer transfer technique (MLTT) was established on one of the more polluted peatland sites.

Modeling Vegetation Carbon Stock and Soil Greenhouse Gas Emission Dynamics in Undrained Degraded Peat Swamp Forests of Indonesia and Peru

Kristell Hergoualc'h[1], Erin Swails[1], Jia Deng[2], Steve Frolking[2]

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[2]University of New Hampshire, Durham, USA

Degradation of peatlands impacts vegetation carbon (C) stocks and can raise net soil greenhouse gas (GHG) emissions even without drainage. However, data on vegetation C storage and soil GHG dynamics in degraded undrained peatlands, and their recovery timeframe are limited. Additionally, despite their important extent across the tropics, these systems remain unconsidered by the Intergovernmental Panel on Climate Change guidelines for GHG inventories. We used the DeNitrification DeComposition model to simulate undegraded and degraded undrained peat swamp forests in Indonesia and Peru. Based on model results, we derived peat onsite CO_2, N_2O, and CH_4 emission factors (EF) for undrained degraded forests, assessed timeframes for recovery of vegetation C stocks and peat GHG emissions, and investigated relationships among peat GHG fluxes and biogeophysical controls. Degradation activities included partial clearing for agroforestry in Indonesia, and in Peru selective timber harvesting and *Mauritia flexuosa* palm cutting for fruit harvest. Model results aligned well with field observations. Carbon stocks recovered 40 years after modeled disturbance in Indonesia, and 80 years post-disturbance in Peru. Simulated degradation increased the peat onsite CO_2 EF during the first decade post-disturbance by 560% and 72% in Indonesia and Peru, respectively, with recovery by the second decade post-disturbance at both locations. Degradation also induced an increase in soil N_2O emissions in Indonesia (70%) and Peru (150%), with elevation persisting for three decades in Indonesia, and five in Peru. Simulated CH_4 emissions were not substantially different in undegraded and degraded forests at either location. Temporal variations in peat onsite CO_2 and N_2O EF were linked to degradation-driven changes in soil C:N ratio, and for peat CH_4 fluxes to water table and soil water-filled pore space dynamics unrelated to disturbance. These results suggest that peat GHG emissions may be elevated in these forests up to four decades after anthropogenic disturbances end.

How Shrubs Effect on Bacterial and Fungal Growth and Their Carbon Use Efficiency in Forested Shrubby Peatlands?

Mari Könönen[1], Lettice Hicks[2], Jenni Hultman[3], Johannes Rousk[2], Raija Laiho[3]

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Climate and land use change increase shrub presence in Northern Hemisphere. Generally, the shrubification is considered to threaten the peatland carbon (C) pools by replacing the peat forming Sphagnum mosses. It is likely, that the shrubification accelerates decomposition processes through their exudates and drying effect. Simultaneously, the shrub originated secondary metabolites, such as tannins and phenolics, can form decomposition resistant compounds. Furthermore, both C release and stabilization can be linked to Ericoid mycorrhiza that are efficient nutrient miners but also associated in forming hard to decompose compounds. Microbial carbon use efficiency describes the partitioning of C between respiration and growth, and this defines the soil-atmosphere C balance. Therefore, it can be used as a tool to estimate the fate of soil C.

To better understand the role of shrubs on surface peat processes we measured C mineralization rate, and bacterial and fungal biomass and their growth rates, and calculated their carbon use efficiency from peat soils (0-10 depths) under homogenous patches of different shrub species or Sphagnum moss in late summer. To include the site-specific variation, our study sites were a nutrient rich spruce swamp and a nutrient poor pine bog both drained for forestry in the 1960s – the golden decade of forest drainage in Finland.

The outcomes suggest that in the nutrient poor site, the shrub effect on soil C processes is present, while in the rich site no differences between the moss- and shrub-covered patches were not detected. Yet, the microbial carbon use efficiency was higher in poor site. The high microbial carbon use efficiency promotes peat C storage more than its loss; thus, shrubs can be the good guys in peatlands.

Paleoecological History of Two Peatlands Near Mirosławiec

Bartosz Borowski[1,2], Ewa Jabłońska[1,2]

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[2]Wetlands Conservation Center, Warsaw, Poland

This study examines the developmental history and current condition of two peatlands localised near Mirosławiec in northwestern Poland: the Łowicz Wałecki and Piecnik peatlands. Located in an early post-glacial landscape, both areas were significantly altered by 19th-century drainage efforts aimed at agricultural and pastoral use.

Using field-based paleoecological methods—such as stratigraphic profiling and peat core analysis—combined with laboratory microscopy, we reconstructed the stages of peat formation and assessed the impacts of long-term hydrological changes. Additionally, we utilised the Instorf probe to evaluate the total depth and morphology of the peat basins.

Our results indicate widespread peat degradation and mineralization due to historical drainage over the past two centuries. However, in small, isolated areas where water conditions have improved, we observed early signs of peat-forming processes, including the accumulation of Sphagnum peat and sedge-reed deposits. These localised regenerations suggest limited but noteworthy ecological resilience.

Overall, the study highlights the vulnerability of these ecosystems to human disturbance while providing valuable insights into natural recovery dynamics that are relevant for peatland conservation and restoration planning in Central Europe.

Symposium 1:
Making it count: operationalizing the rights of wetlands

30 June
11:15-12:45, Kurrik Hall

Navigating Our Future: Implementing Rights of Wetlands

Gillian Davies

BSC Group, Inc., Worcester, USA
Global Development & Environment Institute, Tufts University, Medford, USA

Numerous global leaders and governance organizations are calling for transformative change as a way to navigate our future, thereby achieving a stable and livable climate and reversing the current biodiversity crash. Through a Rights of Wetlands/Nature lens, such a shift considers humans as part of Nature, not separate or superior to Nature, and often has been led by Indigenous Peoples who, for millennia, have viewed Nature as kin. This paradigm shift translates the ethical valuing of wetlands/Nature's rights to exist, to have a place to exist, and to participate in Earth's natural processes into legal rights so that they can be defended, and so that the current trajectory of ongoing degradation and destruction of wetlands/Nature can be halted. After a brief introduction to Rights of Wetlands, this presentation will focus on approaches to operationalizing the Rights of Wetlands/Nature, including discussion of specific case studies. Attendees will learn about key decisions required during the process of implementing Rights of Wetlands, successful approaches, and lessons learned from some of the less successful cases. When implemented strategically, a Rights of Wetlands approach can lead to improved outcomes for wetlands, climate, and biodiversity. Links to materials that can assist in increasing wetland preservation and restoration through a ROW approach will be shared including: Rights of Wetlands infographics/Quick Guides; *Transforming Our Relationship with Wetlands: A Guide to the Rights of Wetlands*; the *Universal Declaration of the Rights of Wetlands*; links to peer-reviewed journal articles on ROW; and a link to the Rights of Wetlands website.

Community Experience in Implementing Rights of Wetlands

Matthew Simpson

35percent, Stroud, United Kingdom
Cobra Collective, Egham, United Kingdom
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Implementing Rights of Wetlands (ROW) as a way of promoting socio-ecological resilience and adaptation, requires moving away from a dualistic world view that places people outside of and above Nature and instead moves towards the understanding that humans are one of many species in wetland ecosystems and an equitable relationship among all species, processes and ecosystem structure is required. For communities that do not already have this type of relationship with nature a ROW approach requires a cultural and behavioural shift to a position where the right of a wetland to exist and to function naturally is respected.

The identification and sharing of wetland best practice from Indigenous Peoples and Local Communities (IPLCs), that implement a ROW approach, can help support governments and communities that want to develop an equitable, healthy and sustainable relationship with nature. A Darwin Initiative, UK Government, funded project entitled “Rights of Wetlands Operationalisation for Biodiversity and Community Resilience” is exploring how Rights of Wetlands can be implemented by governments as national policy, legislation and governance and by communities and stakeholders through actions at specific wetlands in Ecuador, Bolivia, Guyana, Sri Lanka and Kenya. This presentation will examine the different experiences of communities within the five countries and share the lessons they have shared regarding implementing ROW.

Calling for a Better Coupling Between Rights of Wetlands and Wetlands Wise Use

Ritesh Kumar[1], Max Finlayson[2]

[1]Wetlands International South Asia, New Delhi, India
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Davies et al. (2020) proposed steps towards a 'Universal Declaration of Rights of Wetlands' based on a constellation of eight rights around the right to exist. These rights challenge the notion that nature is to be simply viewed as property to which humans have a right to exploit and manage, and instead promote the adoption of a more 'biocentric' perspective which recognises nature as an entity with fundamental rights which are to be protected while taking into account human needs. The Ramsar Convention, the multilateral environmental agreement providing an international forum for conserving wetlands, propounds 'wise use' as its central tenet. Defined in the Convention as 'maintenance of ecological character', wise use recognises human-nature interactions within strategies and actions for conserving and sustainably managing wetlands. It is pertinent that the Rights of Wetlands framework and the Ramsar Convention's wise use approach are aligned, or else there is a danger that the current rights framing may be insinuated to promote a human-nature disconnect and a move towards an idealised notion of nature bereft and antithetical to humans and human interactions. The Convention has bridged the human-nature disconnect through progressively evolving the wise use definitions, and seeking to address the paradoxical situations that can arise when considering human-wetland interactions. The rights of wetlands can further support this alignment through: a) promoting an inclusive conceptualisation of wetlands which includes and recognises that humans derive ecosystem services from wetlands in their natural and altered states; b) including human embeddedness in the trajectory and evolution of wetlands interactions within the description of the natural and evolving regime of wetlands, which are intended to act as a reference for several rights; and c) including the role of human agency in effecting these rights by promoting ecosystem stewardship and recognising the plural values people hold for wetlands.

Rights of Wetlands: Wetland Policy and Legislation in Aotearoa New Zealand

Shona Myers

Environment Court of New Zealand, Auckland, New Zealand

This paper will investigate how the rights, intrinsic and cultural values of wetlands and ecosystems are recognised in policy and legislation in Aotearoa New Zealand, and how this approach is being interpreted and implemented.

In New Zealand wetlands are regarded by Māori as taonga and have cultural and spiritual significance, can be reservoirs of mātauranga (knowledge) and wellbeing, are critical for mahinga kai (food resources) and provide significant habitat for species.

We have lost over 90% of our wetlands since European settlement. The importance of wetlands is recognised as a matter of national importance in legislation. Wetlands and freshwater ecosystems are critical to protect and restore for their intrinsic values, their indigenous cultural values and the ecosystem services they provide. Protecting water and its mana (life-force, power) is identified in policy as being of fundamental importance in protecting the health and well-being of the wider environment.

As part of Treaty settlements, legislation has been developed that recognises the legal personhood of sacred natural areas encompassing mountains, rivers, forests and associated wetlands. Assigning legal personhood status to a natural ecosystem aligns with the Māori view of ecosystems and provides a governance framework for caring for the ecological health of the system as whole. The recent Taranaki Maunga Collective Redress Bill 2025 explains that the concept of legal personality for Te Kāhui Tupua is primarily concerned with giving legal status to the tūpuna maunga of Ngā Iwi o Taranaki within the national park. A similar legal personality has been delivered in Treaty settlements in respect of Ngāi Tūhoe (Te Urewera) and the Whanganui River (Te Awa Tupua).

A snapshot will be presented of how the rights of wetlands and ecosystems as a whole are addressed in legislation and policy and approaches to implementation.

The Rights of Wetlands for Native American Tribes in the USA

Marinus L Otte[1,2], Donna L Jacob[1,2], Gavin Parisien[1]

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The lands of several Native American tribes in the USA have high densities of wetlands. They provide important ecosystem services, including traditional, cultural, and spiritual, yet are poorly protected.

The main objective of this project is to assess the feasibility of establishing formal wetland protections. If possible, this will be based on the concept of the Rights of Wetlands, to ensure continuation of wetland ecosystem functions and services for future generations. The goal is to produce a document outlining the pros and cons of implementing such laws and regulations. Implementation of regulations has consequences for communities, and not all of those may be perceived as positive. For example, restrictions on access or activities may affect cultural, traditional, and spiritual uses, including hunting, fishing, and collection of plants.

It is therefore essential that an inventory of all possible uses of water and wetlands on tribal lands is carried out, so that a balanced proposal can be submitted that will have full support of the local population. The project therefore aims to:

- Assess the opportunities and obstacles, legal and otherwise, at all levels of government (federal, state, county, tribe) and the communities, to establish Tribal Wetland Protection Acts (TWPA) that strike a balance between the need to preserve the wetlands and their provision of all ecosystem services.

- Assess people’s perceptions on and off tribal lands about water and wetlands.

- Assess the uses of water and wetlands on and off tribal lands, as a resource, as well as for cultural, traditional, and spiritual uses.

- Assess the pros and cons of basing a TWPA on the concept of the Rights of Wetlands.

This project started in August 2024. Progress to date will be presented.

Symposium 2:
Developing wetland carbon policy: science, technology, & stakeholder needs

1 July
11:30-13:00, Kurrik Hall

Toward a Rapid Assessment of Carbon Stocks in Global Wetlands

Etienne Fluet-Chouinard[1], Max Finlayson[2]

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Wetlands are important components of global carbon (C) cycling given the large amount of carbon stored in their soils. They can sequester and store different quantities of carbon, owing to differences in hydrology, salinity, vegetation, etc. Given the benefits accrued from long-term carbon storage in undisturbed wetlands , managers can benefit from a rapid assessment of the carbon stocks in wetlands when making decisions that will affect carbon stores and avoid increasing emissions of CO_2 and CH_4.

To support decision-makers and increase their awareness of the potential importance of wetlands for storing carbon, a tool for the Rapid Assessment of Stored Carbon in Wetlands (RASC) is being developed to support an initial assessment of carbon stocks in different wetlands. This effort was initiated by the Ramsar Regional Centre East Asia (RRC-EA) and supported by an international team of experts. The tool draws on two primary sources: 1) global maps of wetland type (ex. Global Wetland and Lake Database version 2) and characteristics including vegetation cover and soil properties (ex. SoilGrids), and 2) databases of wetland carbon content from soil core measurements (ex. Coastal Carbon Atlas, National Wetland Condition Assessment). The data are combined to estimate carbon storage for the simplified Ramsar wetland classification presented in the 2018 Global Wetland Outlook report. In addition to generating a global baseline estimate of wetland carbon storage, this analysis will investigate which wetland characteristics can best predict C storage and inform on gaps in current measurement networks.

This rapid assessment tool can provide impetus and guidance for management of wetland carbon storage in managed sites globally. This tool does not estimate the sequestration potential or rate over time, nor carbon flux estimates from wetlands, but those remain important future components of understanding the present and future carbon balance of wetlands.

Monitoring Greenhouse Gas Budgets Across the Arctic-Boreal Zone – How Community Coordinated Research Is Improving Carbon Flux Detection and Policy Action

Jennifer Watts

Woodwell Climate Research Center, USA

The Arctic-Boreal Region (ABR) represents 20% of Earth's land surface, encompassing large expanses of forest and tundra, wetland and aquatic systems. Much of this landscape is underlain by permafrost — ground that has remained frozen for thousands of years. This region is extremely important as it holds over 50% of the global soil organic carbon pool and over 30% of global wetlands. The ABR is crucial from a climate perspective, as thawing permafrost may release large amounts of greenhouse gases (GHGs; i.e., CO_2 and CH_4) over the next century, further escalating the climate crisis. However, the amount of GHGs released from this domain, the net ecosystem CO_2 and CH_4 budgets (accounting for gas sink in addition to source), and their trajectories in response to a warming climate, have been largely unknown. Consequently, for many years the ABR has been among the most important, yet least understood, terrestrial regions on Earth in regard to GHG budgets and ecosystem/climate feedbacks.

This presentation overviews progress made in addressing CO_2 and CH_4 budget uncertainty for the ABR, with emphasis on recent advances achieved through international collaborations and working groups formed within ABR science communities. These efforts include identifying regional gaps in flux measurements and other data needed for GHG assessments, the consolidation of existing data through synthesis activities, strategic improvements to flux tower observational networks, benchmarking/improvements of models (i.e., machine learning, hybrid diagnostic, and process-based) used for GHG budgeting and future predictions within the region, and increasing communication and knowledge-sharing between scientists, policy makers, and Indigenous knowledge holders. Lastly, this presentation identifies how lessons learned from the ABR might benefit GHG accounting efforts in other regions, especially those focused on complex wetland environments.

Challenges in Quantifying Wetland Carbon Stocks from Satellite Data in Permafrost Regions

Annett Bartsch

b.geos, Korneuburg, Austria

More than 20% of the northern hemisphere is underlain by permafrost. The majority is located in lowlands with abundant wetlands and carbon rich soils. As permafrost is thawing, increased carbon release is expected. Precise estimates of carbon stocks are needed in order to quantify current and future fluxes. Satellite observations provide a range of tools which can potentially be used for such mapping. This comprises the identification of landcover patters, including water bodies and vegetation communities, as well as biogeophysical proprieties such as near surface soil moisture and state (frozen versus unfrozen). These observations provide, however, only proxies of subsurface carbon stock and fluxes with various limitations. Challenges include spatial and temporal sampling and the assumption that surface parameters reflect subsurface carbon stocks or are reflecting flux patterns. The different approaches will be briefly introduced, and their advantages and disadvantages discussed. In addition, the capabilities of future approved satellite missions (with expected launch dates until 2032) for permafrost wetland monitoring will be reviewed.

The Success of Blue Carbon Policy Is Influenced by Spatial Variability in Blue Carbon Ecosystem Resilience

Kerrylee Rogers, Jeffrey Kelleway

University of Wollongong, Wollongong, Australia

The spectre of climate change has focused attention on reducing atmospheric carbon and efforts are underway to leverage blue carbon ecosystems (BCEs) to contribute to national and international climate mitigation strategies. Accordingly, blue carbon policy largely seeks to maintain existing carbon stores through conservation and loss minimisation and increase carbon storage by expanding global extent. Challenges remain that limit widespread success of BCEs as a climate mitigation strategy. Not least is the looming threat of climate change stressors, such as sea-level rise and climatic variability, on the preservation and long-term capacity of BCEs to continue sequestering atmospheric carbon. This threat is exacerbated by other climate-related stressors, such as bushfires and cyclones, that are projected to increase in intensity and frequency. We present research from Australia regarding adaptation of mangrove forests to these stressors, including compounding effects from sea-level rise, climatic variability, bushfires and cyclones. We demonstrate the resilience of a mangrove forest is dependent upon i) exposure to climatic events, such as cyclones and bushfires, ii) localised environmental conditions that underpin maintenance of mangrove forests in situ, such as sediment supply and plant productivity, and iii) tidal impediments across coastal floodplains that limit landward extension of tidal inundation as sea level rises. Using a simple model, we simulate that BCEs could drawdown atmospheric carbon over the next century in some locations providing warming is limited, sea-level rise is moderate and exposure to other climate-related stressors is low. Information regarding exposure to climate-related stressors, operation of geomorphological and ecological processes, and the effect of anthropogenic stressors at the local scale are crucial for improving confidence in BCEs as a climate mitigation strategy. Blue carbon policy should recognise spatial variability in the likely success of BCEs as a climate mitigation strategy and provide guidance to enhance success at the local scale.

Through Carbon Goggles: How Climate Policy and Finance Are Remaking Latin American Wetlands

Naomi Millner

University of Bristol, Bristol, United Kingdom

Recent remote sensing data has revealed that Latin America contains far more peatland than previously estimated, significantly expanding our understanding of global carbon storage. These newly identified peat-rich wetlands—spanning Peru, Colombia, Brazil, and Patagonia—are now recognized as crucial carbon sinks or stores. However, many of these landscapes lack historical or cultural identification as 'peatlands' and remain only partially integrated into conservation frameworks. As a result, they are increasingly vulnerable to degradation. When damaged, peatlands—estimated to hold 33% of global terrestrial carbon—shift from carbon sinks to carbon sources, emitting CO_2.

This paper examines how climate finance mechanisms, particularly carbon credit and offset schemes, are reshaping the politics of these wetlands. While carbon markets aim to quantify and monetise peatland carbon, these frameworks risk marginalizing Indigenous and Local Environmental Knowledge (ILEK) and eroding community land rights. The process of translating peat into a financialised carbon assets also collapses deep ecological timescales into immediate market logics, reinforcing historical narratives that treat wetlands as empty, underutilised spaces.

At the heart of this inquiry is a tension between 'fast carbon'—extraction, commodification, and carbon accounting—and the 'slow carbon' of peatland formation, shaped by organic accumulation, hydrological stability, and socio-ecological entanglements. While dominant policy frameworks view carbon as discrete, tradeable units, emerging ecological research suggests a more dynamic perspective, where carbon is relational—shaped by geophysical processes, microbial transformations, and human management practices. In this presentation I review the social and political implications.

Through case studies of Amazonian swamps, high Andean *páramos*, and Patagonian *bofedales*, this paper explores how these different understandings of carbon are coming into conflict, with significant implications for both conservation and climate governance.

Linking Restoration Approaches with Carbon Dynamics in Freshwater Wetlands

Yinru Lei[1,2], Andy Herb[3], Max Finlayson[4]

[1]Institute for Wetland Research, Chinese Academy of Forestry, Beijing, China
[2]State Key Laboratory of Wetland Conservation and Restoration, Beijing, China
[3]AlpineEco, Denver, USA
[4]Gulbali Institute, Charles Sturt University, Albury, Australia

Freshwater wetlands are critical for global carbon sequestration, yet their climate mitigation potential depends on restoration strategies tailored to site-specific carbon dynamics. Synthesizing evidence from 36 studies and case analyses from China, the U.S., Australia, India, South Africa, and the Netherlands, this study examines how hydrological, vegetative, and geomorphic interventions influence carbon storage and greenhouse gas (GHG) fluxes.

Key findings reveal that hydrological management—including rewetting/controlled inundation, groundwater connectivity restoration, and hydroperiod adjustment—directly affects redox conditions, thereby reducing CO_2 emissions while mitigating CH_4 production. Vegetation strategies, such as reintroducing native high-productivity species, promoting multi-strata plant communities, and managing invasive species, amplify carbon storage capacity by 15–20% or curb CH_4 emissions by 15–40% in restored systems. Soil amendments (e.g., biochar) and microtopography modifications further enhance soil carbon retention and microbial CH_4 oxidation..

Low-tech approaches (e.g., ditch plugging, environmental flows management) prove effective in depressional wetlands, achieving 60–80% of natural reference carbon stocks within 20–64 years. In contrast, higher-tech interventions (e.g., floodplain reengineering) often excel in returning dynamic riverine processes that support many ecosystem functions but require careful GHG monitoring due to potential disturbance-driven carbon losses. Cross-regional comparisons highlight the urgency of prioritizing peatland and forested wetland preservation, as their degradation releases 3–5 times more CO_2-equivalent emissions over 100 years than their restoration can offset in the same timeframe. We propose a checklist of technical and managerial measures to assist practitioners in selecting restoration approaches that maximize carbon storage while also considering other key ecosystem functions (e.g. wildlife habitat, flood attenuation) and address region-specific challenges (e.g., invasive species, eutrophication)—thereby advancing multi-objective wetland restoration aligned with the Ramsar Convention's principles.

Linking Wetland Carbon Science to Policy & Practice: Approaches, Challenges, and Practical Considerations

Gillian Davies

BSC Group, Inc., Worcester, USA
Global Development & Environment Institute, Tufts University, Medford, USA

Understanding the well-documented value of wetlands for carbon storage and sequestration, governments at national, regional/state, and local levels are seeking or developing wetland carbon databases, mapping, tools, and assessments, and beginning to use these information sources as the scientific basis for wetland carbon policy and regulatory development. Such wetland carbon policy development can assist governments to reach carbon emission targets and to contribute to carbon emission mitigation, if based on sound science and if effective tools and data are available. This presentation will discuss where such policy development is happening, what some of the goals of different governments are with regard to wetland carbon, and what some of the various policy approaches and options are. Wetland carbon policy, regulatory approaches, and goals will be discussed relative to data needs, stakeholder concerns, and both technical and social/governance challenges. Approaches to engaging communities and governing bodies in development of wetland carbon policies and regulations also will be discussed, including case studies. Because wetland carbon is not well understood by many stakeholders, communication tools are important. Examples of some wetland carbon communication tools will be shared during the presentation. Additionally, science-based wetland carbon policy can be implemented at a variety of scales including local, state, regional, national, and international governance levels. Information relevant to a variety of scales will be included.

Symposium 3:
Going back to the future: making strides to restore and rehabilitate wetland ecosystems around the globe

30 June
14:45-16:15, Kurrik Hall
16:45-18:15, Kurrik Hall

Setting Targets for Restoration: Can We Identify 'Appropriate Native Reference Conditions' for Ramsar Wetlands?

Peter Gell[1], Max Finlayson[2]

[1]Diponegoro University, Semarang, Indonesia
[2]Charles Sturt University, Wagga Wagga, Australia

The International Principles and Standards for the Practice of Ecological Restoration recognize the need for ecological restoration to be informed by the identification of 'native reference systems', while considering environmental change'. Native reference systems can be explored by developing reference models. They can also be recovered by access to records of past states including through historical records, traditional ecological knowledge and paleoecology. In combination, these can assist in the identification of reference sites and the development of a baseline inventory that can be used to develop targets for restoration programs. The Ramsar Convention on Wetlands invites signatory nations to identify the 'natural ecological character' of wetland sites listed as internationally important. Commonly, this description is based on the nature of the wetlands at the 'time-of-listing'. As the Convention was developed in response to widespread recognition of the loss and degradation of the world's wetlands, it stands that the condition of many wetlands had changed by the time they were nominated. Further, it is recognized that many of the world's wetlands have degraded further over the last 50 years despite the influence of the Convention in slowing that decline. It would be timely, given the decade of ecological restoration, for the Ramsar Convention to invoke more strongly the need for restoration and to encourage the identification of past wetland conditions as potential native reference systems to guide restoration measures. In doing this it could assist signatories make more realistic decisions about reference conditions as a basis for their restoration planning and practice.

The "Leverage Points" Theory in Nature-Based Wetland Restoration

Lijuan Cui

State Key Laboratory of Wetland Conservation and Restoration, Beijing, China
Chinese Academy of Forestry, Beijing, China

In response to the ambitious targets of the Freshwater Challenge—launched at COP28 in Dubai (2024) with commitments from 38 nations to restore 300,000 km of degraded rivers and 350 million hectares of wetlands by 2030—this study addresses the critical limitations of conventional ecological restoration practices. Traditional approaches, developed for localized or landscape-scale interventions, rely heavily on intensive labor and financial investments, rendering them impractical for achieving restoration at national or global scales. To bridge this gap, we propose an innovative theoretical framework called "Leverage Points".

Many wetland ecosystems exist in a state of balance between two alternative attractors: a healthy state and a degraded one, with a tipping point separating them. Once a system passes the tipping point, it may become locked into a degraded state, making recovery more difficult. Our goal is to shift ecosystems toward the healthy attractor by incubating the desired critical leverage point with minimal human interference. A critical leverage point is fostering localized self-organization by establishing native vegetation patches. These patches act as nuclei for broader ecological regeneration, initiating a cascading “domino effect” across the landscape. Enhancing positive species interactions, such as predator-driven regulation of herbivore pressure, can further accelerate plant establishment. Once these self-sustaining sub-systems are established, feedback loops—including nutrient cycling, soil stabilization, and biodiversity enhancement—amplify recovery, reducing reliance on intensive management.

Harnessing ecosystem resilience and self-organization can create critical ecological leverages to amplify the effects of local interventions on the degraded wetlands. This method minimizes disturbance to the ecosystem, is low-cost, requires minimal input, and does not necessitate continuous maintenance, making it an ideal tool for large-scale restoration initiatives worldwide.

The FIT Principle: Guidance on the Practice of Wetland Restoration

Andy Herb

AlpineEco, Denver, USA
Charles Sturt University, Bathurst, Australia

Many wetlands around the globe have been degraded by various anthropogenic activities and would benefit from targeted wetland restoration efforts (and many have). Although there are many published documents on the principles and importance of wetland restoration, some site managers and restoration practitioners may lack guidance on the applied techniques they need to effectively restore natural and sustainable wetland systems. In this presentation, I will introduce and explain what I call the *FIT Principle,* which summarizes the fundamental aspects of wetland restoration planning, design, and implementation that are essential to restoring the ecological processes needed to sustain healthy wetlands. “F” refers to replacing *form* and *function*; “I” refers to the need for thorough *investigation* of the site and watershed, and the *integration* of various data into the design; and “T” stands for the employing science-based *techniques* and dedicating ample *time* to monitoring and long-term management. I will provide specific guidance and highlight examples from various freshwater restoration projects in the Rocky Mountains, USA to help managers and practitioners implement the *FIT Principle*, with the goal of improving wetland restoration outcomes.

Three Decades of Wetland Restoration / Rehabilitation in the Upper St. Johns River Basin Floodplain – Getting the Water Right

Kimberli J. Ponzio, Steven J Miller

St. Johns River Water Management District, Palatka, Florida, USA

The Upper St. Johns River Basin (USJRB) in east-central Florida is a diverse ecosystem characterized by a mosaic of wetland habitats that originally spanned over 160,000 hectares. Beginning in the early 1900s, over half the historic USJRB floodplain was drained and converted to agriculture. Drainage activities not only reduced wetland area, but also significantly altered the natural hydrology of the remaining system by reducing water retention times, lowering water levels, and accelerating downstream flows. The St. Johns River Water Management District partnered with the U.S. Army Corps of Engineers in the 1980s to develop the USJRB Project utilizing a "semi-structural" approach to water management. With this approach, wetland storage capacity within the USJRB was expanded through the acquisition and restoration / rehabilitation of over 28,000 hectares of previously drained floodplain, in conjunction with the construction of retaining levees, and water control structures. Hydrologic regulation schedules were implemented to provide flood protection. However, when not being operated for flood protection, water management has been guided by a suite of environmental hydrologic criteria (EHC) to restore the spatial and temporal attributes of a more natural hydrologic regime. To delimit optimal hydrologic metrics, we considered parameters including mean depth, inundation frequency, maximum depth, water level recession rate, and magnitude, duration, and seasonality of water-level fluctuations. Each project area in the USJRB has its own specific criteria that we aim to meet over the long term (30+ years). We present three cases where hydrologic conditions have been on a continuum of too dry to too wet and the ecological implications of those conditions. Ultimately, we plan to update the EHC to reflect lessons learned over the last three decades and, through hydrologic restoration, ensure the ecological integrity of the diverse wetlands in the USJRB.

Back to the Past: Returning Agricultural Fields to Original Wetlands at Lake Apopka, Florida, USA

Dean Dobberfuhl

St. Johns River Water Mgmt Dist, Palatka, USA

Lake Apopka, FL, USA is a 12,000 ha lake that once had an adjoining 8,100 ha wetland on the north side. Beginning in the 1940s, the floodplain wetland area was separated from the lake by a levee, drained, and converted to agriculture. The area was seasonally pumped dry for farming and reflooded for pest control. The pumped discharge caused hypereutrophication in the lake. The state began purchasing farms in the 1980s with the goal of restoring the area to wetland habitat. Substantial challenges arose during restoration, including pesticide contamination, phosphorus enrichment, invasive species, and flood protection. Pesticide risk delayed land management options and restoration progress for many years. Novel, cost saving methods were developed to minimize the risk of contamination and phosphorus. We have made progress reducing invasive species but that remains an ongoing maintenance challenge. Flood protection remains a considerable management constraint, especially during large precipitation events. However, water conveyance infrastructure within the wetland has been improved to facilitate land management and restoration activities. As the former farms were a major source of phosphorus to the lake, wetland restoration has dramatically reduced loading to the lake with concomitant improvements in habitat and water quality. The wetland has also become a recreational mecca with incredible faunal diversity, hiking and biking trails, and a popular unpaved wildlife drive.

Restoration of High Energy Valley Bottom Wetlands: Lessons Learnt from South African Palmiet Wetlands

Alanna Rebelo

Agricultural Research Council of South Africa, Natural Resources and Engineering, Water Science Unit, Cedara, South Africa
Stellenbosch University, Department of Conservation Ecology and Entomology, Stellenbosch, South Africa

Wetland plant communities are shaped by high levels of stress, disturbance and competition. Using South African palmiet wetlands as a case study (*Prionium serratum* dominated valley-bottom wetlands), I investigated whether autogenic or allogenic succession is the dominant process driving community dynamics. Several wetland restoration programmes in South Africa use the dominant wetland species palmiet (*P. serratum*) as a pioneer to facilitate recolonization. However research is needed on palmiet wetland dynamics and formation to guide these restoration efforts.

Vegetation patterns were explored by analysing which environmental parameters drive dominance of palmiet, resulting in the characteristic patchiness of palmiet wetlands, and which plant functional traits account for this. In 20 plots from three palmiet wetlands distributed across the Cape Floristic Region of South Africa, key soil, groundwater and vegetation parameters, as well as community composition were measured. Twenty-two dominant species were selected and 13 functional traits measured. Soil pH and relative groundwater depth were the main environmental parameters driving community assembly in palmiet wetlands. Palmiet-dominated communities were characterized by greater stem diameter, leaf length–width ratio, leaf area and cellulose and lignin concentration compared to other communities. These traits suggest adaptations to disturbances such as fires (thicker stems) and floods (long, thin leaves, flexible shoots and thicker stems).

I propose three hypotheses of palmiet wetland development, offering insights for restoration efforts. Additionally, I will present case studies of restoration successes and failures to illustrate the challenges and opportunities in palmiet wetland conservation.

Boreal Peatlands: How Back History of Peat Stratigraphy Leads to Future Success of Wetland Restoration

Line Rochefort[1,2], Eeva-Stiina Tuittila[3]

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[3]Peatland and Soil Ecology Group, School of Forest Sciences, University of Eastern Finland, Joensu, Finland

Paleoecology as an aid to peatland restoration is underused. Although paleoecology is an important tool for understanding peatlands and other ecosystems, stratigraphic studies of peatland development are only occasionally considered in peatland repair or rebuilding. They should, if possible, be undertaken before the ecosystem is exploited or within the nearby margins of the surrounding natural remnants. Such studies can answer a variety of questions, beginning with assistance in defining the goal of a given peatland restoration project where layers of peat have been taken out, setting back in time the stratigraphy to an earlier stage of development. Exposing peat soils, centuries and millenia year old, results in residual surface substrate conditions unrelated to pre-disturbance conditions. So, setting a goal to a pre-disturbance state is often not an option for peatland ecosystems where layers of peat have been extracted. Additionally, the pattern of succession and trajectory pathways through time has proven useful in developing the Moss Layer Transfer Technique (MLTT) restoration approach for degraded Sphagnum-dominated peatlands and for giving insight for the target state of peatland restoration after the forestry use. Consequently, using paleoecology to study the history of peat stratigraphy can enhance the success in rebuilding peatlands especially when the peat surface has been lowered to an earlier stage of development.

Translocation of Intact Wetland Soil and Vegetation Can Enhance SOM and Ecological Function in Restored and Created Wetlands

Gillian Davies

BSC Group, Inc., Worcester, USA
Global Development & Environment Institute, Tufts University, Medford, USA

Translocation of intact wetland soil and vegetation can enhance soil organic carbon and ecological function in restored and created wetlands, thereby creating opportunities to improve wetland carbon conservation and to accelerate wetland function. In implementing wetland soil and vegetation translocation at a wetland restoration and creation site, our objective was to compare the vegetative success, soil characteristics, and hydrology of an experimentally translocated wetland replication area (ETWRA) to that of a traditionally constructed wetland replication area (TCWRA) as well as a reference wetland (RW). We also identified conditions that facilitate effective implementation of this approach, as well as constraints. We established vegetation data plots and soil pits in each of the three wetlands being monitored. Vegetation measures included species diversity and richness, percent cover, percent wetland indicator species, and presence/absence of invasive species. Soil measures included soil profile data, bulk density, total organic matter, total organic carbon, total nitrogen, carbon to nitrogen ratio, extractable nutrients, pH, depth to water table, and soil saturation. We found that at the end of the first growing season, the ETWRA had greater species diversity and overall vegetative cover than the TCWRA, and more closely resembles the RW. In addition, soil properties in ETWRA more closely resemble those of RW. ETWRA soil retained moisture to a greater degree than TCWRA soil during the Massachusetts 2016 drought. By preserving soil and plant structure, impacts to ecological functioning in ETWRA appear to be reduced, compared to TCWRA. Preliminary results support the idea that translocating blocks of intact soil and vegetation from impacted wetland areas to wetland restoration and creation areas can be a Best Management Practice when site and project conditions allow. Further studies of the differences in functionality between translocated wetland replication areas and traditionally constructed wetland replication areas are needed.

An Assessment of Carbon Cycling in Restored Wetlands on Ranchland in South Florida, USA

Tracey Schafer[1], Joseph Prenger[2], Todd Osborne[1]

[1]University of Florida- Whitney Laboratory for Marine Biosciences, St. Augustine, USA
[2]United States Department of Agriculture, Gainesville, USA

The Wetland Reserve Easement (WRP/WRE) programs run by the United States Department of Agriculture restore freshwater wetlands in agricultural areas to reestablish important wetland functions. The majority of these wetlands provide various ecosystem services, such as wildlife habitat and carbon capture, however, the potential loss of carbon through carbon dioxide (CO_2) and methane (CH_4) emitted from these restored wetlands has not previously been thoroughly examined. Freshwater wetlands are known to emit greenhouse gases, such as CO_2 and CH_4, at varying rates depending on substrate type, quality, and hydrology. In order to examine carbon cycling within a subset of WRE/WRP wetlands, a study of ten semi-permanent sites have been established within a ranch and nearby reserve containing WRP/WRE wetlands in south-central Florida. Every two months, CO_2 and CH_4 flux measurements are taken with a LI-7810 Licor CO_2/CH_4/H_2O trace gas analyzer at each site in addition to groundwater and surface water monitoring. Soil and plant carbon measurements have also been completed to determine carbon storage within these wetlands. Findings indicate that hydrology and residence time of water within the wetlands is the determining factor in carbon storage and dominant greenhouse gas generating processes. Well-drained or ephemeral wetlands lose carbon through CO_2 emissions, and poorly-drained wetlands have low enough oxygen concentrations seasonally to support production of CH_4. Although the benefits of carbon storage in wetlands outweigh any impacts from their greenhouse gas emissions, taking flow and inundation time of wetlands into account with wetland restoration could help to capture larger amounts of carbon and mitigate seasonal carbon losses.

Trajectory of Wetland Soil Biogeochemistry with Thin Layer Dredge Material Amendment in an East Coast Salt Marsh

John White[1], Jacob Cheng[1], Jacob Berkowitz[2]

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The intentional thin layer placement (TLP) of dredged sediment is an increasingly popular approach to maintaining marsh elevation and restoring degraded marshes, which can improve conditions for vegetation establishment. Prior TLP restoration projects assessed shortly after construction evaluated soil, hydrology, plant, and faunal responses. However, no long-term studies (>1 yr) investigate TLP-induced shifts in soil properties and biogeochemical cycling. In response, this study revisited a salt marsh >6 years after TLP restoration and determined both soil physiochemical and microbial properties related to plant growth (N mineralization) and water quality (denitrification). Data were compared with samples taken before TLP introduction and 0.5 years after project completion. Bulk density increased to 342% of the control 0.5 years after project completion and was 272% of the control after 6 years, suggesting significant sediment retention in the marsh over time. Microbial biomass declined to 7.6% of the control following TLP, then rebounded to 29.4 % of control after 6 years. The N mineralization rate, increased from 22% to 31% of control after 0.5 years and 6 years respectively. Notably, live root density was 3x higher in the TLP marsh compared with the control, suggesting that the restored marsh likely responded to reduced nutrient availability (approximately 1/3) by generating additional belowground biomass. Restored marsh denitrification rates were not significantly different from the control suggesting the water quality improvement ecosystem services recovers quickly. While soil properties became more similar to controls over time, long-term studies are needed to inform the unique ecological trajectories of sediment amended marshes.

Symposium 5:
Remote sensing–based monitoring of wetlands and their restoration

1 July
17:00-17:40, Maailmafilm Hall

Predicting Gross Primary Productivity in Peatland Using Landsat Remote Sensing Data

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Gross primary productivity (GPP) plays a critical role in the functioning and sustainability of peatland ecosystems. Accurate mapping and prediction of GPP are essential for informed decision-making in peatland management and restoration. This study used 30-meter resolution remote sensing data from Landsat 8-9 to predict GPP across peatland types in three European countries: Finland, Estonia, and Germany. The primary objectives were to develop robust predictive models using random forest regression, identify the most effective predictors of GPP from Landsat 8-9 data, and upscale the results across different peatland types at the regional scale. We calculated various vegetation indices from Landsat 8-9 data, along with individual spectral bands, as predictors in the regression models. Our results demonstrate that GPP can be accurately predicted using a combination of spectral bands and vegetation indices, with explained variance (%var) ranging from 29% to 72%, depending on the site. Model performance varied across sites and peatland types, underscoring the importance of site-specific calibration. This study highlights the potential of high-resolution (30 m) Landsat remote sensing imagery for spatially explicit mapping of GPP, providing valuable insights for sustainable peatland ecosystem management and resource conservation.

Leveraging Remote Sensing for Mapping Biodiversity and Ecosystem Services in Boreal Drained Peatland Forests

Parvez Rana, Andras Balazs

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Boreal drained-peatland forests support diverse, interconnected biodiversity and ecosystem services (BES). Mapping BES is crucial for effective conservation and management, yet optimal spatial resolution and data integration strategies remain underexplored. This study mapped multiple BES indices including biodiversity conservation, habitat suitability, non-timber forest products (e.g., bilberry and cowberry yield), scenic beauty, timber production, and carbon storage using airborne laser scanning, UAV, and optical satellite data (PlanetScope, Sentinel-2, Landsat 8-9). We aimed to: (1) identify key RS predictors for BES, (2) develop random forest models for BES estimation, (3) compare RS data performance, and (4) upscale BES distribution across closed, partial, and open canopies. Preliminary results show BES predictions achieve 13–90% explained variance, with canopy structure influencing BES potential. Closed canopies exhibited higher BES values. These findings highlight RS as a powerful tool for spatial BES assessment, supporting sustainable forest management.

Symposium 6:
Drivers and processes of soil CO_2, CH_4, and N_2O emissions in forested peatlands

3 July
16:45-18:15, Kurrik Hall

Lessons From Ecosystem Decay to Restoration Practices: GHG Emissions in a Low Peatland Area in Southern Europe (Portugal)

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EU2030 biodiversity strategy and EU Nature Restoration Regulation call for conservation and restoration of peatlands particularly through rewetting techniques. Studies on southern locations in peatland areas are scant because these types of habitats normally occur on Northern parts of the hemisphere on tropical and subtropical areas. Paul da Goucha Local Nature Reserve is a willow, ash and alder forest in a unique 90h relict of a low peatland area (unsure if still active), that reaches 9m of depth of peat in some areas. Integrated in REWET project (www.rewet-he.eu) we measured above canopy GHG flux measurements continuously since March 2024 with an eddy covariance system installed in a 10 meters' tower. To study ground GHG we made in situ measurements of CO_2 and CH_4 emissions using closed flux chambers using Licor XXX portable device. Sampling was conducted twice in Spring and Autumn. To further understand Paul da Goucha GHG emissions pattern we also surveyed 6 extra points with other land use practices outside the wetland area.

CHG data shows a marked seasonal emission pattern, with Spring and Autumn being the seasons with higher emissions and Winter and Summer the seasons with less emissions. Low and High temperature periods seem to have a key impact on GHG emissions. Results are most probably related to soil biological activity fueled by vegetation decay, temperature and water levels. Our results show that management options need to be carefully designed to minimize carbon emissions. Rewetting the area needs to be carefully studied since in Southern locations soil biological processes (dependent on temperature) must be taken in regard. An alarming message maybe that even with Rewetting strategies and considering climate change we may no longer be able to contain all natural degradation processes, while we still can at least minimize these through appropriate conservation and restoration measures.

Measuring GHG Emissions from Rewetted Forested Peatlands Using Automatic Double-Chamber Systems

Cornelius Oertel, Paul Matras, Julian Gärtner, Andreas Kaufmann, Marc Seimert, Jonas Sitte, Nicole Wellbrock

Thünen Institute of Forest Ecosystems, Eberswalde, Germany

2.4% of the German forest area stands on peatlands and other organic soils. The rewetting of formerly drained forested peatlands is an ongoing process. This rewetting process requires further scientific monitoring, as there is limited long-term data available on GHG emissions. Particularly in Central Europe, measurements from forested peatlands remain rare, especially after rewetting. This is crucial for accurately assessing the sink function of rewetted forest peatlands, particularly in terms of IPCC reporting.

Using automatic double-chamber systems, we accompany the rewetting process of a bog with Picea abies stands and a fen with Alnus glutinosa stands in Germany. Each site is equipped with five fully automated chamber towers. Each tower includes both transparent and an opaque chamber, allowing for the sequential determination of the CO_2 fluxes net ecosystem exchange and ecosystem respiration from the same spot. From these measurements, gross primary production can be calculated for each spot. CH_4 and N_2O fluxes are also analysed at each spot, which is relevant for measurement in ditches of peatlands. In addition to gas measurements, common weather parameters such as temperature, humidity, wind, and precipitation are measured. Special focus is given to CO_2-relevant radiation parameters PAR and incoming and outgoing radiation. At each chamber tower, soil temperature and soil moisture are measured at three depths. The peat water level is continuously measured, as it is an important factor in explaining GHG emissions and observing the effects of rewetting. The same applies to the change in ground level elevation, which is regularly determined.

Combined with tree stand inventories and point dendrometers, the GHG-emission measurements allow us to derive changes in the net C storage over time.The results can also be used to derive climate-friendly management of forested peatlands, taking into account GHG emissions and tree stands.

Short-Term Impact of Remedial Ditching on Peatland Greenhouse Gas Emissions Following Clearcutting

Aldis Butlers, Andis Lazdiņš, Mārtiņš Vanags Duka

Latvian State Forest Research Institute "Silava", Salaspils, Latvia

In forested lands, soil greenhouse gas (GHG) monitoring has most commonly been conducted in forest stands. However, GHG emissions are influenced not only by the forest stand developmental stage but also by forest management activities. Undrained peatland forests can be significant sources of greenhouse gas emissions due to methane hotspots, especially following clearcutting, which often leads to an elevated water table. Therefore, limiting the rise in the water table following harvesting is being considered as a measure to reduce the CH_4 emissions. In this study, we monitored soil GHG efflux using the manual chamber method before and after clearcutting, with and without subsequent remedial ditching. The study was conducted at five undrained peatland forest sites. Before harvesting, the annual mean water table level (WTL) at both the ditching and control sites was 13 ± 1 cm. After clearcutting, the mean WTL rose to 1 ± 7 cm at the control sites, whereas at sites with remedial ditching, it dropped to an annual mean depth of 28 ± 12. As a result of ditching, CH_4 emissions in clearcut areas were reduced by an average of 239 kg CH_4 ha^{-1} yr^{-1}, thereby avoiding more than a twofold clearcut induced increase in CH_4 emissions. Remedial ditching did not affect CO_2 emissions following clearcutting - CO2 emissions increased from an average of 4.5 ± 0.4 to 8.9 ± 0.1 t CO_2-C ha^{-1} yr^{-1}. While N_2O emissions increased from mean 0.6 ± 0.3 to 2.7 ± 1.2 and 4.4 ± 1.1 kg N_2O ha^{-1} yr^{-1} in control and ditched sites. Although the impact of ditching on clearcut emissions was -1% for CO_2 and +59% for N_2O, the total emissions, expressed in terms of 100-year global warming potential, were reduced by 14% due to a 77% reduction in CH_4 emissions.

Groundwater Level Driving the Dynamics of Soil Greenhouse Gas Fluxes in Old-Growth Hemiboreal Birch (*Betula spp*.) Stands on Organic Soils

Valters Samariks, Kristaps Ozoliņš, Laura Ķēniņa, Endijs Bāders, Āris Jansons

Latvian State Forest Research Institute "Silava", Salaspils, Latvia

Tree biomass and soil, especially organic soil, are the largest carbon pools in forest ecosystems in the hemiboreal region. Soil is not only a carbon store but also a source of greenhouse gas (GHG) emissions, mainly resulting from soil respiration (root and microbial activity) and decomposition of organic matter. Deriving quantitative estimates to characterize this dynamic balance is crucial for modeling the contribution of such ecosystems to climate change mitigation goals. Forest management activities such as drainage alter soil aeration, shifting microbial processes that regulate gas emissions, and influence soil respiration. Recent studies on GHG emissions from organic soils have focused on coniferous species, but the share of broadleaves is increasing, especially in light of climate change adaptation and biodiversity maintenance measures. The study aims to assess the inter-annual dynamics of soil carbon dioxide (CO_2) and methane (CH_4) flux in hemiboreal old-growth birch (*Betula spp*.) stands growing on organic soils with contrasting groundwater levels (drained and undrained). Total forest floor respiration of CO_2 (R_{ff}) and CH_4 fluxes was evaluated in four stands (114–127 years old). The average R_{ff} is similar between drained and undrained soils, thus the effect of drainage is not distinct. Moreover, R_{ff} exhibits a distinct seasonal pattern linked to soil temperature, suggesting a potential rise in CO_2 efflux under warming climatic conditions. CH_4 flux dynamics are predominantly influenced by fluctuations in groundwater levels and display considerable variability. Drained organic soils function as a consistent CH_4 sink throughout the monitoring period, whereas undrained soils act as a CH_4 source during wet periods and transition to a sink during drier conditions, particularly in summer. The establishment of a drainage system that lowers excessive groundwater levels promotes a sustained increase in soil CH_4 uptake, contributing positively to climate change mitigation in the hemiboreal region.

Heterotrophic Soil Respiration in Three Forestry-Drained Boreal Peatlands Dominated by Downy Birch (*Betula Pubescens* Ehrh.)

Md Rezaul Karim[1,2], Jani Anttila[1], Katja T. Rinne-Garmston[1], Sakari Sarkkola[1]

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Boreal peatlands contain a significant terrestrial carbon storage. Many of the boreal mire sites support tree growth naturally, and tree stands largely affect their carbon dynamics controlling the decomposition and new carbon inputs. Most research has focused on the conifer stands, with limited attention given to carbon emissions from peatland sites dominated by stands of deciduous tree species and how the emissions change along stand succession. We studied heterotrophic soil respiration (CO_2) using site-specific temperature and water table interaction models and simulations at half-hourly intervals over two growing seasons (May–September 2021–2022) in three downy birches (*Betula pubescens* Ehrh.)-dominated drained nutrient-rich peatland sites in Finland. The stand represented three developmental classes: young stand (stand age 10 years), middle-aged stand (50 years), and mature stand (80 years). Instantaneous CO_2 fluxes ranged from 0.09 to 1.37 g CO_2 m^{-2} h^{-1}, and mean cumulative fluxes ranged 11.0–28.9 g m^{-2} day^{-1}. For the summer period, the cumulative fluxes showed to decrease along the stand age being highest (2661 g m^{-2}) in young stand, and lowest (1012 g m^{-2}) in mature stand. Water table level proved to be another one independent factor significantly explaining the variation in the respiration fluxes.

Spatiotemporal Differences of N_2O and CH_4 Emissions in Boreal (Finland) Drained Peatland Forests: Impacts of Vegetation and Water Levels

Jyrki Jauhiainen, Juha Heikkinen, Liisa Ukonmaanaho, Tuula Larmola

Natural Resources Institute Finland, Helsinki, Finland

Human activities in peatlands often lead to significant changes in vegetation composition, water levels, and nitrogen cycling, which in turn profoundly affect the dynamics of nitrous oxide (N_2O) and methane (CH_4) emissions from these ecosystems. Accurate estimation of N_2O and CH_4 fluxes is particularly challenging due to inherent uncertainties associated with their temporal variability and small-scale spatial heterogeneity of these fluxes between the atmosphere and various respiring surfaces. Drained peatland forest floors exhibit a mosaic of ground vegetation types alongside diverse water levels and soil moisture conditions, creating a complex environment for greenhouse gas dynamics. Oxygen availability is a primary factor controlling CH_4 dynamics, while soil moisture and water table levels play acknowledged roles in regulating both CH_4 and N_2O formation and consumption. In addition to soils, also ditches and tree trunks contribute to the gas fluxes in these systems. This study employs closed dark chamber measurements to investigate both temporal and small-scale spatial variations in N_2O and CH_4 fluxes across boreal drained peatland forest floor vegetation types and tree trunks over warm season. Drier conditions increased N_2O emissions, averaging (Average±S.D.) 47±101 µg m^{-2} h^{-1} from soils and 21±69 µg m^{-2} h^{-1} in ditches, while emissions from tree trunks were ten times lower. Wet ditches had the highest average CH_4 flux during warm seasons at 2125±541 µg m^{-2} h^{-1}. Conversely, permanently drained soils acted as CH_4 sinks, averaging -53±61 µg m^{-2} h^{-1}. Overall, CH_4 fluxes from tree trunks were negligible compared to those from soils. In presented analyses, we will correlate flux data collected 1-3 times per week with seasonal water table levels, soil moisture, temperature, and ground vegetation types. This approach aims to enhance the understanding of the spatiotemporal dynamics of N_2O and CH_4, and insights needed for improving emission modelling in peatland ecosystems.

Spatio-Temporal Variability of Soil CO_2, CH_4, and N_2O Fluxes Under Alternative Harvesting Managements in Boreal Drained Forested Peatland

Boris Ťupek[1], Aleksi Lehtonen[1], Jani Anttila[1], Qian Li[1], Eduardo Martínez García[1], Tijana Martinovic[2], Petr Baldrian[2], Alexandre Raimbault[2], Raisa Mäkipää[1]

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Overview: This study examines the effects of different forest management practices on soil greenhouse gas (GHG) fluxes in the Ränskälänkorpi boreal drained forested peatland, Southern Finland. The site is part of the HoliSoils project (*Holistic management practices, modelling, and monitoring for European forest soils*; https://holisoils.eu/). The study compares three management approaches: non-harvested control (CTR), traditional clear-cut harvesting (CUT), and selection harvesting (COV), where 57% of the basal area was removed. The harvesting treatments were implemented in spring 2021. The primary objective is to quantify differences in soil CO_2, CH_4, and N_2O fluxes and refine annual emission estimates.

Measurements and Analysis: Post-harvest measurements were conducted biweekly during the growing season (May–November), capturing soil CO_2, CH_4, and N_2O fluxes, along with soil temperature, moisture, water table depth, and air temperature. Additionally, soil chemistry, understory vegetation, and microbial populations were analyzed to explore their influence on the spatial patterns of GHG fluxes. To assess relationships between fluxes and environmental variables and model their spatio-temporal dynamics, we applied machine learning and Bayesian data assimilation techniques.

Key Findings: Clear-cutting (CUT) led to a rapid and sustained increase in the water table, with significantly higher levels compared to the control (CTR) and selection harvesting (COV) sites. Significant differences in mean soil CO_2, CH_4, and N_2O fluxes were observed across all treatments (CUT, COV, and CTR).

Implications: Our results highlight the spatio-temporal variability of GHG fluxes across different forest management practices and emphasize the role of harvesting methods in modifying environmental controls on CO_2, CH_4, and N_2O fluxes. The findings contribute to narrowing the knowledge gap regarding the impacts of forest harvesting on GHG fluxes in boreal drained forested peatlands.

Soil Disturbances Affect GHG Emissions, Organic Carbon Pool and Microbial Community in Drained Peatland Forest

Qian Li[1], Tijana Martinović[2], Bartosz Adamczyk[1], Sylwia Adamczyk[1], Anne Tyvijärvi[1], Vendula Brabcová[2], Aleksi Lehtonen[1], Petr Baldrian[2], Raisa Mäkipää[1], Mikko Peltoniemi[1]

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Soils in drained peatland forests are losing their carbon stocks and increasing GHG emissions under warming climate. Natural disturbances like storms can exacerbate these changes by altering soil structure and nutrient inputs. Uprooted trees lift up surface soil and create root pits, whereas needles and branches from fallen canopy load on soil cause excess nutrients input. Thus, disturbances increase the spatial heterogeneity of soil microclimate, properties and break existing root and fungal network, leading to changes in soil processes and carbon balance. To study the impacts of two types soil disturbances – topsoil removal and residues cover – on the GHG emissions, soil organic carbon (SOC) pool and microbial community in drained peatland forest, disturbance treatments were established in clearcut and canopy-covered forest sites in southern Finland. Due to the topsoil removal treatment, CO_2 emissions decreased but N_2O emissions increased compared to the untreated soil (control) in both clearcut and canopy-covered forest during 2 years measurement period. Topsoil removal treatment also decreased the soil CH_4 sink, even switching clearcut to CH_4 source. Residue-covered soil treatment showed higher CO_2 and N_2O emissions than control in the canopy-covered forest. Both disturbance treatments increased the global warming potential in the canopy-covered forest. The stable SOC fraction significantly decreased due to topsoil removal, while residue cover enhanced soil C stabilization by increasing the proportion of stable SOC after 2 years treatments. Topsoil removal altered fungal community composition and reduced fungal and bacterial biomass. Although bacterial communities showed stable in most treatments, clearcutting combined with topsoil removal led to a distinct shift, decreasing the relative abundance of methane-oxidizing bacteria. Our results revealed that soil disturbances can cause global warming effects in short term and lead to high spatial variability of soil microbes and SOC pool. Longer term studies are needed to understand the soil recovery after disturbances.

Short-Term Effects of Harvesting Methods on Soil N_2O Fluxes and Their Spatio-Temporal Variation in a Drained Boreal Peatland Forest

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The need to mitigate climate change has led to a growing interest in understanding nitrous oxide (N_2O) emissions from forests, which account for 15–55% of global emissions. Forests cover one-third of the Earth's surface, with half being managed. In this context, a considerable proportion of the boreal forestry-drained peatlands in Finland are reaching maturity, which will result in their imminent harvest. It stresses the need for further research on how diverse harvesting methods affect their soil N_2O fluxes. This study was conducted at Ränskälänkopi, a mature fertile boreal peatland forest located in southern Finland. A comparative analysis was made of traditional clear-cutting-based rotation forestry (CC) and alternative continuous-cover-based forestry (CCF) sites, harvested in March 2021, relative to a non-harvested control (C) site. Soil N_2O fluxes were measured using automated and manual chambers across the sites. The findings revealed that N_2O fluxes were relatively stable at the C site, with air temperature and precipitation being the main temporal controlling factors. In contrast, N_2O fluxes were higher and more variable at the CC and CCF sites, with soil moisture and water table level being dominant temporal factors. Additionally, temporal patterns of N_2O fluxes were influenced by preceding environmental conditions. We also found significant spatial variation in N_2O fluxes, with hotspots more common at the CCF site. Factors like soil fertility, temperature, and bulk density were strongly linked to this spatial heterogeneity. Overall, harvesting increased short-term soil N_2O emissions, but spatial variability in nutrient availability appeared to play a greater role in their control. These results provide insights into the effects of different harvesting strategies on soil N_2O emissions and support better forest management decisions. However, further research is required to assess the long-term effects of clear-cutting and selection harvesting on the soil N_2O dynamics of boreal forestry-drained peatlands.

Symposium 7:
Negative carbon emissions from coastal wetlands: mechanisms, practices, and challenges

1 July
15:00-16:30, Kurrik Hall

The Influence of Water Table Level and Grazing on Greenhouse-Gas Exchange in Salt Marshes

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Vegetated coastal ecosystems such as salt marshes have gained increased interest due to their large carbon accumulation and climate mitigation capacity. In the Nordic salt marshes, livestock grazing is widely used in nature management, however grazing could potentially alter the carbon dynamics in these ecosystems. As salt marshes are very dynamic ecosystems due to frequent tidal inundation, we hypothesized that the effect of grazing on the carbon stocks could be influenced by the magnitude of tidal inundation. Here, we investigated the effect of grazing and tidal inundation on above and belowground biomass patterns, soil carbon stocks and a range of soil and plant trait parameters in five grazed and ungrazed Danish salt marshes. Grazing strongly reduced the aboveground biomass of salt marshes with low tidal influence, while grazing in sites with high tidal influence did not significantly affect the aboveground biomass. However, grazing reduced soil compaction, increased root depth, and stimulated belowground biomass allocation in these sites, likely as a compensatory response. This coincided with a higher organic matter content (LOI) for salt marshes with high tidal influence, with grazed Skallingen having the highest mean soil organic matter content of 22.45 ± 2.62 %. The photosynthetic capacity was generally enhanced by grazing, however this did not drive higher soil organic matter content. More intense grazing and soil compaction (bulk density) seemed to be the limiting factor for belowground biomass production, as these parameters generally increased with lower tidal ranges. These results suggest that grazing can have a positive effect on carbon accumulation in low marshes more affected by tidal inundation, while grazing in high marshes with low tidal influence is more likely to have a negative effect on carbon accumulation. Therefore, high marshes should be considered restoration targets with restricted grazing to stabilize carbon losses in Nordic salt marshes.

Native *Phragmites Australis* Promotes Greater Carbon Sequestration and Stocks Than *Spartina Alterniflora* with Future Warming

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Projections indicate a substantial rise in global mean temperature by the end of the 21st century. Elevated temperature affects plant physiology within coastal wetlands, thereby affecting carbon sequestration processes, which may affect their ability to counter increased warming. However, there is limited knowledge about how native and invasive plant differ their physiological response to climate warming; warming may enable invasive plant expansion at the cost of carbon sequestration. Here, we simulated projected temperature increases using in-situ open top chambers (OTCs) to understand photosynthetic and growth responses of a C_3 native grass, *Phragmites australis*, and versus a C_4 non-native grass, *Spartina alterniflora*, in Yancheng, China. Warming slightly reduced the leaf net photosynthetic rate (P_n), specific leaf area, and chlorophyll content of *P. australis*, potentially from an early termination of its relative growing season within our OTCs. In contrast, warming significantly enhanced the P_n and chlorophyll content of *S. alterniflora*. For both species, shoot height increased while shoot density decreased. However, warming decreased the overall aboveground biomass of *S. alterniflora* by 24.5% but only slightly decreased P_n of *P. australis* by 5.9%. The *P. australis* wetland maintained a greater carbon stock and sequestration rate compared to *S. alterniflora* with elevated temperatures by 1.5°C. As *S. alterniflora* invades Chinese marshes, an implication is for reduced over carbon sequestration and biomass storage with future warming.

Integrative Landscape Restoration in the Ebro Delta: Advancing Wetland Conservation and Climate Resilience

Nil Alvarez, Silvia Frias-Vidal, Carles Ibañez

Eurecat, Centre Tecnològic de Catalunya, Climate Solutions and Ecosystem Services Unit, Amposta, Spain

Coastal wetlands play a crucial role in climate resilience, acting as long-term carbon sinks while providing essential ecosystem services. However, these ecosystems are increasingly threatened by climate change, land-use pressures, and hydrological alterations. The Ebro Delta, one of the most ecologically and socioeconomically important wetlands in the Mediterranean, is experiencing habitat degradation due to sea-level rise, reduced sediment supply, and other anthropogenic pressures. Addressing these challenges requires a holistic, landscape-based approach that integrates wetland conservation with sustainable land-use and climate strategies.

Our work in the Ebro Delta is structured around four interconnected research lines: (1) Ecosystem restoration, involving both hands-on wetland restoration through nature-based solutions and the development of restoration plans, design as actionable frameworks for authorities to implement at a larger scale; (2) Sustainable rice agriculture, which seeks to mitigate the environmental impact of rice production by implementing sustainable practices such as AWD techniques to reduce methane emissions, while developing economic incentives through carbon markets; (3) Environmental monitoring, employing advanced methodologies including static chambers and trace gas analyzers as well as eddy covariance towers to measure carbon fluxes in both natural habitats and paddy fields; and open-top chamber experiments to assess climate change effects on different wetland ecosystems; and (4) Blue carbon assessment, which aims to quantify carbon stocks and sequestration rates of coastal blue carbon systems across the entire delta to identify optimal management practices to maximize carbon sequestration for climate change mitigation while enhancing ecosystem resilience.

By integrating these strategies within a landscape-scale framework, we aim to develop and model effective pathways toward carbon-negative wetland systems. This approach not only strengthens the role of wetlands in climate mitigation but also aligns conservation and adaptation strategies to ensure long-term ecosystem functionality and socioeconomic viability, maximizing the potential for wetland conservation, restoration and improved management practices as nature-based solution.

Climate Warming and Environmental Stressors Threaten Carbon Preservation in Huang-Bohai Sea Wetlands: Microbial Insights and Management Implications

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Coastal wetland ecosystems, characterized by high primary productivity, serve as critical carbon reservoirs and are pivotal for implementing ocean negative carbon emissions (ONCE). However, climate warming and anthropogenic environmental changes may alter carbon cycling patterns, threatening the preservation of these carbon sinks. Reducing carbon emissions from sediment organic matter (SOM) mineralization and enhancing carbon sequestration remain key challenges in global carbon cycle research. Although SOM decomposition is influenced by environmental variables such as temperature, hydrology, oxygen levels, and substrate availability, it is fundamentally a microbially mediated process. Furthermore, SOM decomposition rates exhibit latitude-dependent responses to warming and environmental shifts. Here, we conducted decomposition incubation experiments using reed (*Phragmites australis*) roots and leaves across latitudinal gradients in the Huang-Bohai Sea (HBS) coastal wetlands, integrating microbial and chemical analyses to explore mechanisms of soil carbon preservation. Results revealed that warming modestly enhanced carbon decomposition rates but significantly increased microbial biomass, strengthened the complexity and connectivity of microbial co-occurrence networks, elevated the abundance of carbon-cycling functional taxa, and reduced microbial diversity in most cases, with more pronounced effects at higher latitudes. These findings suggest that global warming may weaken the resilience of coastal wetlands' carbon sequestration capacity, posing long-term risks to carbon storage. Notably, contrary to the conventional view that reductive conditions slow decomposition, one site with the most complex microbial networks and strongest reducing conditions exhibited ~30% higher decomposition rates, likely due to internal eutrophication in pore water accelerating SOM breakdown. This study highlights that under climate warming, poor hydrological management (e.g., water quality and water table regulation) could synergistically trigger catastrophic consequences for coastal carbon sinks. Future ONCE initiatives must prioritize strategic water management to mitigate internal eutrophication-driven carbon loss.

Keywords: microbial community, prokaryotes, fungi, water quality, water table, ocean negative carbon emission

Global Mangrove Stem Methane Emissions Offset Blue Carbon Sequestration

Faming Wang, Guoming Qin

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Mangroves are recognized as crucial blue carbon ecosystems in mitigating climate change. However, methane (CH_4) emissions may partially counterbalance their C sequestration capacity. While recent studies indicated that methane oxidation minimized emissions in mangroves, the contribution of plant-mediated methane release remains underexplored. Emerging evidence suggested that wetland (including mangroves) trees can emit significant amounts of soil-derived methane through their stem, a factor that has not been well quantified in mangrove blue C sequestration. Here, we examined in situ mangrove stem CH_4 emissions along a latitudinal gradient and built a global mangrove CH_4 data set. We found that stem emissions, previously overlooked, can partially offset the blue carbon function of mangroves. Mangrove stem CH_4 flux rates were well correlated with wood density, soil organic content and salinity, with lower wood density salinity and higher wood water content facilitating higher emissions. Strong correlation between stem CH_4 emissions and soil CH_4 flux, suggesting that the majority of stem CH_4 emissions originate from mangrove sediments. Through a synthesis of mangrove CH_4 emission data, we estimate that global mangrove stem CH_4 emissions amount to 730.60 (95%CI: 586.09– 876.93) Gg yr^{-1}, which can partially offset 16.9 % blue carbon burial in mangroves. If we included the soil-mediated methane, the total methane emissions in mangroves can offset 27.5% blue C burial. Therefore, mangrove methane emission is greater than previously estimated. Our findings emphasize the importance of incorporating stem CH_4 emissions into future blue carbon budgets for mangroves.

Greenhouse Gas Emissions from Nordic Salt Marshes: Influences of Water Table Level, Grazing, and Vegetation

Hans Brix, Dan Yang, Brian Sorrell, Asger B. Jensen, Franziska Eller

Aarhus University, Aarhus, Denmark

Saline wetlands play a crucial role in climate regulation through their robust cooling effect, attributed to rapid carbon sequestration and minimal methane (CH_4) emissions. However, the underlying mechanisms governing carbon exchange and their contribution to greenhouse gas mitigation remain poorly understood, particularly in salt marshes affected by global climate change.

In this study, we examined the effects of water table levels, grazing, and plant community composition on CO_2 and CH_4 fluxes in Nordic salt marshes during the growing season. We conducted a controlled manipulative experiment alongside in-situ measurements to assess these influences. Our results showed that rising water table levels increased CH_4 emissions but decreased photosynthesis and ecosystem respiration. In contrast, grazing enhanced ecosystem respiration while reducing plant photosynthesis. Additionally, CH_4 emissions in *Phragmites*-dominated communities were nearly a thousand times higher than in *Spartina*-dominated communities.

Our results indicate that salt marshes with near-surface water levels function as potent CO_2 sinks and minor sources of CH_4 during the growing season, while grazed *Phragmites*-dominated salt marshes act as carbon sources. By integrating CH_4 fluxes, CO_2 uptake, and emissions, our study identifies key mechanisms controlling carbon exchange in these ecosystems. This approach is essential for evaluating the potential of saline tidal wetlands as net atmospheric carbon sinks and for developing science-based climate mitigation policies.

Symposium 8:
Blue carbon in tropical wetlands

30 June

14:45-16:15, Maailmafilm Hall

Blue Carbon in Tropical Wetlands: A New Frontier

Wei-Ta Fang

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Blue carbon studies underscore the vital role of coastal wetlands—mangroves, seagrasses, and salt marshes—in mitigating climate change by sequestering carbon. These ecosystems, known as “blue carbon” ecosystems, store three to five times more carbon per unit area than tropical forests. Globally, tidal wetlands accumulate around 53.65 teragrams (Tg) of carbon per year. The main issues are how tidal wetlands play a crucial role in mitigating climate change by sequestering carbon. Scientists aim to conserve and manage these wetlands sustainably for their climate benefits. Key research developments include: 1) Global trends (2012-2023): A bibliometric study highlights blue carbon's role in sustainable development and the global carbon cycle, identifying challenges in achieving Sustainable Development Goals (SDGs) related to blue carbon; 2) Research evolution (1993-2023): Increasing interdisciplinarity and international collaboration are noted, with restoration, conservation, and remote sensing technology identified as key areas; and 3) Future directions: Research has evolved from exploratory stages to focused studies on carbon sequestration and ecosystem restoration. Future research should enhance scientific understanding to support global carbon neutrality strategies. Case studies emphasize the importance of tropical wetlands in climate mitigation and community support. These ecosystems act as significant carbon sinks, providing coastal protection, water filtration, and marine habitats. The studies aim to boost nationally determined contributions (NDCs) and promote sustainable wetland management. Emerging trends in blue carbon research include: 1) Interdisciplinary and international collaboration; 2) Restoration and conservation; 3) Remote sensing and advanced technologies; 4) Climate change mitigation; and 5) Sustainable Development Goals (SDGs). Researchers examine how blue carbon ecosystems contribute to SDGs, especially those related to climate action, life below water, and life on land. Emphasis is on developing policies to support blue carbon initiatives, highlighting the field's role in tackling global environmental challenges and promoting sustainable development.

The Impact of Mangrove Removal on Carbon Sequestration in the Jhuoshuei River Estuary, Taiwan

Hsing-Juh Lin[1], Wei-Jen Lin[2], Shang-Hung Pao[1], Jun-Yuan Lai[1]

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Coastal blue carbon represents organic carbon sequestered in mangroves, seagrass meadows and salt marshes. Recently, the mangrove species *Avicennia marina* has rapidly expanded on the south side of the Jhuoshuei River estuary along the western coast of Taiwan. To protect the habitat of the Taiwan endemic fiddler crab (*Xeruca formosensis*), 0.36 hectares of dense mangrove area were removed at the end of September 2023. After the removal, the carbon stock of the mangrove trees decreased by 6.8 tonnes of carbon, equivalent to a loss of 18.91 tonnes of carbon per hectare, which is the same as cutting down 500 trees. The emission of CH_4 increased dramatically from 1.27 to 292.11 mg CH_4 m^{-2} d^{-1}. This significant rise can be attributed to the disturbance of the subsoil caused by heavy machinery during the removal process. This increase is equivalent to emitting 16.8 tons of CO_2e, which is comparable to cutting down 1.7 hectares of forest or approximately 17,000 trees. The disturbance in the emission of nitrous oxide was minimal. The removal of mangroves shows that these trees and soil can help nations avoid releasing significant amounts of greenhouse gases. Our findings also reveal that mangroves can store 4.8 times more carbon than forests.

The Impact of Mangrove Removal on Macrobenthos in the Estuary of Jhuoshuei River Estuary, Taiwan

Chuan-Wen Ho[1], Hsing-Juh Lin[1], Wei-Jen Lin[2], Chi-Mei Chia[3]

[1]Department of Life Sciences, Taichung, Taiwan
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Mangrove ecosystems offer essential services such as microclimate regulation, water purification, coastal stabilization, habitat provision, carbon sequestration, environmental education, and economic benefits. In Taiwan, mangroves have been expanding due to favorable climate conditions and continuous nutrient input from estuaries. However, this expansion has led to issues like river narrowing and alterations in mudflat organism distributions. Notably, the estuarine area at the boundary of the Jhuoshuei River is the largest habitat for the endemic Taiwanese fiddler crab (*Xeruca formosensis*), a key species in Taiwan's national ecological conservation network. The ongoing mangrove expansion may threaten the habitat and population of this species. In September 2023, the Yunlin County government, Formosa Plastics Group, and NGOs collaborated to remove mangroves at the south estuary of the Jhuoshuei River. This study aims to understand the impact of mangrove removal on macrobenthos. Monitoring over three months recorded a 50% decrease in benthic animal density post-removal, especially sipunculid worms in densely planted areas. By February 2024, *Avicennia marina* saplings reappeared, indicating potential challenges in mangrove management. Additionally, Taiwanese fiddler crabs were found in the pneumatophore zones of *A. marina* in the removed area, suggesting a non-exclusive relationship between the species and mangroves. Further observation is needed to determine if the impact of mangrove removal on benthic organisms is a long-term trend or a short-term disturbance, and to better understand the interactions between the Taiwanese fiddler crab and mangrove forests.

Age Matters: Unraveling the Carbon Sequestration Rates of *Kandelia Obovata* Mangroves in Subtropical Taiwan

Wei-Jen Lin[1], Jun-Yuan Lai[2], Chiao-Wen Lin[3], Hsing-Juh Lin[2]

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Mangrove ecosystems function as critical carbon sinks within the coastal carbon cycle. However, the extent to which mangrove carbon sequestration varies with tree age remains uncertain. This study constructed mangrove carbon budget models for six *Kandelia obovata* mangrove forests of varying ages along western coast of Taiwan to investigate the relationship between tree age and carbon sequestration rate. Our results indicated that the carbon burial rates of *K. obovata* mangroves ranged from 0.25 to 4.00 Mg C ha^{-1} yr^{-1}. The aboveground net primary production (ANPP) varied between 15.82 and 31.36 Mg C ha^{-1} yr^{-1} and exhibited a quadratic relationship with tree age, peaking at approximately 62 years. In contrast, belowground net primary production (BNPP), which ranged from 2.40 to 9.87 Mg C ha^{-1} yr^{-1}, showed no significant correlation with stand age. These findings provide valuable insights into the temporal dynamics of carbon sequestration of *K. obovata* mangroves. Based on these results, a rotation period of approximately 60 years is recommended for the sustainable management of *K. obovata* mangrove forests, providing guidance for long-term conservation and management strategies.

Study on the Seasonal Variation in Greenhouse Gas Emissions from Rhizophora Stylosa Mangroves in Taiwan

Chiao-Wen Lin[1,2], Chen-Ying Ko[1], Tzu-Chieh Chiu[1], Hsin-Hsun Wu[1], Wei-Jen Lin[3], Hsing-Juh Lin[4]

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The coastal blue carbon ecosystem includes mangroves, salt marshes, and seagrasses, which exhibit high carbon sequestration capacity. However, the anaerobic soil environment in mangroves releases greenhouse gases, partially offsetting their carbon storage potential. *Rhizophora stylosa* is relatively intolerant of cold temperatures. This study, conducted from spring 2023 to winter 2025, utilized greenhouse gas analyzers combined with the closed-chamber method to measure greenhouse gas emissions from the soil and tree stems of *Rhizophora stylosa* in the Haomeiliao Wetland, Chiayi County, Taiwan. The results showed that greenhouse gas fluxes from *Rhizophora stylosa* stems over eight seasons ranged as follows: CO_2: -0.59 to 1.55 g CO_2 m^{-2} d^{-1}; CH_4: 0.00 to 0.35 mg CH_4 m^{-2} d^{-1}; N_2O: 0.00 to 0.10 mg N_2O m^{-2} d^{-1}. For soil greenhouse gas fluxes, the ranges were: CO_2: -1.46 to 6.63 g CO_2 m^{-2} d^{-1}; CH_4: 0.33 to 7.89 mg CH_4 m^{-2} d^{-1}; N_2O: 0.03 to 0.83 mg N_2O m^{-2} d^{-1}. Greenhouse gas emissions varied significantly between seasons. Notably, CO_2 emissions from soil and tree stems differed significantly between 2023 and 2024 (p<0.05), while CH_4 and N_2O emissions showed no significant differences. Using global warming potential (GWP) conversion factors, CH_4 and N_2O were converted into CO_2 equivalents. The results indicated that, in 2023, the CO_2 equivalent emissions from tree stems were 1.48 tonnes CO_2e ha^{-1} yr^{-1}, while soil emissions were 4.63 tonnes CO_2e ha^{-1} yr^{-1}. In 2024, tree stem emissions increased to 3.93 tonnes CO_2e ha^{-1} yr^{-1}, and soil emissions rose to 17.65 tonnes CO_2e ha^{-1} yr^{-1}. This study will establish a comprehensive carbon sequestration database, providing a potential pathway for nature-based climate adaptation strategies.

Carbon Absorption of Marsh Plants in Dongyuan Peatland, Taiwan

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This study examines the carbon absorption capacity of the Dongyuan Peatland floating grassland by assessing its net primary productivity (NPP) and organic carbon content. Wetlands play a crucial role in carbon sequestration, with monocotyledonous plants contributing significantly to organic matter accumulation. Understanding their carbon dynamics is essential for wetland conservation and management. The research was conducted from January to December 2023, with monthly sampling and measurements. The study area was divided into five zones based on vegetation composition and topography. The NPP of dominant species, *Leersia hexandra* and *Hedychium coronarium*, was estimated using the harvesting method, and organic carbon content was analyzed with an elemental analyzer. The results showed that the average NPP across zones 1 to 5 was 5030.76, 3008.95, 3871.78, 3526.62, and 3650.98 g DW m^{-2} yr^{-1}, respectively. The wetland areas of these zones measured 4, 2.8, 7, 2.5, and 11 hectares, contributing to an annual carbon absorption of 38.37, 17.01, 55.37, 18.26, and 82.46 tons, respectively. The total carbon absorption of the Dongyuan Peatland was 211.48 tons per year, indicating its vital role as a carbon sink. These findings underscore the importance of preserving and managing the Dongyuan Peatland to enhance its ecological function. As a significant carbon-absorbing wetland, it holds potential for mitigating climate change impacts and should be prioritized in conservation efforts.

Greenhouse Gas Emissions from Floating Treatment Wetlands Used for Nitrogen and Phosphorus Removal

Wei Ping Wu, Jung-Chen Huang

Department of Environmental Engineering, National Cheng Kung University, Tainan, Taiwan

Floating treatment wetland (FTW) is a relatively novel type of constructed wetland, where plants grow on floating platforms placed on the water surface. Their roots are suspended directly in the water, providing a large surface area for biofilm attachment and directly absorbing nutrients from the water. In this study, we set up two 100 L FTWs and treated them with water from Cheng Kung Lake in National Cheng Kung University, Taiwan. The mean removal efficiencies were 37.9%, 38.5%, 40.5% and 30.2% for NH_4^+-N, NO_3^--N, TP and COD, respectively for *Typha orientalis*, which were 41.9%, 27.4%, 35.3% and 26.9%, respectively for *Iris pseudacorus*. In addition, CO_2 and CH_4 emissions were measured as part of the study, which were -1027.93 mg m^{-1} h^{-1} and 0.25 mg m^{-1} h^{-1}, respectively for *Typha orientalis* in daytime, while they were -566.23 mg m^{-1} h^{-1} and 0.33 mg m^{-1} h^{-1} for *Iris pseudacorus*. At night, the fluxes of CO_2 and CH_4 were 167.72 mg m^{-1} h^{-1} and 0.24 mg m^{-1} h^{-1}, respectively for *Typha orientalis*, which were 152.38 mg m^{-1} h^{-1} and 0.27 mg m^{-1} h^{-1} respectively for *Iris pseudacorus*. The results demonstrate that these wetland plants play an important role in nutrient removal and are capable of capturing carbon dioxide from the atmosphere.

Symposium 9:
Wetland restoration techniques, strategies and management

1 July
17:00-18:30, Kurrik Hall

Wetland Changes, Driving Forces and Restoration Strategies in China

Ming Jiang

Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun, China

China's wetlands have undergone significant changes over the past 40 years. Overall, the total area of wetlands shrank significantly by 2015, with a net loss of 60,900 km^2, a relative loss rate of 12%. The wetland area recovered slightly from 2015 to 2020. The spatial and temporal heterogeneity of the change characteristics of different types of wetlands was obvious, and the natural wetland significantly decreased, while the constructed wetland significantly increased. The loss of natural wetlands has been more or less offset by the extensive increase in constructed wetlands. The driving forces of wetland change in China include natural factors and socio-economic factors. In terms of natural factors, inland wetlands are closely related to average temperature and cumulative precipitation. For example, in the arid region of Northwest China, cumulative precipitation affects wetland area. In the northern region, the average temperature is positively correlated with the wetland area, which can increase the wetland water source. In addition, population growth, agricultural irrigation, and land use change are also important drivers of wetland change. China has basically formed a relatively mature wetland restoration technology system, including wetland habitat hydrological regulation technology, plant rapid propagation and community maintenance technology, habitat multi-element coordinated directional restoration technology. Further implementation of wetland conservation and restoration projects in major national strategic areas; Strengthen regional coordination and resource integration, and plan to build national parks with different wetland types as the main body. At the same time, we should strengthen the optimal allocation and comprehensive management of water resources, innovate wetland protection mechanisms and policies, improve the compensation mechanism for wetland ecological benefits, and establish a long-term wetland protection system.

Restoration and Construction of New Wetlands Alone Can Effectively Reduce Pollutant Loads to Below Acceptable Levels

Marinus L Otte, Kyle D Boutin, Mosammat M Khanaum, Qi Tiansong, Xuefeng Chu

North Dakota State University, Fargo, ND, USA

It is well known that wetlands significantly improve water quality. For this reason, damaged natural wetlands are being restored and new wetlands constructed with the aim of improving water quality. However, little is known about how much area of wetlands would be needed to reduce sediment/nutrient loads to below acceptable levels in entire watersheds.

Using the SWAT and PTMApp modeling approaches, we studied three watersheds in North Dakota and Minnesota, USA, which are known to be impaired by loads above acceptable standards. The main question was: How much greater would the area of wetland need to be within each watershed to decrease those loads below the thresholds?

PTMApp and SWAT use different methods and are used for different purposes, but they have in common that they use past observations for predictions into the future. However, they are limited in how they take wetlands within watersheds into account. We improved the models to better account for variation in wetland conditions and then changed parameters to fit future conditions under three scenarios. The main outcome was that the increase in wetland area needed within each watershed to decrease pollutant loads below acceptable levels is around 5% of the entire watershed.

Symposium 10:
Ecosystem service benefits and valuation of wetland restoration: from case studies to a broader understanding of societal benefits

1 July
11:30-13:00, Maailmafilm Hall

Open Access Database on Wetland Ecosystem Services: Summarizing Ecosystem Service Trade-Offs in Wetland Restoration

Louis Skovsholt[1], Brian Sorrell[1], Tom Heuts[2], Agata Klimkowska[3], Mateusz Grygoruk[4], Claudia Nielsen[5], Christian Fritz[2]

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As the importance of wetland restoration increases, so does the need for information on best management practices, to provide certainty for managers and policy makers that restoration efforts yield the desired outcomes. Uncertainty in the extent and diversity of ecosystem services provided by rewetted areas can lead to delays in restoration action and uncertainty of restoration outcomes. Additionally, altered ecosystem properties may lead to some ecosystem services improving while others decrease (i.e. 'trade-offs'). We are therefore undertaking a broad, wide-ranging assessment of restoration outcomes and are quantifying ecosystem service shifts induced by re-wetting, also in combination with other management actions. By the creation of a quantitative database on ecosystem services provided by degraded and restored wetlands on a European scale, we aim to provide a tool for anyone with an interest in assessing and considering projected outcomes of future restoration projects. This will aid in setting clear goals for restoration projects and for following up on whether these goals have been met. Emphasis will be given to peatland and wetland specific manifestations of ecosystem services. Furthermore, this will help address key challenges facing restoration success, particularly with respect to the goals of individual projects. Eventually, the comprehensive dataset developed in this framework will allow us to identify the trade-offs and gaps that have, until now, made wetland restoration an underutilized method of wise management. We currently have an open access database online with a working summary tool in the form of a free to use web-application. In this talk I will present our database, give examples of use and talk about future perspectives.

How Wetland Use, Attitudes and Values Influence Willingness to Pay for Wetland Restoration: Insights from Six European Countries

Leo Raivonen[1], Annika Tienhaara[1], Emmi Haltia[1], Katja Kangas[2], Eija Pouta[1]

[1]Natural Resources Institute Finland, Helsinki, Finland
[2]Natural Resources Institute Finland, Oulu, Finland

The economic valuation literature on wetland restoration has studied diverse geographical and wetland habitat contexts during the last two decades. However, less is known about how citizens' wetland use, values, and attitudes affect their willingness to pay for wetland restoration. Focusing on a national wetland restoration program, we aim to understand how this relationship works in six European countries: Sweden, Finland, Estonia, Latvia, Austria, and Spain. To achieve this, we use public participatory GIS and contingent valuation (CV) data collected from residents in the six countries. The contingent valuation scenario is framed to imitate the properties of the Nature Restoration Law recently put in place in the European Union. The data will be analyzed using interval regression.The expected results show how wetlands are used and viewed in different geographical and cultural environments and provide insights into how these components influence preferences for restoration. Willingness to pay estimates for the proposed restoration scenario are presented to address the value of the ecosystem benefits of wetland restoration in monetary terms. Our results aim at increasing understanding of citizens' wetland use and restoration views. By combining information on wetland use, values, and attitudes with the CV data, we look to advance the inclusion of psycho-social measures and recreational use information in the wetland restoration valuation literature. Finally, our results will provide valuable information for EU member states who prepare their National Restoration Plans.

Heterogeneity in Preferences for the Restoration of Peatlands and Small Water Bodies

Artti Juutinen[1], Janne Artell[2], Anne Tolvanen[1], Eija Pouta[2]

[1]Natural resources Institute Finland (Luke), Oulu, Finland
[2]Natural resources Institute Finland (Luke), Helsinki, Finland

Restoration efforts aim to accelerate reaching habitat conservation targets. This study examines the preferences that Finnish people hold for restoration efforts in peatlands and small water bodies by using a discrete choice experiment. The results indicate that the respondents are willing to pay for the restoration of peatlands and small water bodies. The respondents favour the restoration of small water bodies and state-owned lands to the restoration of peatlands and private lands. The proximity of restoration sites has, in general, no significant effect on the respondents' choice. There is, however, evidence for preference heterogeneity, including regional preferences. Overall, the potential restoration programs considered in this study provide significant benefits or welfare effects. The annual WTP values vary from €275 to €367 per household. For the nationwide Helmi restoration program in Finland, the benefits exceed the costs. However, the heterogeneous restoration preferences underline the need to consider the 'winners' and 'losers' of the restoration programs to increase the social acceptance of restoration in society. Using a latent class model (LCM), we illustrate the preference heterogeneity and explain it through socio-economic background and recreational use profiles. Additionally, factor and cluster analyses identify different attitude and perception groups regarding nature restoration. Comparing these two classifications offers a comprehensive view to citizen support and opposition, along with underlying arguments.

Valuing Wetland Restoration: A Choice Experiment on Citizens' Preferences Across Six EU Countries

Annika Tienhaara, Leo Raivonen, Emmi Haltia, Eija Pouta

Natural Resources Institute Finland (Luke), Helsinki, Finland

Comprehensive knowledge of the biodiversity and ecosystem benefits from wetland restoration at the European Union (EU) level is currently lacking. To address this gap, this study investigates citizens' preferences for wetland restoration, focusing on five key ecosystem services: flood and drought mitigation, biodiversity provision, water purification, and climate change mitigation. The valuation scenario is designed to reflect the EU's Nature Restoration Law, recently implemented to guide biodiversity and ecosystem recovery efforts.

Data are collected from six EU countries—Austria, Estonia, Finland, Latvia, Spain, and Sweden—with the aim of gathering 1,000 respondents from each country. Coordinated choice experiments (CE) are employed in each country, allowing the levels of attributes to be based on the current national environmental contexts. By applying conditional logit and mixed logit models, we analyze preferences and willingness to pay (WTP) for the various benefits of wetland restoration. Additionally, by incorporating country interactions, we aim to uncover any significant differences in preferences across countries.

The expected results will provide important insights into how citizens from different EU countries value wetland restoration and its associated ecosystem services. By identifying variations in preferences, the study will help improve our understanding of the factors driving public support for wetland restoration and the value people place on wetland restoration. This information can inform the development of more targeted, effective restoration strategies that align with public preferences and local conditions.

Ultimately, the findings will contribute valuable knowledge to support the EU's Nature Restoration Law and the preparation of National Restoration Plans. Understanding citizens' preferences and WTP is critical for ensuring these plans are both effective and well-supported by the public. This study will provide policymakers with essential data to enhance the design and implementation of restoration initiatives, contributing to the long-term success of ecosystem restoration efforts across Europe.

Cost Benefit Analysis Applied to Blanket Bog Restoration in Ireland

Craig Bullock

University College Dublin, Dublin, Ireland

The Green Deal WaterLANDS project is demonstrating wetland restoration in accordance with the upscaling sought by the Nature Restoration Law in six active sites across the EU. One of these sites is a blanket bog in the west of Ireland where the project is working with local farmers. A cost benefit analysis of the actions has been undertaken for this site. The analysis is preliminary in that we expect additional data to become available as the project progresses. A change from carbon emissions to sequestration is the main objective and can, in principle be quantified, although there is much uncertainly. Other benefits such as water quality, water retention and biodiversity are more challenging. The project has been successful in enlisting the support of farmers, but this has also entailed much engagement with high up-front costs. In the process, we have gathered some interesting insights into how best to achieve this cooperation. The presentation will demonstrate some key truths when choosing where and how to restore peatlands.

Symposium 11:
Ecohydrology and wetland ecosystem succession and application

1 July
15:00-16:15, Maailmafilm Hall

The Role of Riverine Carbon Transfers in the Land Carbon Budget – Lessons Learned from an Integrated Modelling Approach

Ronny Lauerwald[1], Haicheng Zhang[2], Simon Bowring[3], Philippe Ciais[3], Pierre Regnier[4]

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[4]Université Libre Bruxelles, Brussels, Belgium

The river network plays an important role in the global carbon cycle, as major transfer route of land-derived carbon to the ocean as well as important net-emitter of CO_2. The amounts of carbon lost through the river network are a sizeable component of the land carbon budget, which at present absorbs one fourth of anthropogenic CO_2 emissions. Projections of how the land carbon budget may respond to future climate and land use change must not ignore potential changes in river carbon transfers. Moreover, to better understand how dynamics in river carbon transfers affect the land carbon budget, a quantitative understanding of the (semi-)terrestrial sources of carbon to the river network is needed. For that purpose, we have developed a model that represents not only carbon cycling in terrestrial ecosystems but also includes a representation of transfers and reactions of soil derived carbon within the river-floodplain network.

Applying that model to large river systems across the major biomes of the Earth, we were able to reproduce observed river carbon fluxes and to confirm what has been hypothesized in experiment studies: most of the CO_2 emissions from the river network are actually fed by soil respiration, and riparian wetlands contribute disproportionally to carbon inputs to rivers, relative to their surface area. Transfers of organic carbon are quantitatively less important, but, in contrast to CO_2 transfers, they have a direct impact on the soil carbon storage. Further, while river carbon transfers are most sensitive to changes in water flows, simulated long-term trends mainly show a flux increase in response to increased terrestrial primary production. However, accumulation of carbon in the biosphere in response to global greening, a consequence of the delayed response of respiration fluxes, increases more strongly, and the relative importance of changes in river carbon transfers decreases over time.

Applying the WBSRC Framework for Sustainable Catchment Management: A Case Study of Floodplain Wetlands in the Pilica River, Poland

Paweł Jarosiewicz[1], Damaris Rios Guzmán[1], Patrycja Chamczak[1], Aleksandra Chamerska[1,2], Katarzyna Izydorczyk[1]

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Water management often prioritizes individual goals, leading to increased fragmentation rather than fostering holistic approaches aligned with sustainable development goals. A new concept emerging from the ecohydrological approach addresses the multidimensional potential of catchment sustainability. The WBSRC framework (*Water quality and quantity, Biodiversity, ecosystem Services, Resilience to climate change, and Culture*) provides a comprehensive perspective on water resource management. This approach has been promoted in the recent phase of the UNESCO Intergovernmental Hydrological Programme (IHP) and implemented in the LIFE Pilica project (LIFE19 IPE/PL/000005) within the Pilica River Catchment, Central Poland, a designated UNESCO IHP Ecohydrology Demonstration Site.

This study aimed to develop a model approach for managing floodplain wetlands and oxbow lakes in the Pilica River Catchment. Through intensive fieldwork conducted between 2022 and 2024, we identified 300 previously undocumented wetland sites, carried out annual observations at 150 locations, and performed detailed environmental assessments at 50 sites. Based on the WBSRC framework, five high-complexity areas were selected for restoration and protection using ecohydrological approaches and nature-based solutions (NBS). In 2024, an in-depth study of one floodplain system examined hydrology, biodiversity, and biogeochemical cycles, highlighting its critical role in water retention, water quality improvement, biodiversity support, and ecosystem service provision.

Our findings emphasize the urgent need for targeted ecohydrological measures to restore floodplain connectivity and natural flooding cycles, which are in line with the flood pulse concept. However, increasing human impact and climate change-induced terrestrialization pose significant threats to these ecosystems, necessitating proactive management strategies. The WBSRC-based approach is essential for preserving these vital habitats and ensuring their long-term resilience. During the presentation, we will discuss key study findings and explore potential solutions for sustainable floodplain management.

Soil Carbon, Nitrogen and Phosphorus Biogeochemical Process in Sphagnum Moss Wetland of Guizhou, China

Zhongli Chen, Ying Shao

Chongqing University, Chongqing, China

Sphagnum moss wetlands, integral to peatland ecosystems, are vital for carbon sequestration, water regulation, and biodiversity conservation. Despite their ecological significance, Sphagnum moss wetlands in Guizhou, China, remain understudied, leaving critical gaps in understanding their microbial ecology and biogeochemical processes. This study investigates the microbial diversity and biogeochemical cycling in a typical Sphagnum moss wetland in Dapingjing, Guizhou, through metagenomic analysis and exploration of the interplay between wetland water physicochemical properties and microbial carbon, nitrogen, and phosphorus cycling.

The soil microbial communities exhibit pronounced spatial heterogeneity, strongly influenced by soil physicochemical properties. Vertical stratification reveals a tripartite succession pattern: the 0-20 cm layer is dominated by aerobic Pseudomonadota, driving carbon-nitrogen coupled metabolism; the 20-40 cm layer is characterized by microaerophilic Acidobacteriota, mediating sulfur-iron-carbon co-metabolism; and the 40-60 cm layer is primarily inhabited by anaerobic Euryarchaeota, specialized in recalcitrant carbon utilization and methanogenesis. Functional gene analysis highlights depth-dependent variations in carbon, nitrogen, and sulfur cycling. Key genes such as *tauD*, *phsA*, and *TST* are implicated in organic sulfur mineralization, sulfur oxidation/disproportionation, and thiosulfate disproportionation, respectively. Nitrogen cycle genes (*glnA*, *narG*, *nirB*) dominate processes including nitrogen fixation, denitrification, and anaerobic denitrification across different depths. Additionally, phosphorus and metal ions (e.g., Mn, Fe), alongside carbon, nitrogen, and sulfur forms, collectively drive microbial community differentiation.

These findings demonstrate that microbial communities in the Sphagnum moss wetland have evolved a functional cascade of "carbon degradation-nitrogen-sulfur transformation-methane metabolism" through combinatorial adjustments of functional genes. This adaptation enables them to thrive in the heterogeneous wetland environment and play a pivotal role in regulating biogeochemical cycles. This study provides critical insights into the microbial ecology of Sphagnum moss wetlands in Guizhou, underscoring their importance in global carbon storage and nutrient cycling, while highlighting the need for further research to inform conservation and management strategies.

The Impact of Water Level Fluctuations on Vegetation Carbon Sink Dynamics in the Three Gorges Reservoir Riparian Zone

Ma Honghai, Li Zhe, Cao Yunpeng

Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences, Chongqing, China

Riparian zones are hotspots of carbon source and sink in rivers, with periodic water level fluctuation significantly influencing vegetation carbon sink dynamics. However, vegetation carbon sinks in the riparian zone exhibit highly heterogeneous characteristics, and the limited representativeness of research data hinders accurate characterization. Focusing on the Three Gorges Reservoir (TGR), this study integrates field surveys and model simulations to develop a coupled hydrodynamic-vegetation carbon sink model for quantifying vegetation carbon dynamics under fluctuating water levels. The results showed that vegetation carbon sink follows a Gaussian growth pattern with increasing inundation duration. Within 5 years after TGR impoundment , the vegetation carbon sink in riparian zone increased from 267 g C/m^2 to 342 g C/m^2, and showed variations across elevation zones. Specifically, the carbon sink in the 145–150 m zone experienced a decline from 449 to 157 g C/m^2 due to high-frequency inundation, whereas the 155–175 m zone increased from 206 to 412 g C/m^2, driven by reduced inundation stress and vegetation adaptation. The proposed model overcomes spatial and temporal limitations, enabling precise assessment of carbon dynamics and supporting carbon management in rivers.

Linkage Between Soil Nutrient Dynamic and Seedbank Along an Urban River: Perspective for Vegetation Restoration

Mengxia Zhang, Yuting Du, Ying Shao, Zhongli Chen

Chongqing University, ChongQing, China

Urban riparian vegetation plays a pivotal role in providing critical ecological functions, including biodiversity conservation, pollutant interception, and water purification. However, rapid urbanization has caused severe degradation of these ecosystems, necessitating urgent vegetation restoration efforts. This study investigated the Qingshui Stream in Chongqing China through field surveys and seed germination experiment to analyze the composition and germination dynamics of soil seed banks (SSB), it's relationship with aboveground vegetation, and the physicochemical and spectral characteristics of soil and pore water. The research specifically examined the variations in seed germination processes and the availability of nutrient components in riparian soils. Results revealed that SSB was predominantly composed of annual herbs from *Poaceae* and *Asteraceae* families. Significant spatial heterogeneity in seed bank density was observed (mean: 254 ± 38 seeds/m²), with explosive germination dynamics dominated within the initial three weeks, indicating favorable seed viability. Species similarity between SSB and vegetation showed notable spatial variation (Sørensen index 0.08-0.80), influenced by anthropogenic disturbances. Soil total carbon (TC: 15.45 ± 1.05 mg/g) exhibited longitudinal decline along the stream, showing significant negative correlation with SSB density ($p < 0.05$), while increasing pH (7.57 ± 0.41) demonstrated positive correlation. Temporal fluctuations in pore water dissolved organic carbon (DOC) and total nitrogen (TN) significantly affected germination patterns. Fluorescence indices (BIX > 1.0) indicated predominant allochthonous DOC sources in pore water. High nutrient concentrations (TN: 10.06-0.61 mg/L; TP: 0.09-0.61 mg/L) suppressed seedling diversity ($p < 0.05$). The findings suggest urban riparian SSB exhibits seasonal sensitivity to nutrient variations: elevated TC and DOC levels in winter compared to spring constrain regeneration potential, while balanced N:P ratios enhance restoration resilience. This study provides novel insights for urban riverine restoration, proposing integrated hydrological regulation and pollution control to optimize nature-based vegetation rehabilitation through seed bank utilization.

Symposium 12:
Financing wetland restoration by private sector – leveraging the EU Taxonomy, CSRD/ESRS – actionable insights

3 July
11:15-12:45, Kurrik Hall

Wetland Restoration in the Context of Economic Theory and ESG Regulations

Tamara Bińczak

ING Bank Śląski S.A., Warsaw, Poland

Despite widespread recognition of the ecological and economic benefits of wetlands—such as carbon sequestration, flood regulation, and biodiversity preservation—mobilizing financial resources for their restoration remains a challenge. This presentation will examine market failures, externalities, and the difficulties of monetizing ecosystem services within traditional financial models, as well as the frameworks that can help address these challenges.

In Europe, one of the key pathways to unlocking private sector financing for wetland projects lies in understanding and leveraging EU legislative frameworks, including the EU Taxonomy, CSRD, and ESRS. This presentation will explore how these regulatory mechanisms shape corporate sustainability strategies and create opportunities for wetland restoration financing. The EU Taxonomy establishes clear environmental criteria that companies must meet to qualify for sustainable investments, providing an entry point for wetland projects aligned with biodiversity and climate objectives. Meanwhile, the CSRD and ESRS introduce stricter sustainability reporting requirements, compelling corporations to disclose their environmental impacts and mitigation efforts, which can serve as leverage for NGOs and wetland restoration advocates to attract funding.

By understanding the economic context and relevant legislation, participants will be better equipped to develop strategies that align wetland restoration efforts with corporate and investor interests, ultimately bridging the gap between conservation needs and financial viability.

Peatland Finance Ireland: Securing Sustainable Financing for Peatland Restoration in Ireland

Laoise Dillon[1], Shane Mc Guinness[1,2], Bryan Irvine[2]

[1]ERINN Innovation, Dublin, Ireland
[2]Peatland Finance Ireland, Dublin, Ireland

Securing sustainable funding for peatland restoration remains a significant challenge, which requires collaboration between public and private sectors. Peatland Finance Ireland (PFI) was established in 2022 to create a national financing system that aligns carbon, water, and biodiversity goals with opportunities for local communities and economies. This presentation will explore PFI's efforts to integrate private investment into restoration initiatives, with a focus on the development of the Peatland Standard for Ireland. Designed to follow voluntary market principles, the Peatland Standard provides a structured framework for quantifying ecosystem improvements from peatland restoration projects. By issuing robust, high-quality certificates, it aims to attract investment and ensure a financial return for project capital and long-term management.

The presentation will explore PFI's journey to date, highlighting milestones such as the establishment of a governance structure that brings together key stakeholders including government departments, semi-state bodies, community groups, and academia. It will also examine the development of a public consultation process, which has played a crucial role in shaping the Peatland Standard. By seeking input from diverse stakeholders, PFI is working to ensure that the Standard is both scientifically rigorous and practically implementable, offering a credible mechanism for financing peatland restoration at scale.

Additionally, the presentation will highlight strategies for building effective partnerships and engaging corporate stakeholders in wetland restoration. It will provide insights into crafting compelling narratives that align with corporate sustainability priorities, helping businesses see peatland restoration not just as an environmental obligation but as a valuable opportunity for impact investment. Through this discussion, participants will gain a deeper understanding of how to mobilise private finance for nature-based solutions while ensuring long-term benefits for ecosystems and local communities alike.

Błota Rakutowskie in Poland – Perfect Example of Cooperation of NGOs and Business Entities for Wetland Restoration

Magdalena Zadrąg

WWF Poland, Warsaw, Poland

Błota Rakutowskie is a wetland area in central Poland, a peatland that was drained in the 1970s and then used as meadows and pastures. This use ceased in the early 21st century, leading to overgrowth by bushes and trees. The area is now a habitat for species like the redshank, lapwing, and black-tailed godwit, all of which require open habitats with suitable vegetation. Alauda, a local NGO, has been working in this area for over 10 years, implementing a number of projects aimed at improving these habitats. Alauda has already achieved some successes, notably the return of black-tailed godwits breeding after nearly 10 years of absence. Since 2023, WWF Poland has partnered with Alauda to enhance and scale up these efforts. In August 2024, WWF Poland secured the involvement of ING Bank Śląski (the Polish branch of an international bank) in the project. This is the first example in Poland of such a collaboration, where NGOs, supported by private sector funding, implement a wetland restoration project in line with EU taxonomy (CSRD – the European law on assessing business impact on biodiversity). The project is also certified by another Polish NGO, UNEP GRID. As part of the project, we are purchasing land plots where conservation measures are carried out, including mowing, removal of brush and trees, and grazing by Konik Polski horses. Additionally, we monitor bird and amphibian populations. In the long term, we also plan to implement measures to raise water levels. These types of projects create new opportunities for fundraising for wetland restoration by engaging companies that want to sponsor initiatives that demonstrate their commitment to being more wildlife-friendly.

Business and Biodiversity – Touchpoints and Pitfalls

Piotr Mikołajczyk

UNEP/GRID-Warsaw, Warsaw, Poland

Biological diversity has, in the recent period, come into a stronger focus of the business community. The companies had been of course already accustomed to various reporting requirements related of their environmental and social impacts extending beyond core business operations and financial balances, including energy efficiency or calculating GHG emissions. However, the new EU Corporate Sustainability Reporting Directive (CSRD) adopted in November 2022, brought about additional expectations and requirements related gauging and reporting on the mutual relationships of business operations with ecosystems and species.

Many companies, striving to fulfill the CSRD provisions and also demonstrate their pro-environmental agenda (with growing importance along the whole value chains) became interested and engaged in projects related to conservation and restoration of biodiversity. Among the ecosystems that seem particularly attractive in this context are wetlands. It seems to have already been broadly understood and accepted that their role in carbone storage is crucial. Other vital ecosystem services provided by wetlands have also been gradually gaining attention of companies, particularly those that directly rely on natural resources.

The presentation will discuss the principles and conditions of sound, greenwashing-free wetland restoration projects carried out with financial support of business companies. The pros and cons will be discussed, and some pitfalls in approaches and implementation - such as "GHG-perspective-only" - discussed.

Finally, concrete best practices of business-supported wetland restoration projects implemented in Poland by UNEP/GRID-Warsaw in trilateral cooperation with its business and nature conservation partners under the UN Decade of Ecosystem Restoration will be presented.

Symposium 13:
Restoration of wetlands: pathways, trade-offs and co-benefits

30 June

11:15-12:45, Maailmafilm Hall

The Future Role of Boreal Peatland Ecosystems in a Changing Climate: Oil Sands Mining and Global Warming in Alberta Canada

Melanie Vile[1], Kelman Wieder[2], Kimberli Scott[2]

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Globally, peatlands cover less than 3 % of the Earth's land surface, yet store an estimated 25 % of the world's soil carbon (C). More than 85 % of the global peatland area can be found in boreal regions of the northern hemisphere, with roughly 10 % of that total located in the boreal plain of western Canada. Peatlands, ombrotrophic bogs and minerotrophic fens, cover 365,157 km^2 of the land surface of northern Alberta, Saskatchewan, and Manitoba, Canada. The substantial accumulation of organic C as peat results from a long-term excess of net primary production (NPP) of *Sphagnum* mosses over peat decomposition. In the northern hemisphere, boreal peatlands have accumulated more soil C during the Holocene than any other terrestrial ecosystem. Peatlands also contain 9–16 % of the world's soil nitrogen (N). Peatlands in Alberta Canada have evolved over the last 8-10,000 years under pristine conditions and are now experiencing enhanced nitrogen (N) deposition with the expansion of the Alberta Oil Sands Mining Operations (AOS). Additionally, these boreal peatlands are also subjected to several climate-change stressors such as increasing fire frequency. Ecosystems that have persisted under conditions of low atmospheric N deposition have the potential to change, structurally and functionally, when exposed to increasing N deposition and a changing climate. Here we discuss the ability for peatlands in boreal Alberta Canada to continue to accumulate C when exposed to multiple economic and climate stressors.

Forty Years of Fen Meadow Restoration in the Valley of the Zuidleie (Belgium): Lessons Learnt

Kris Decleer

INBO, Brussels, Belgium

Traditional mowing management was reinstalled in 1982 after 30 years of abandonment, while drainage ditches were no longer maintained. In 1992 and 2002, 5 hectares of fen meadow that were raised with more than one meter of sludge in the 1960s were successfully restored after the removal of the sludge up to the peat soil. Many key plant species recolonised the site, while the ecosystem engineer Pedicularis palustris was reintroduced. Gradually the site became wetter during the winter period, but during summer, climate change resulted in a higher frequency of extremely low groundwater levels up to one meter below the soil surface. The impact of all these events on the vegetation and peat soil development and the biomass production of the site is discussed.

Moss Vegetation Impacts Ditch Methane Emissions from Boreal Forestry-Drained Peatlands

Tuula Larmola[1], Antti Rissanen[2], Paavo Ojanen[1,3], Jyrki Jauhiainen[1], Lukas Kohl[4], Liisa Ukonmaanaho[1], Raisa Mäkipää[1]

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[2]Tampere University, Tampere, Finland
[3]University of Helsinki, Helsinki, Finland
[4]University of Eastern Finland, Kuopio, Finland

In forestry drained peatlands, ditches cover ca. 3% of the area, but contribute to up to 100% of methane (CH_4) emission. Peat soil can be a CH_4 sink under efficient drainage. Therefore, emissions from ditches will impact whether drained peatland is a net CH_4 sink or source. The net CH_4 flux is likely to be impacted by the conditions in the ditches, the extent of plant cover and the time since drainage. We examined the fluxes and the underlying CH_4 cycling processes in two nutrient rich peatland forests in Southern Finland during 2021-2024. We compared the ecosystem-atmosphere CH_4 fluxes and their $\delta^{13}C$ values from moss-dominated and open water ditches. We determined CH_4 and CO_2 mixing ratios and their $\delta^{13}C$ values in water, in sediment and bubbles using gas chromatography and isotope and gas analyzer. We also assessed the role of CH_4 as a carbon source for *Sphagnum* mosses growing in ditches, by analyzing $\delta^{13}C$ values in submerged and partly submerged *Sphagnum* using Isotope-ratio mass spectrometer. Mean seasonal CH_4 emissions from moss-dominated ditches were 90% lower than from open water surfaces, moss-dominated ditches were occasionally net sinks of atmospheric CH_4. These results can be explained by methanotrophic microbes inhabiting surface water and moss layer and using CH_4 as a source of carbon and energy. Isotopic mass balance calculations accounting for the measured $\delta^{13}C$ values of *Sphagnum* moss and dissolved CO_2 and CH_4 indicated that 10-28% of carbon in mosses potentially originated from oxidized CH_4. Ditch maintenance, including removing mosses, is likely to decrease along with changing peatland forest management, e.g., continuous cover forestry. Our results suggest that ditches overgrown by mosses may reduce CH_4 emissions from drained peatland forests and be an additional GHG mitigation measure to practices that maintain a continuous forest cover, attenuate the changes in soil water level.

WET HORIZONS - Upgrading Knowledge and Solutions to Fast-Track Wetland Restoration Across Europe

Shubiao Wu

Aarhus University, Aarhus, Denmark

Wetlands are vital ecosystems for carbon storage, biodiversity conservation, and climate resilience, yet they are increasingly under threat due to land-use change, drainage, and climate extremes. Recognizing the urgent need for restoration at scale, Wet Horizons is a multi-national research initiative funded by the EU Horizon Programme, bringing together 14 partner organizations from 8 countries. The project takes a holistic and science-driven approach to accelerate wetland restoration through improved knowledge, advanced monitoring tools, and stakeholder-driven decision-making frameworks.

At this conference, we will share the key achievements of the project so far, including the development of comprehensive European wetland and peatland maps, updated greenhouse gas (GHG) emission factors, and state-of-the-art predictive models assessing the impacts of restoration under diverse environmental conditions. Additionally, we are designing decision-support tools to assist policymakers and land managers in implementing effective and sustainable wetland restoration strategies.

By integrating remote sensing, process-based modeling, and socio-economic assessments, Wet Horizons provides a framework for data-driven restoration efforts while ensuring that restoration measures align with biodiversity goals, climate policies, and socio-economic realities. The project actively collaborates with government agencies, conservation organizations, and industry stakeholders to enhance the adoption of best practices across Europe.

As we advance, Wet Horizons aims to provide critical guidelines and management tools to fast-track wetland restoration, bridging the gap between research and practice. We invite researchers, practitioners, and policymakers to engage with us in discussing the challenges, opportunities, and future directions for large-scale wetland restoration in Europe.

AquaLinks Tool – A Versatile Tool to Address Causal Links Involving Activities, Pressures, Biodiversity, Ecosystem Functions and Services in Aquatic Ecosystems

Bruna R.F. Oliveira[1], Ana Lillebø[1], Anis Guelmami[2], Constantin Cazacu[3], Marinka van Puijenbroek[4], Elisa Ciravegna[4], Justine Raoult[4], Volkert Beekman[4], Nico Polman[4], Antonio Camacho[5], Carlos Rochera[5], Daniel Morant[5], Marija Kataržytė[6], Martynas Bučas[6], Diana Vaičiūtė[6], António J.A. Nogueira[1]

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[6]Klaipeda University, Klaipeda, Lithuania

Human activities create pressures on habitats, their components and associated biota (responsible for ecosystem functions and services) and in this may compromise the sustainability of ecosystems and human well-being. The AquaLinks tool was developed, in the framework of the EU H2020 AQUACROSS project, to support the implementation of Ecosystem-based Management (EBM) in different aquatic ecosystems (freshwater and marine) from Sweden to Morocco and from Romania to the Azores islands (Portugal) in the Atlantic Ocean. The tool can be used to access the likelihood of a significant risk associated with linkage chains of activities-pressures-ecosystem components-ecosystem services and/or activities-pressures-ecosystem components-ecosystem functions. To achieve this goal for each chain an impact score and a supply score from which a risk quotient is calculated. The scores are derived from the knowledge base produced within AQUACROSS with contributions and expertise from case-studies.

The linkage chain integrated in AquaLinks addresses explicitly five out of fifteen key principles of EBM: consider ecosystem connections, APPROPRIATE SPATIAL & TEMPORAL SCALES, adaptive management, USE OF SCIENTIFIC KNOWLEDGE, integrated management, stakeholder involvement, account for dynamic nature of ecosystems, ECOLOGICAL INTEGRITY & BIODIVERSITY, sustainability, RECOGNISE COUPLED SOCIAL-ECOLOGICAL SYSTEMS, decisions reflect societal choice, distinct boundaries, interdisciplinarity, appropriate monitoring, and ACKNOWLEDGE UNCERTAINTY. The tool allows the user to create suitable linkage chains to infer vulnerability risks of specific linkage in the form of vulnerability quotients. The implemented allows the identification of the activities that pose a greater risk to the provisioning of ecosystem services by ecosystem components. The knowledge built into the tool covers aquatic habitats (from freshwater to marine environments) and associated terrestrial interfaces as well as highly mobile biotic groups. The rationale implemented in AquaLinks Tools was applied in the context of the EU Project "RESTORE4Cs – Modelling RESTORation of wEtlands for Carbon pathways, Climate Change mitigation and adaptation, ecosystem services, and biodiversity, Co-benefits".

Greening vs. Rewetting of Abandoned Peat Extraction Sites and Their Climate Impact in Life Cycle Assessment

Liisa Ukonmaanaho[1], Anna Kwokori[2], Rathish Rajan[2], Ashraful Alam[1], Lasse Aro[3], Timo Lötjönen[4], Egidija Rainosalo[2], Paula Jylhä[5]

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Peat extraction has historically been a major source of greenhouse gas (GHG) emissions and ecosystem degradation. However, once abandoned, these sites offer an opportunity for climate mitigation through restoration strategies such as greening (afforestation or vegetation re-establishment) and rewetting (restoring high water tables). This study aims to assess the climate impact of these two approaches using Life Cycle Assessment (LCA), with a particular focus on their global warming potential (GWP) over the long term.

As part of this study, we cultivate various plant species—including reed canary grass, hemp, birch, and willow—on an abandoned peat extraction site and compare their emissions to those resulting from rewetting, Additionally, the cultivated biomass is utilized for biogas and biochar production, all these (cultivation and production) within a theoretical framework using LCA calculations in Simapro. The LCA framework accounts for carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions. Beyond emissions from cultivation, the assessment also includes site establishment and management, fertilizer production and use, and transportation.

We hypothesize that greening may have a lower overall climate impact than rewetting, but its effectiveness depends on site conditions and vegetation type. While rewetting is effective in halting peat decomposition, it requires careful management to mitigate CH_4 emissions. By applying LCA methodologies, this study provides a comprehensive evaluation of the trade-offs between these two restoration strategies, helping policymakers and land managers make informed decisions regarding post-extraction peatland management.

By quantifying the GWP of greening and rewetting, this research enhances understanding of the climate benefits and challenges associated with abandoned peatland rehabilitation, ultimately contributing to more effective climate mitigation policies.

Slow Vegetation Recovery in Restored Wetlands Delays Achieving Climate Mitigation Effects

Ilona Tamm[1], Dennis Baldocchi[2], Evelyn Uuemaa[1], Kadir Yildiz[1], Mihkel Pindus[1], Daphne Szutu[2], Joseph Verfaillie[2], Kuno Kasak[1,2]

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Ecological wetland restoration aims to restore the structure and function of degraded wetlands. Monitoring restoration outcomes is needed to evaluate success, with plant assemblage recovery being a key indicator. Eddy Covariance (EC) method enables us assess the recovery of the biogeochemical function of the area.

This study compares two wetland restoration sites from mediterrean and temperate climate. Hill Slough (HS) tidal marsh is located in the Sacramento River Delta, California. The HS restoration project aimed to restore tidal marsh and enhance upland managed wildlife habitat. Ess-soo (ES) peatland is an abandoned peat extraction area located in Estonia. Both sites were restored in 2021 by restoring their water regime and until now vegetation recovery has been minimal (<5% of total area). To study CO_2 and CH_4 fluxes, open path EC analysers (LI-7500 and LI-7700, LICOR Biosciences) were installed in 2021 in Hill Slough and 2023 in Ess-soo.

Annual cumulative net ecosystem exchange (NEE) in HS was 334.2, 307.6, and 289.4 gC m^{-2} y^{-1}, with CH_4 fluxes of 4.6, 21.4, and 21.7 gC m^{-2} y^{-1} in 2022, 2023, and 2024, respectively. In ES, cumulative NEE was 167.0 gC m^{-2} y^{-1}, and CH_4 flux was 5.5 gC m^{-2} y^{-1} in 2024. While in HS CH_4 flux responded strongly to latent heat flux and water table depth in 2023 and 2024, the main drivers were less pronounced when flux rates and their daily and seasonal variability were low, as observed in HS (2022) and ES.

This study shows that wetland restoration projects should be carefully planned and implemented to create optimal conditions for plant growth. Slow vegetation recovery will delay achieving climate mitigation effects or other function of wetlands.

Symposium 14:
Global perspectives on applied wetland science and policy: insights and innovations from practitioners worldwide

30 June
16:45-18:15, Maailmafilm Hall

Application of Federal, State, and Local Environmental Regulations in the United States: Washington State's Fish Passage Barrier Removal Program

Shelby Petro

Society of Wetland Scientists, Seattle, USA
Parametrix, Seattle, USA
HNTB, Seattle, USA

Environmental regulation of water resources in the United States occurs at the federal, state, and local levels. This presentation examines the application of environmental regulations in the context Washington State's fish passage barrier removal program as implemented by the Washington State Department of Transportation. The program aims to improve fish habitat connectivity under public transportation infrastructure while complying with a federal injunction requiring fish barrier removal in Washington State. Implementing the program includes wetland and stream assessments, biological evaluations, and permitting requirements for habitat restoration, mitigation, and monitoring. This presentation will provide an overview of the environmental regulatory framework and ecology of the Puget Sound region in western Washington and will examine the challenges and lessons learned from the planning, permitting, construction, and monitoring phases.

The Intricacies of Determining the Ecological Water Requirements to Sustain and Protect Sensitive Habitats and Species in Sierra Leone

Katherine Taggart

Jones & Wagener Engineering & Environmental Consultants, Johannesburg, South Africa

Freshwater and estuarine ecosystems require a specific quantity and quality of water to maintain their structure, function, and dependent species. Historically, water allocation was driven primarily by economic needs, with human and environmental requirements often considered secondary. This unsustainable approach has evolved into a more comprehensive and sustainable strategy, thanks to advancements in the field of Ecological Water Requirements (EWRs).

This project focused on determining the EWRs required to sustain the freshwater and estuarine ecosystems in Sierra Leone, whilst trying to balance the water quality and quantity requirements of a proposed sand mining operation and minimise the potential impacts this mining could have on these water resources.

The project area borders large estuaries and extensive mangrove forests, which extend into the project footprint. Additionally, extensive inland freshwater wetlands are located along the upstream edge of these mangrove forests. Strong seasonal variability in flow from rivers and wetlands into the tidal mangrove forests results in a naturally dynamic freshwater/saltwater interface that supports a sequence of habitats and vegetation zones along the salinity gradient.

Mining could potentially result in a redistribution of flows, a reduction in freshwater flows, increased saltwater intrusion, and altered sediment distribution in these systems. These changes may result in, amongst others, a loss of the freshwater fish community during the dry season, a change in mangrove species distribution, a loss of marine fish species due to salt tolerance sensitivity, and an impact on sensitive species abundance due to water turbidity.

A multi-disciplinary approach was used to determine the EWRs of these sensitive systems, involving extensive ecological data collection and complex hydrological, geohydrological, and sediment modelling. The project demonstrated that with a collaborative effort between engineering, environmental and mine planning teams, it is possible to achieve outcomes that meet both mining and environmental objectives.

Reframing Wetlands Wise Use Through the Lens of Multiple Values and Worldviews

Ritesh Kumar

Wetlands International South Asia, New Delhi, India

At its founding in 1971, the Ramsar Convention propounded ‘wise use’ as a central philosophy for wetlands conservation, which reflects in the ‘maintenance of its ecological character’. In 2017, responding to repeated asks within Ramsar Convention resolutions to strengthen frameworks and approaches to working on the wetlands-society interface, and also inspired by the IPBES approach for valuing nature’s contribution to people, the Ramsar Convention adopted guidance on ‘integrating multiple wetland values in decision-making’. The findings of the IPBES Methodological Assessment on the Diverse Values and Valuation of Nature can be used to enrich and refine the wetland wise use approach and makes its implementation fit for purpose in the current contexts. Firstly, the predominant ecological framing of wise use can be widened by recognizing diversity in world views and values through which wetlands are valued in decision-making at various levels and within sectors. This recognition provides headspace for creating an inclusive understanding of wetlands from multiple perspectives, including those of indigenous peoples and local communities, and thus builds the case for broadening the tools for inventorying, assessing and monitoring wetlands. Secondly, understanding the ways in which values are formed and change can provide policymakers with better options for nurturing outcomes towards wetlands wise use. This can lead to significant enrichment of the Communication, Education, Participation and Awareness toolkit. Thirdly, recognising the co-dependencies of wise use pathway with decision-making processes that recognise and balance the representation of diverse values of nature can help address underlying power asymmetries that limit consideration of these values in various spheres of decision-making. We argue that a significant transformation agent can be crafting institutions that underpin and support values that are aligned with wetlands wise use in its revised and broad framing.

Cross-Sectoral Approaches to Tackling Plastic Pollution in England: The Plastic Free Mersey and Plastics Action Projects

Luca Marazzi[1,2], Aidan Hubbard[1], John Sanders[3]

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[3]Mersey Rivers Trust, Stockport, United Kingdom

Plastic pollution is a highly concerning global problem. The Plastic Free Mersey project (https://www.thames21.org.uk/plastic-free-mersey/) is a highly collaborative initiative bringing together environmental NGOs and plastic industry partners to stem plastic pollution within the Mersey catchment in NW England. Since November 2021 over 20 trained citizen scientists have helped quantify the amount and types of plastic and other litter items on riverbanks and at estuary sites in the Mersey catchment by means of co-designed survey methods. Plastic food packaging, cigarette butts, plastic bags, sanitary items (e.g. wet wipes), and paper were the five most prevalent litter categories. On average, plastic litter accounted for >80% of the total litter found, with more litter items observed at survey sites without bins than at sites with bins. Using citizen science data, the effects of some interventions (such as more or different bins and creative signage) on litter abundance will be tested; the findings will inform local, regional, and national policy. The project has so far engaged almost 200 people in litter picks (removing around 5 tonnes of litter) and over 300 students in education and engagement sessions in schools. A workshop with stakeholders was conducted to discuss our findings and the next steps with local authority representatives in the Mersey catchment. Local Mayors participated in project events in the last 3.5 years and they are now including some of our recommendations in their waste and water management plans.

A complementary project across England, Plastics Action, has been completed with the dissemination of a Roadmap to scale-up community action to reduce plastic pollution in and around rivers. A series of workshops and interviews with local volunteer groups and a national conference with >80 attendees yielded useful insights for the Roadmap, such as how concerned citizens can set up and run river clean-up events effectively.

Symposium 15:
Achieving ecological outcomes with water for the environment

3 July
14:45-16:15, Kurrik Hall

Management of Environmental Flows for Waterbirds in Large Floodplain Wetlands, Australia

Kate Brandis

University of New South Wales, Sydney, Australia

Large numbers of colonial waterbirds nest on floodplain wetlands in Australia's Murray-Darling Basin. Many of these wetlands are on river systems where the flow is regulated by dams in the upper catchment. As a result, flooding in the wetlands has been reduced impacting on waterbird breeding. To mitigate the impacts of river regulation Australian water management policy includes a mechanism of supplying water for the environment. Environmental water (e-water) is a component of water stored in dams that can be released to achieve identified environmental outcomes. An example of this is the provision of e-water to support waterbird breeding. In several key wetlands that support large rookeries (>100,000 nests), this type of water management is critical for ensuring reproductive success and supporting Australia's waterbird populations.

This presentation will outline the policy and processes in place to facilitate the management of environmental water to achieve on-ground results and present case studies of where e-water has been used to support colonial waterbird breeding.

The Murray-Darling Basin, Australia: How Much Wetland Conservation Will US$10 Billion Buy?

Jamie Pittock

Australian National University, Canberra, Australia

Failure of a major program to restore wetlands in a major river basin is assessed to identify lessons for other jurisdictions globally. The Basin of the Murray and Darling rivers in south eastern Australia covers a seventh of the continent. Wetland ecosystems occur over nearly 6% (5.7 million hectares) of this area.

Significant degradation of these wetlands has occurred since the 1990’s, largely due to excessive water abstraction. Since 2012 a Basin Plan and associated programs have reallocated water from irrigated agriculture to the rivers in the context of a water entitlements market, and establish an environmental flows program to conserve wetlands biodiversity. Around US$10 billion has been budgeted and around 2,100 GL (billion litres) of annual water entitlements have been reallocated to restore the environment.

Regrettably, Basin Plan implementation from 2012 to present has largely failed to reverse the loss of biodiversity. Our 2025 assessment of 12 environmental indicators assessed with independent data suggest that conditions are worse for 5 indicators, there is no improvement for another 5, and there was improvement in just two indicators (one due to an unrelated closure of commercial fisheries).

Our research suggests a number of lessons to improve environmental outcomes:

As the climate changes and human demand for water grows globally, the Murray-Darling Basin provides important lessons for better wetlands conservation.

Long Term Vegetation Monitoring at Narran Lakes and the Role of Environmental Water in Resilience

Rebekah Grieger, Samantha Capon, Jaiden Johnston-Bates

Australian Rivers Institute, Brisbane, Australia

Floodplains are key components of inland river systems of arid and semi-arid Australia with floodplain vegetation having important roles in habitat provision, nutrient cycling, and strong cultural values. These vegetation communities are highly dynamic, rapidly responding to changes in water availability, particularly flooding. Decades of water development has led to highly managed water resources, strongly linked to the decline in wetland and floodplain habitats for this region. We explored patterns in vegetation response to wetting and drying over twenty years at Narran Lakes, a terminal floodplain system in the northern Murray-Darling Basin, Australia. We collated data from previous monitoring efforts and resampled permanent plots for understorey vegetation and lignum shrubland structure. We captured vegetation communities across four flood events as paired surveys of initial drawdown (minimal standing water remaining) and dry (6 months after flood). Overall we observed a high diversity of native plant species (~150 species) in standing and soil seed bank communities but composition varied substantially between flood events and within years. Notably species richness and cover was greatest in the 2023 survey following a significant flood event where environmental water contributed to the extent and duration of flooding. Exotic species showed greater cover, but not richness, after recent flood events but had decreased substantially after six months of drying, although their presence in the soil seed bank suggests potential for persistence. Lignum shrublands showed increased condition but decreased lignum cover over time. While the role of environmental water in maintaining long-term vegetation patterns is unclear, large flood events are critical for supporting vegetation resilience. Continued long-term monitoring of vegetation through flood cycles at Narran Lakes will be critical to understanding ecological responses to longer-term changes in climate and hydrology to inform management, particularly for environmental water requirements.

Inundation Advantage: Flooding Duration Filters Germination from Floodplain Soil Seed Banks

Jaiden Johnston-Bates

Griffith University, Brisbane, Australia

Dryland floodplains in eastern Australia are dynamic ecosystems characterised by high hydrological variability, with periods of drought punctuated by flooding. Vegetation responses often follow a boom-bust model of productivity, and whilst native plants are well adapted, it remains unclear whether these conditions also facilitate plant invasions. Post dispersal, many native plants which characterise eastern Australian floodplains utilise mechanisms of dormancy whilst awaiting the appropriate conditions for germination. Similarly, many of the world's most successful plant invaders have traits which allow for them to thrive in riverine contexts, including many associated with seed dispersal and seed bank persistence. We conducted glasshouse experiments on soil seed bank samples collected from sites across the northern Murray-Darling Basin. We exposed samples to simulated rainfall, a short flood (two weeks), and a long flood (one month). The germination of every seed was measured temporally, and a short drought followed by secondary inundation was also incorporated. Our primary objective was to assess how inundation impacts native and non-native germination across growth forms and endemicity. Seed banks were highly diverse, particularly for native species which featured a variety of growth forms, whilst non-native assemblages were primarily made up of forbs and grasses. Longer inundation promoted native species and reduced non-native germination, suggesting non-native seeds are often inadequately equipped to sustain viability during periods of inundation. In contrast, regular wetting (rainfall) resulted in a similar representation of native and non-native germinants. The secondary inundation phase showed that most non-native seeds had either germinated or lost viability in the first round of inundation, further highlighting a general vulnerability to prolonged inundation. Our findings suggest that extended periods of inundation (i.e., flooding) can negatively impact non-native species and conversely promote native germination, highlighting opportunities for non-native plant management in situations where ecosystems are subject to anthropogenically managed river flows.

POSTER PRESENTATIONS

Session 1:
Social and economic aspects

30 June
18:35-20:00

The Urban Riparian Zone: Exploring Plant Composition and Structure in Developed Landscapes

EJ Henderson

Australian Rivers Institute: Griffith University, Brisbane, Australia

The composition and movement of riparian plant species in cityscapes is not well documented. These wetland plant communities provide essential habitat corridors and fodder for many urban dwelling wildlife species and deliver functional services to urban areas including bank stabilisation, and run-off filtration. The study area includes 65 urban riparian creek-adjacent sites across South East Queensland, Australia, where ecological data regarding plant composition, structure, and health was collected. Using this data, we investigate the species composition, a native versus non-native species assessment, the structure and form of extant vegetation, and how these change across sites within an urban landscape. These findings can assist in understanding these novel landscapes and provide insight into potential management best practices, as well as infer predictions regarding the ecological future of riparian zones in urbanising areas.

Session 2:
Biogeochemistry

30 June
18:35-20:00

Northern Peatlands as Sources of Reactive N-Gases

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Northern peatlands are significant storages of both carbon (C) and nitrogen (N), making them potential sources of reactive N-gases such as nitrous acid (HONO) and nitric oxide (NO). Despite being integral to the soil N-cycle, emissions of HONO and NO have not been reported from many ecosystems, including northern peatlands. HONO plays a crucial role in the atmosphere; it produces hydroxyl radicals (OH), which are key atmospheric oxidants that help remove pollutants like methane and participate in cloud formation. On the other hand, NO is essential for regulating the ozone cycle and the formation of nitrate radicals in the atmosphere. Climate change is expected to impact C and N-cycles in peatlands, thereby influencing their potential to release reactive N-gases. Our goal was to clarify the role of northern peatlands in the emissions of these gases. To achieve this, we investigated emissions of HONO, NO, and nitrous oxide (N_2O) from various peatlands, ranging from northern palsa mires in Sweden to southern bogs in Finland. The study was conducted under laboratory conditions using intact soil cores sampled from various study sites, including waterlogged peatlands and those drained for forestry and agriculture. We found that waterlogged peatlands were mostly minor sources of these gases, while emissions from drained peatlands varied significantly, with peatlands used for agriculture being the most substantial sources.

Intra- and Interannual Dynamics of Carbone Dioxide Flux on a Constructed Wetland: An Eddy Covariance Approach

Tom Saade[1], Julien Tournebize[1], Cédric Chaumont[1], Carmen Kalalian[2], Laura Bignotti[2], Erwan Personne[2]

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Carbon dioxide flux analysis on wetlands has been studied over the last decade and has allowed a better understanding of exchange between the biosphere, hydrosphere and atmosphere. Eddy Covariance methods have been applied on some wetland and constructed wetland site, but intra- and interannual carbone dioxide flux dynamics are rarely highlighted in the different works.

To spotlight these dynamics, as part of Horizon Europe project - ALFAwetland (https://alfawetlands.eu/), we analyzed ten years of Eddy Covariance data from a constructed wetland near of Paris (Rampillon, France) from 2014 to 2024. The constructed wetland was built in 2010 and mainly studied for water quality improvement (Nitrate and Pesticides). In 2014, an Irgason Campbell Eddy Covariance Tower was set up in the middle of the 0.5ha of restored wetland and measured almost continuously humidity and CO_2. In average the wetland is covered by 30% of vegetation and has a sub-area that is always wet and another one temporarily dry.

Raw data are analyzed and filtered to keep correct data, then shorts gap are filled to improve data continuity over time. Lastly, carbon dioxide fluxes are split into two terms : ecosystem respiration (Reco) and gross primary production (GPP), following two scenarios : day-time partitioning strategy and night-time partitioning strategy. Afterward, we investigated carbone dioxide flux variation at different time scales (month, season and year) and linked fluxes to biogeochemical and hydrological parameters (discharges and water level). Comparing same period with similar condition among years bring to light carbon dioxide dynamics.

Enhanced Isotopic and Microbiological Analyses for Precise N-Transformation Processes in Contaminated Aquifer – Groundwater Incubation Study

Sushmita Deb[1], Mikk Espenberg[2], Dominika Lewicka-Szczebak[1]

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Excessive nitrogen in groundwater is an important environmental concern, particularly in regions near agricultural fields, where fertilizers primarily pollute groundwater with nitrate. This study investigates nitrogen cycling in groundwater from region where yeast production wastewater is used as fertilizer. We integrated isotopic analysis, microbial gene quantification, and the FRAME (isotope FRActionation And Mixing Evaluation) model to trace nitrogen transformations. Groundwater samples, with elevated nitrate (NO_3^-) concentrations were subjected to laboratory incubations using a novel low-level ^{15}N tracing technique. Isotopic analyses revealed significant $\delta^{15}N$ and $\delta^{18}O$ enrichment in NO_3^- during denitrification, with $\delta^{15}N$-NO_3^- increasing by 20–33‰ and $\delta^{18}O$-NO_3^- by 12–18‰ in the first incubation phase. Despite this, nitrite (NO_2^-) isotopic data ($\delta^{15}N$-NO_2^-: -50‰ to 0‰; $\delta^{18}O$- NO_2^-: highly variable) indicated that only 4.4–20.4% of NO_2^- originated from NO_3^- reduction, while the majority was linked to dissolved organic nitrogen (DON) oxidation.

Post-incubation, isotopic data for N_2O ($\delta^{15}N$-SP and $\delta^{18}O$) indicated bacterial denitrification as the dominant pathway for N_2O production, contributing 80–85% in the later stages as supported by FRAME modeling. This was further validated by DNA extraction and qPCR-based microbial genes quantification which revealed a shift from archaeal-driven nitrification to bacterial denitrification under suboxic conditions stimulated by glucose addition, with significant increase in *nirK, nirS*, and *nosZI* gene abundance. The results also revealed simultaneous NO_3^- reduction and formation, with NO_3^- concentrations increasing by 7–30 mg L^{-1} in the later phase due to DON oxidation.

To further refine our understanding of nitrogen transformation, ongoing metagenomics analysis explores microbial community composition and processes in nitrogen cycle. Integrating isotopic fractionation patterns with microbiome, this study provides a framework for addressing nitrogen pollution in groundwater systems and improving water quality management strategies.

Assessing the Contribution of Marine and Terrestrial Organic Carbon in Contrasting Coastal Wetlands: A Multi-Tracer Approach

Benjamin Amann[1], Bénédicte Dubillot[1], Eric Chaumillon[1], Marie-France Dignac[2], Cornelia Rumpel[2], Axel Felbacq[2], Maël Destampes[1], Marie Arnaud[2], Thomas Lacoue-Labarthe[1], Christine Dupuy[1]

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Coastal wetlands serve as carbon sinks, storing particulate organic carbon (POC) in sediments over long periods. However, POC preservation varies based on habitat type, environmental conditions, sediment depth and the sources and composition of organic matter. This study investigates POC preservation across sediment depth gradients in three temperate coastal wetlands in France: a ditch of freshwater marsh, a salt-marsh, and a mudflat. A multi-tracer approach including POC content, C/N, $\delta^{13}C$ values, lignin phenols and fatty acids reveals key differences in POC storage and composition. POC ranged from 11.42 to 23.16 mgC/g dry sediment. Its concentrations decreased in the order salt-marsh > mudflat > freshwater marsh. $\delta^{13}C$ values and C/N highlighted distinct POC sources in the environments. Salt-marsh sediments contained a mix of marine and terrestrial carbon, with a dominant contribution from allochthonous coastal-marine sources. Mudflat sediments were mainly influenced by marine organic carbon. Freshwater marsh sediments showed high terrestrial carbon inputs, likely derived from vascular plants. Vascular plant-derived lignin phenols represented 0.4 to 2 % of organic carbon and were present in all habitats but in varying amounts. The lowest lignin content was found in mudflat sediments, while salt-marsh and freshwater marsh sediments showed higher values. POC was most degraded in the mudflat, as indicated by the highest syringyl acid-to-aldehyde ratio of lignin phenols. Fatty acids represented less than 0.7% of POC. In mudflat sediments, fatty acids derived from diatoms and bacterial markers decreased rapidly with depth, in contrast to salt-marsh and freshwater marsh. Our multitracer approach suggests that plant-derived organic compounds could be predominant in the salt-marsh and the freshwater marsh, while in the mudflat, marine carbon sources could contribute to carbon storage. Moreover, this study highlights the connectivity between different types of coastal wetlands and their role in the preservation of labile plant-derived organic matter.

Integrating Orbitrap Mass Spectrometry for Characterization of Soil Organic Matter Chemistry and Biogeochemical Cycling in Wetland Soils

Kien Yung Teo[1,2], Carsten Simon[3,4], Jaan Pärn[1], Mikk Espenberg[1], Simon A. Schroeter[3], Gerd Gleixner[3], Lulie Melling[5], Ülo Mander[1]

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Wetlands are unique ecosystems formed from accumulated slow-decayed organic matter due to the anoxic and waterlogged environment. Soil organic matter (SOM) plays a significant role in supporting biogeochemical cycling, maintaining water quality, and regulating greenhouse gas emissions. Under natural conditions, the molecular compounds that dissolve in water are identified as water-extractable organic matter (WEOM). The study of WEOM at the molecular level across wetlands under different agricultural use intensities and climate regions remains under study. We analyse WEOM through ultrahigh-resolution Orbitrap mass spectrometry and integrate it with varying types of climate, agricultural intensities, soil water content, molecular groups, microbial functional genes diversity, and field-measured ecosystem respiration, methane, and nitrous oxide fluxes. Soil sampling was conducted globally at 25 regions representing four agricultural intensities: (1) no agriculture, (2) non-intensive grassland, (3) intensive grassland, and (4) arable land. The assigned molecular formulas with mass ranging from 100 to 1000 Daltons detected by Orbitrap were 14,890 counts. Correlations between agricultural intensities and formula classes containing N, S, or P of different climate types (tropical, temperate, continental) were visualised using van Krevelen diagrams. We further examined the influence of climate types and agricultural intensity on WEOM through a principal coordinates analysis (PCoA). We linked WEOM quality changes with gas fluxes, available microbiomes, and environmental characteristics. Ecosystem respiration, nitrous oxide emission, and agricultural intensity were positively correlated with the persistence of WEOM (i.e., aromaticity vs. aliphaticity) and negatively correlated with soil water content. Diversity of bacteria and archaea, as well as methane emission, were positively correlated with soil pH, but unrelated to WEOM quality. Our findings offer fresh perspectives on how WEOM composition shifts in response to different environmental and land management factors, deepening our understanding of its significance in global carbon and nutrient dynamics.

Keywords: wetland, WEOM, GHG emissions, Orbitrap, climate, agricultural intensity

Ecosystem Respiration During Snowmelt and Soil Thaw Drive the Highest Annual CO_2 Balance in a Boreal Fen Over 17 Years

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Non-growing season carbon fluxes are a critical component of the annual ecosystem carbon balance. As global temperatures continue to rise, winter fluxes are expected to undergo significant changes, potentially altering the timing, magnitude, and direction of carbon exchange between ecosystems and the atmosphere. Using 17 years of net ecosystem exchange (NEE) data from Siikaneva fen in Southern Finland, we analyzed non-growing season carbon dioxide (CO_2) fluxes alongside environmental and meteorological variables. On average, non-growing season CO_2 emissions offset 57% of the subsequent growing season's uptake, with the fen acting as an annual CO_2 sink with a mean balance of -50.9 ± 39.4 g C m^{-2}. However, two years—2016 and 2018—were CO_2 net sources, with 2016 standing out due to anomalous spring-time ecosystem respiration during snowmelt and soil thaw. This six week period alone offset 38% of the following growing season's carbon uptake. This event was potentially triggered by rapid soil temperature shifts during the winter and spring, and release of trapped CO_2 under ice and snow. A random forest analysis revealed high uncertainty in non-growing season flux drivers (photosynthetically active radiation (PAR), vapor pressure deficit, water table depth, and soil temperature), while growing season fluxes were predominantly driven by PAR. Transition months (April and November) showed statistically significant shifts in driver importance, with soil temperature dominating with PAR. These findings highlight the importance of snowmelt and soil thaw dynamics in regulating ecosystem respiration and demonstrate how short-term events can significantly influence the annual carbon balance.

Comparative Study of CO_2 Fluxes from a Restored Pond and a Temporary Pond with a Short Annual Hydroperiod

Corinna Borchard, Marlen Heinz, Stefan Lorenz, Karin Meinikmann

Julius Kühn-Institut, Berlin, Germany

Although the crucial role of inland wetland-associated greenhouse gas dynamics in the global carbon cycle and warming is well recognized, it is not yet fully understood. Particularly lentic small water bodies (SWB, < 1 ha) are, due to their small size, difficult to map and mostly neglected in greenhouse gas estimations.

Here we report results of the ongoing project “Rewetting of agricultural waters as an immediate climate protection measure (WAKS)” that monitors the revitalization process of a lentic SWB located within an agricultural landscape in Northeastern Germany that has remained on the brink of drying out for years.
The pond was dredged in November 2022, leading to a permanent rise of the water level. *In situ* CO_2 fluxes were measured along two defined transects for the restored and a nearby reference pond. To account for photosynthetic activity, vegetation was not removed and canopy chambers were used from April 2024. Monthly measurements of CO_2 fluxes were accomplished from April to October 2023 and 2024 along with samplings for the analysis of nutrients, DOC and chl *a*.

We observed clearly reduced CO_2 emissions for the rewetted pond compared to the reference pond, and a pronounced CO_2 uptake for areas with dense floating macrophytes. Chl *a* peaked in July/August along with a nutrient draw down followed by the highest DOC concentrations in August and September. The reference pond was dry year-round in 2023, however, in the spring 2024, there was a short hydroperiod with the lowest CO_2 emissions, before they increased as the pond again dried up in the summer months.

Our results confirm previous reports on the influence of different hydrological phases on CO_2 fluxes from inland wetlands and additionally highlight the need for a more detailed monitoring of carbon flows affected by temporal patterns of photosynthetic activity.

Simultaneous Trace Gas Flux Monitoring of Up to 10 Greenhouse Gases and Air Pollutants with a Single Instrument

Jonas Bruckhuisen, Etienne Smith, Oleg Aseev, Morten Hundt

MIRO Analytical, Zürich, Switzerland

Monitoring of trace and greenhouse gas fluxes is key to understand the interaction between atmosphere, plants, and peat-/wetlands and therefore to improving our understanding of the climate system in general.

Complex flux systems, in environments where both biogenic and anthropogenic sources and sinks may play a role, require measurement of many different inert and reactive trace gases and greenhouse gases simultaneously to obtain a complete budget.

Until recently, however, the monitoring was usually limited to only a few gases per measurement device making the technique complex and expensive but providing only a limited picture. MIRO Analytical has developed a novel multicompound gas analyzer that can monitor up to 10 air pollutants (CO, NO, NO_2, O_3, SO_2 and NH_3), greenhouse gases (CO_2, N_2O, H_2O and CH_4) and other atmospheric trace gases such as (OCS, $HONO$, CH_2O) simultaneously at ppb level.

The eddy covariance (eddy flux) technique is often used to measure fluxes of trace gases but requires a high time resolution. Our compact instrument, combing several mid-infrared lasers (QCLs), offers 10 Hz sampling rate, outstanding precision, selectivity and accuracy and an automatic water vapor correction, which makes it ideal for eddy covariance flux measurements.

In our contribution, we will introduce the measurement technique and will demonstrate application examples of this all-in-one atmospheric flux monitor. The system will be compared to alternative devices in parallel measurements and results of long-term observations and shorter campaigns will be presented.

Air-Water CO_2 Fluxes in a Saltmarsh Tidal Creek and Their Implications for the Coastal Carbon Budget

Songjie He

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Salt marsh soils sequester organic carbon at rates higher than most ecosystems in the world. It is important to assess the pathway by which carbon stored in salt marshes can be released. Previous studies have indicated that considerable amounts of dissolved organic carbon and dissolved inorganic carbon (DIC) can be exported laterally from salt marshes to adjacent surface waters through tidal exchange. Such estimates are difficult in part because a large portion of the DIC transported from marsh to adjacent water bodies can also be quickly degassed to the atmosphere via air-water CO_2 exchange. The magnitude of CO_2 degassing in the tidal water adjacent to coastal salt marshes is thought to be high due to DIC enriched porewater exchange but currently not well studied. In this study, we conducted high frequency pCO_2 measurements in a tidal creek of a salt marsh in coastal Louisiana. We deployed dissolved pCO_2 sensors in the tidal creek at our study site to record high frequency variability in pCO_2 for periods ranging from 2 to 38 days. Between January 2021 and July 2022, pCO_2 concentrations varied from 120 µatm to over 20,000 µatm. Preliminary results show that air-water CO_2 fluxes are highly correlated with creek water level and passages of cold fronts. Comparisons between the air-water CO_2 fluxes and the CO_2 emissions measured by an eddy covariance tower on the same marsh will also be evaluated to improve our current understanding of marsh-sourced CO_2 degassing in tidal waters and its impact on coastal carbon budget.

Individual Responses of Carbon and Nutrient Dynamics in Small Depressional Wetlands (Kettle Holes) in Northeastern Germany

Marlen Heinz, Kathrin Fisch, Corinna Borchard, Stefan Lorenz

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A high density of small depressional wetlands (kettle holes) characterizes the agricultural landscape in Northern Germany. Besides their role as important biotopes for a variety of water organism, they play an important role in water- , carbon- and nutrient cycling. The majority of these small waterbodies is located directly on, or adjacent to cultivated areas, which often results in high nutrient loads into these water bodies. Nutrient and dissolved organic carbon (DOC) status can largely vary between waterbodies. Thereby waterbody characteristics (e.g. connectivity to groundwater, shore vegetation, morphology) affect the loads into the kettle holes, but also have an effect on internal nutrient and carbon processing.

To assess how nutrient and DOC status vary over different seasons and this may differ between waterbodies we sampled 11 kettle holes monthly, over a 2-year period and analysed DOC and dissolved inorganic nutrients (nitrate, nitrite, soluble reactive phosphorous, ammonia), chl *a* content and physicochemical properties. We additionally sampled surface near groundwater from piezometer wells at five sampling sites, to evaluate the influence of subsurface flow on nutrient and DOC status of the waterbodies and to assess whether this varies between seasons.

Our results show, that some of the kettle holes, even though closely spaced (distance < 100m) and subjected to identical management practices, show distinctly different nutrient and DOC patterns. Consequently, kettle holes should be considered as independent entities in terms of DOC and nutrient dynamics and their individual characteristics should be taken in account when it comes to implementation of mitigation measures.

From Roots to Atmosphere: Tree Contributions to GHG Fluxes in a Mediterranean Floodplain Under Different Flooding Regimes

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Soils are a major natural GHG source, primarily releasing carbon dioxide (CO_2) through aerobic respiration. However, in riparian areas, shallow groundwater levels and flooding events promote anaerobic processes that also release methane (CH_4) and nitrous oxide (N_2O). Recent studies have highlighted the role of trees in CH_4 emissions, but little is still known about the origin of these emissions, the processes involved, and their contribution to the global carbon and nitrogen cycles. To address this, we measured CO_2, CH_4, and N_2O emissions from soils and the stems of two riparian tree species (*Fraxinus angustifolia* and *Quercus robur*) across a soil moisture gradient (from wet to flooded conditions) in a Mediterranean floodplain forest. Measurements were performed only once under optimal flooding conditions. Additionally, we analyzed the isotopic carbon signature of emitted GHG and the microbial communities inhabiting within tree stems by 16S rRNA gene sequencing. Our results showed that CH_4 emissions from tree stems were 100 times higher in flooded soils than in wet soils, while CO_2 and N_2O emissions remained unchanged. Under flooded conditions, tree stems contributed up to 20%, 40%, and 60% of total CH_4, CO_2, and N_2O emissions, respectively. Keeling plot analysis suggested that CO_2 stem emissions originated from soil transport, whereas CH_4 had a different source. Methanogens were almost absent in the wood microbiome. Yet, the significantly higher presence of methanotrophs in wood compared to soil suggested that, although CH_4 emitted by stems may originate from soil microbial activity, microbial consumption within the tree stem could have altered its isotopic signature. Overall, our findings suggest that riparian trees in this Mediterranean floodplain primarily act as passive conduits for soil-derived GHGs rather than active producers.

Cotton Strip Degradation as an Indicator of Organic Matter Decomposition in Wetlands Across a European Latitudinal Gradient

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The objective of this study was to study the decomposition of organic matter in wetlands along a European latitudinal gradient. To do so, we adapted the Cotton Strip Assay methodology, which serves as a proxy for organic matter decomposition. Standardized cotton strips, uniform in size and material, were buried at a depth of 10 cm in the soil at 20 different sites across Europe (Spain, France, Belgium, Estonia and Finland). All the study sites are part of the EU-funded ALFAwetlands project. Those sites included different typologies of wetlands: Peatlands, Mountain Peatlands, Drained peatland Forests, Alluvial Forests and Floodplains. Three extractions were conducted at different time intervals: the first two ranging from 7 to 15 days depending on the site, and the third after 59 days of incubation at the maximum. These measurements allowed us to calculate the loss of tensile strength as a proxy of decomposition, expressed in degree-days, for each site.

To determine which typologies or sites exhibited the highest decomposition rates and explore the potential underlying causes, we compare the decomposition rates with conventional soil characteristics (e.g., carbon, nitrogen, C/N ratio, phosphorus, potassium, calcium, magnesium, pH, and organic matter percentage), along with continuously recorded soil temperatures and volumetric water content (VWC) using TOMST data logger. These analyses enabled us to identify the main driving factors per site.

Our preliminary results suggest that VWC is not as significant a factor as initially expected. Instead, the soil typology determines the decomposition activity, being faster in mineral soils (Alluvial Forests and Floodplains) than in organic ones (Peatlands, Drained Peatland Forest, and Mountain Peatland). Specifically the main factors which determined decomposition rates were soil pH, CN molar ratio, and organic matter content, where acid soils with high organic matter content and CN molar ratios, showed lower decomposition rates.

Dynamics of N_2O Emissions from Amazonian Tropical Peat Forest and Partitioning N-Processes Using 15N Isotopes

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Tropical peatlands are crucial for global nitrogen (N) cycling because they store large amounts of carbon and N. This study, conducted in November 2023, investigated the dynamics of N_2O emissions from Amazonian peatland forests in Peru. It focused specifically on two peatland forest sites in Iquitos: the *Quistococha* and *Zungarococha* forests. We conducted static chamber gas measurements to assess soil greenhouse gas (GHG) fluxes. Additionally, we took soil samples for physical and chemical properties and soil microbiome (DNA & RNA). In order to investigate the source processes for N_2O production and consumption, we applied ^{15}N isotopes as tracers in soil and also investigated the natural abundance signatures of nitrogen in N_2O. Our results indicate that both forests exhibited different trends in soil GHG fluxes and N substrates. Quistococha had higher levels of soil nitrate and ammonium compared to Zungarococha, which correlated with increased N_2O emissions from Quistococha. Contrastingly, Zungarococha had higher soil moisture levels, which aligned with its lower N_2O emissions. This forest also showed greater soil N_2 emissions, suggesting the potential for complete denitrification. However, this site was also a significant source of CH_4 emissions due to its higher soil moisture. Overall, the two sites demonstrated distinct behaviors: Quistococha was a source of N_2O and CO_2, influenced by intermediate soil moisture. Zungarococha emitted higher levels of CH_4 and N_2 due to its high soil moisture conditions. The application of ^{15}N tracers increased soil N_2O emissions only in Quistococha, while we did not observe a significant increase in Zungarococha, suggesting that complete denitrification may be the dominant process there. This is further supported by ^{15}N isotopic mapping, correlating N_2O emissions with their source processes. The microbiome analyses show similar results, with denitrifying microbes dominating the Zungarococha soil and nitrifying microbes dominating the Quistococha soil.

Session 3:
Hydrology

30 June
18:35-20:00

Precipitation Effects on the Water Table Dynamics in Raised Bog at Different Temporal Scales

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The fluctuations in the bog's water table are like a frame within which biological processes, peat decomposition, the migration of various compounds and many other processes take place, and a clearer understanding of the hydrological "rhythm" is important for explaining both the mechanisms of specific processes and the overall development of the bog. The aim of this study is to assess how the hydrological characteristics of the raised bog habitats are related to precipitation indicators of different temporal scales, and what kind of trends of change emerge in the water table fluctuations. The study area is the pristine Čepkeliai raised bog on the southern edge of Lithuania. The study is based on 1951-2024 Varėna MS precipitation data and 2002-2024 measurements of water table in the raised bog.

Correlation analysis showed a seasonally varying relationship between the raised bog's water table and the amount of precipitation for different time periods: In late spring – early summer there is a strong correlation with short-term precipitation (Standardized Precipitation Index SPI1-SPI2); in the later months the correlation with short-term precipitation weakens, while the correlation with longer-term precipitation strengthens (SPI4-SPI12); in late winter – early spring the correlation coefficient is low to slightly higher only for long-term precipitation (SPI18, SPI24).

An analysis of daily water tables in one of the monitoring wells (2012-2024) showed that over the whole period, 66% were days when water table dropped and 34% when it rose. A statistically significant trend was found of increasing number of days when water table drops. The average number of water table fluctuation cycles per year is ~60, with an average duration of ~2 days for the rise phase and ~4 days for the fall phase. A statistically significant trend of decreasing number of cycles and increasing length of the falling phase was found.

Sensitivity Analysis of Hydrological Components and Vegetation Responses in Mountain Wetlands Due to Climate Variability

Jiyu Seo, Haeun Jung, Sangdan Kim

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Wetlands are highly productive ecosystems that provide a wide range of ecosystem services. Climate change poses a significant threat to mountainous wetlands, altering hydrological processes and causing issues such as acidification and browning. Understanding wetland hydrology and vegetation changes in response to climate change is essential for conservation and restoration.

The hydrological sensitivity of wetlands to climate variability is best analyzed using long-term observations, but such data for mountainous wetlands are scarce. To address this, this study developed a hydrological model, calibrated it using limited observations, and input long-term meteorological data to generate wetland hydrological component data. Meanwhile, wetland vegetation sensitivity to climate change was analyzed using MODIS LAI data, available at a 500-meter resolution every 8 days since 2000, providing about 40 datasets per year.

To examine wetland hydrological functions and vegetation sensitivity to climate variability, the concept of elasticity was applied. In this study, wetland climate elasticity was defined as the rate of change in hydrological components and vegetation in response to a 1% change in climate variables. Additionally, elasticity curves were used to assess climate variable impacts across different percentiles of hydrological components and vegetation. Precipitation and potential evapotranspiration were considered.

The elasticity analysis quantified how climate variable changes influence wetland hydrology, providing a basis for understanding wetland hydrological responses to climate variability. This study contributes to wetland conservation and management strategies, offering insights for maintaining and enhancing wetland ecosystem services.

Keywords: climate change, climate elasticity, elasticity curve, mountainous wetlands, satellite data

Acknowledgements: This work was supported by Korea Environment Industry & Technology Institute(KEITI) through Aquatic Ecosystem Conservation Research Program(or Project), funded by Korea Ministry of Environment(MOE)(2022003050007)

Development of Vegetation Drought Monitoring Index and Quantitative Assessment of Wetland Vegetation Drought

Haeun Jung, Jiyu Seo, Sangdan Kim

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Vegetation drought (VD) is a sustained deterioration in vegetation condition, which is caused by a meteorological drought (MD) caused by changes in meteorological factors such as lack of precipitation and/or increased evapotranspiration. MD can propagate to VD through the hydrological cycle. This spread from one type of drought to another is known as drought propagation. Several meteorological drought indices (MDIs) and vegetation indices (VIs) have been developed and applied to quantify the effects of drought. However, the same drought event can have different results depending on which MDIs and VIs are used. And the results can vary depending on the type of land cover. Therefore, this study aimed to develop and evaluate a vegetation drought index (VDI) that comprehensively reflects various MDIs and VIs. In addition, the VDI developed in this study was used to quantify VD in wetlands located in Far East Asia. The VDI developed in this study has been found to effectively monitor VD in the Far East. The analysis by land cover type also enabled a qualitative assessment of VD in wetlands.

Acknowledgements: This work was supported by Korea Environment Industry & Technology Institute (KEITI) through Aquatic Ecosystem Conservation Research Program (or Project), funded by Korea Ministry of Environment (MOE) (2022003050007)

Session 4:
Wetlands ecology and biodiversity

30 June

18:35-20:00

Smoke Hurts Animals, Too

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Sivil Düşün is an European Union programme supporting active citizens and civil society organisations throughout Türkiye. In this scope, current study titled as "Smoke hurts animals, too" was carried out with the support of Sivil Düşün.

The fires that have occurred in recent years burned forest lands in almost every region of Türkiye. Many small and large animal barns affected and animals such as tortoises, dogs, cats, cows and sheep perished. The majority of the wetland areas in Türkiye are located in the Lake Van Basin. These areas where fires are frequent, home to many bird species. In these fires, many reptiles and insects, especially turtles that cannot escape the flames, as well as piglets, die and nests of many bird species are being destroyed.

Firefighters give priority to human rescue activities in case of fires, and animal rescue activities are overlooked. High temperatures, toxic effects of smoke, and oxygen depletion can therefore cause mortality or impairment of animals. Firefighters often face difficulties during these rescue operations. They make the first response in forest and house fires. If Oxygen masks are used in animals under fires, all the oxygen is going into their lungs and make a positive contribution to animal health as first aid.

The target group of our study was firefighters working in several cities of Türkiye (Balıkesir, Artvin, Şanlıurfa, Konya and Van provinces). Awareness activities, seminars and experimental events to increase animal rescue capacities of first responders were performed. The main activity was to encourage firefighters to use Oxygen masks for animals, unconscious due to smoke or have breathing difficulties during fires. These masks should be available in all Fire Brigades. With the widespread use of Oxygen masks in fires, it will make a positive contribution to animal welfare.

Keywords: animal rescue, fire, wetland, oxygen mask

Mapping Ecosystem Services in Lahaul Pangi in India and Integrating Assessment Findings with Policy Insights

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A detailed evaluation of ecosystem services in the Lahaul Pangi landscape was conducted using qualitative and quantitative methodologies to assess ecological integrity, biodiversity, and service provisioning. The study integrated field surveys, literature reviews, expert consultations, and GIS modelling to categorise land use and land cover (LULC) into several distinct types, including barren land, rangelands, glaciers, wetlands and forests. Validation through field surveys and local interviews confirmed the accuracy of the LULC map and highlighted crucial features such as hydrological systems and tourism hotspots. Findings underscore the landscape's critical provisioning services, with agriculture spanning 6,000 hectares, extensive rangelands, and substantial freshwater output. Regulating services, particularly glacier-mediated climate and water flow management, are essential. Cultural services, including tourism and educational activities, contribute significantly to the local economy. An ecosystem services (ES) matrix, with scores ranging from -1 (negative) to 3 (high), was constructed to highlight the importance of preserving near-natural ecosystems in the landscape, like forests, wetlands and rangelands, for their roles in climate regulation, water flow management and habitat provision. The study advocates for incorporating these economic values into conservation strategies to ensure ecological integrity and the sustainability of vital ecosystem services, thereby providing a framework for informed conservation and sustainable development initiatives.

Exploring the Characteristics of Aquatic Plants Growing in Japan's Major Rivers Through the National Census on River Environments

Chigaya Enju

Public Works Research Institute Water Environment Research Group, Tsukuba, Japan

Approximately 40% of aquatic plants in Japan are on the Red List of the Ministry of the Environment, and their conservation is considered an urgent priority. Because rivers are the second largest freshwater bodies in Japan after lakes and marshes, major rivers are also considered important habitats for aquatic plants, but there is less information on them than lakes and marshes. Therefore, the purpose of this study was to characterize the aquatic plants growing in Japan's major 109 rivers using data from the National Census on River Environments (NCRE) conducted every 5 or 10 years. The relevant aquatic plants were extracted from the NCRE data for 1992-2022, and information on the characteristics of each species (total number of life forms, native or alien species, and life history information) was assigned. Species were defined as stable in major rivers if they were found to be growing in all or except the first of the three to five surveys conducted to date in each river. As a result, 100 of the 292 species were found to be growing stably in major rivers. Of these, 89 were native, 9 were alien species, and 1 was other. Among the native species, many of them were Cyperaceae and Poaceae. In terms of life history, about 35% (16/46 species) were annual and 36% (79/217 species) were biennials or perennials, suggesting that annuals and perennials may grow in the same proportion in the major rivers. Red-listed species accounted for 15% of the total, including, for example, *Lemna trisulca* and *Sparganium japonicum*. Several of these species were unable to find information on their growth outside of major rivers within their watersheds. Therefore, it was considered likely that major rivers in Japan are important habitats for many native aquatic plants.

Effects of Coarse Woody Debris with Morphological Complexity on Organic Matter Retention and the Aquatic Biodiversity in a Riparian Ecosystem

Mana Honda, Yoshinori Minami

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Coarse woody debris (CWD) is important in river ecosystems. It is known that CWD provides habitats for aquatic organisms. However, human activities have significantly impacted on riparian ecosystems, leading to declines in environmental diversity. To conserve these ecosystems, various studies have been conducted including introducing CWD, primarily in North America. In contract, in Japan, obstructions such as CWD are removed to ensure public safety. It is crucial to further clarify the effectiveness of CWD in river restoration, especially in Japan. This study demonstrates introducing various types of CWD can effectively contribute to the restoration of river ecosystems. In particular, this presentation focuses on the effects of CWD with branches, as it is expected that more complex structure will accumulate greater amounts of food resources for macroinvertebrates.

In Augst 2023, we established a study site in a stream in Hokkaido, where we placed several pieces of woody debris. After setting up the site, we measured the physical environment and the degree of leaf litter retention, both directly trapped by the woody debris and accumulated on the riverbed, and we collected macroinvertebrates samples from the riverbed during both the leaf fall and flood season.

This study found that CWD with complex morphological structures trapped more leaf litter than simpler structures. Additionally, CWD with complex structures altered the riverbed’s topography, thereby contributing to providing various habitats. The macroinvertebrates community composition observed in this study differed from previous research on CWD without branches section especially in flood seasons. These findings suggest that macroinvertebrates may expand their distribution toward the water surface along the leaf litter that accumulates and is retained by the branches of CWD. The research highlights the potential of CWD with diverse structural forms to enhance biodiversity in river ecosystems.

Influence of Small Aquatic Invertebrates and Soil Fauna on Litter Decomposition in a Subarctic Wetland Forest in Hokkaido, Japan

Yuta Hamada, Tomoko Yoshikawa, Kei Yokokura, Kiichi Kaneko, Mitsutoshi Tomotsune

Tamagawa University, Tokyo, Japan

Subarctic wetland forests store a large amount of organic matter in their pedosphere, and its decomposition plays a crucial role in regulating atmospheric carbon dioxide levels. However, few studies have examined the effects of small animals on litter decomposition, which represents the early stage of soil organic matter decomposition. In this study, we investigated the relationship between leaf litter decomposition and small animals, including aquatic invertebrates and soil fauna involved in the decomposition process, in a deciduous broad-leaved wetland forest in Hokkaido, Japan. The study was conducted in three different forest floor environments (n=5): (1) constantly flooded areas with spring water, (2) temporarily flooded areas due to snowmelt and rainwater, and (3) non-flooded areas. The litter decomposition rates were measured using the litter bag method with two mesh sizes (0.01 mm to allow only microorganisms and 2 mm to include both microorganisms and small animals) over approximately one year. The litter decomposition rate did not differ significantly among the three forest floor types. Similarly, the contributions of microorganisms and small animals to decomposition were not significantly different. However, the carbon and nitrogen contents of the remaining litter varied significantly among the three environments. Additionally, the abundance of small animals differed greatly across the forest floor types. These results suggest that while the overall litter decomposition rate remained similar across the three environments, the decomposition processes varied considerably. Our findings imply that each site optimizes the composition of small animals to facilitate efficient litter decomposition.

The Role of Spring Water in Kokanee Salmon Spawning Bed Formation

Yuki Yoshida, Yoshinori Minami, Tomoko Yoshikawa

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It is known that salmonid fish such as the kokanee salmon lay their eggs in spawning beds that form on the lake or riverbeds where groundwater seeps out. In lakes and marshes across Japan where kokanee salmon live, fishing restrictions are imposed during the spawning season to preserve the population, but no such measures exist in Lake Kussharo, where no fishing rights have been established. Therefore, this study aimed to investigate the environmental factors surrounding kokanee salmon spawning bed formation in Lake Kussharo and to explore conservation measures for the species during the spawning season.

The survey consisted of the following: 1) measuring the population and distribution range of spawning populations of kokanee salmon, 2) tracking changes in the number of spawning, 3) estimating the location of groundwater discharge based on temperature differences between the bottom sediment and lake water, 4) measurement of the amount of spring water using a seepage meter, and 5) analysis of the water quality.

During the spawning season in 2024, the spawning population was distributed in two main areas. The areas where spawning beds were found had relatively steep mountain slopes near the lakeshore. Although there was no significant change in the number of spawning beds in daily surveys, there was a tendency for the number to decrease on holidays compared to weekdays, which is thought to be due to pressure from fishermen trampling and collecting. In addition, the spawning beds were relatively concentrated in areas where the temperature of the bottom sediment was low, and they primarily located where groundwater selectively discharged. In terms of water quality analysis, the concentration of $NO_3^- + NO_2^-$-N in river water was approximately five times higher than in lake water and groundwater, indicating that most of the water in Lake Kussharo originates from groundwater.

Microbial Processes Driving Greenhouse Gas Emissions in Tropical Peatland Soils of Africa and South-America

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Tropical peatland ecosystems are critical carbon and nitrogen reservoirs, with microbial processes driving biogeochemical cycles that regulate greenhouse gas (GHG) emissions. In these ecosystems, complex interactions among microbial communities mediate soil methane (CH_4) and nitrous oxide (N_2O) fluxes, but yet the active mechanisms have remained poorly characterized. Here, we investigate the active microbial processes governing CH_4, N_2O, and dinitrogen (N_2) emissions in tropical peat soils.

Peat samples were collected from the 0–10 cm topsoil layer from various types of tropical peatlands (n = 34) across Peru, Congo, and Uganda. In-situ measurements of CH_4 and N_2O emissions, potential N_2 fluxes, and key physicochemical parameters were coupled with shotgun metagenomic analyses.

Our findings indicate that microbial dynamics varied significantly among peatlands from different countries and between open and forested environments. CH_4 emissions were recorded as the highest in Peruvian secondary peat swamp forest, corresponding to strongly increased functional potential of methanogen-associated genes compared to primary peat swamp forest. In Ugandan papyrus peat swamp, methanogens were abundant and active, yet methane oxidation markers were elevated during high water table. During severe droughts, Congo's peat swamp forests and grasslands exhibited the lowest overall microbial activity among others, corresponding with a high relative abundance of *Acidobacteriae* and *Ktedonobacteria* class, often predominant in nutrient-limited and stress conditions. Notably, the high abundance of archaeal nitrifiers was observed in this region and could be a key process driving N_2O emissions.

These results elucidate the intricate relationships between microbial functional dynamics and GHG emissions in tropical peatlands, enhancing our understanding of ecosystem responses to climatic shifts. These insights provide a framework for investigations into microbial ecology and its role in mitigating climate change.

Autotrophic Picoplankton Response to Eutrophication and Warming, a Shallow Lake Mesocosm Experiment

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Autotrophic picoplankton (cell size < 2-5 µm) plays an important role in aquatic systems, mainly in oceans. Its role in shallow freshwater ecosystems is less understood, especially regarding its response to eutrophication and the warming world.

The effects of eutrophication and temperature change in autotrophic picoplankton were investigated in a shallow lake mesocosm experiment in Lemming, Denmark. Mesocosms were separated to high nutrient treatment to simulate eutrophication and to low nutrient treatment without additional nutrients. Heating elements in some mesocosms simulated warmer climate scenarios: A2 (3 ºC higher than ambient), A2+ (4.5 ºC higher than ambient) and AMB (without heating elements). Picoplankton was measured in 2019 from May to August using high-performance liquid chromatography.

As expected, picoplankton biomass increased with eutrophication, but its proportion of total phytoplankton decreased as bigger cells have advantage in high nutrient environments. Meanwhile increased nutrient stress gives advantage to smaller cells and picoplankton proportion was higher in low nutrient mesocosms. Macrophyte competition for nutrients seemed to decrease picoplankton abundance even further. The highest temperature treatment mitigated the effect of eutrophication as stronger effects of eutrophication were measured in A2 mesocosms.

Microbial Methane and Nitrogen Cycle in Tropical Peatland Forests and Grasslands of Congo Basin

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Tropical peatlands are regions with high carbon density, remarkable biodiversity, and provide a series of important ecosystem services. The Congo Basin harbors the world's largest contiguous tropical peatlands. However, these peatlands are increasingly threatened by climate change and human activities. This study focuses on tropical peatland forests and grasslands in the Congo Basin, aiming to explore microbial carbon (methane) and nitrogen cycling processes in these two ecosystems.

This research was conducted in March 2024 near the village of Epena, in the northeastern part of the Republic of the Congo. Soil samples were collected from peatland forests and peatland grasslands at two depths: 0-10 and 10-20 cm. Quantitative polymerase chain reaction (qPCR) was used to analyze the abundance of bacterial and archaeal communities, as well as functional genes related to carbon and nitrogen cycles.

The main findings of this study are as follows:

1) The nitrous oxide (N_2O) flux in peatland forests was significantly higher than in peatland grasslands.

2) There were notable differences in the numerical ranges of different genes across sites, indicating substantial disparities in gene abundance or expression levels between the two ecosystems.

3) Some abundances of genes exhibited strong positive correlation. For example, all genes regulating the denitrification process, the abundances of *nirK*, *nirS*, *nosZI*, and *nosZII* genes, showed relatively high correlations, suggesting complete denitrification.

4) Certain physicochemical indicators, such as pH, magnesium (Mg), and potassium (K), were negatively correlated with the abundance of genes, suggesting they may have an inhibitory effect on the activity of these functional genes.

Drainage Influence on Soil and Vegetation Biodiversity in Black Alder Swamp Forests

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Due to its diverse microtopography and microhabitats, black alder swamp forests represent the most species-rich forest type within the hemiboreal zone. However, this forest type is now considered threatened across Europe. Drainage significantly alters soil chemical properties and abiotic conditions, making the habitat unsuitable for specialized species. While plant biodiversity in black alder forests has been studied in this region, research on soil fauna diversity remains limited. Until recently, biodiversity studies have primarily focused on vegetation, as well as microbial and fungal diversity, with less emphasis on the ecological role of soil invertebrates.

Given previous findings indicating correlations between the biodiversity of different trophic groups, we hypothesize that plant biodiversity patterns in alder forests under varying drainage intensities will align with those of soil fauna species adapted to this habitat. This study examines how forest drainage influences the relationship between plant and soil invertebrate biodiversity.

We selected three study sites in central Latvia, representing low, moderate, and intensive drainage conditions. Within each site, ten sampling plots were established to assess soil biodiversity parameters, including mesofauna and macrofauna, as well as vegetation cover and species composition. The results indicate that the highest abundance and diversity of soil invertebrates were observed in areas with the high moisture regime characteristic of black alder swamp forests. However, as water levels decreased, habitat suitability declined. While overall invertebrate diversity increased with drainage, earthworm diversity exhibited an opposite trend compared to other macrofauna groups. Vegetation diversity and the presence of wetland specialist species followed a similar trend to macrofauna, increasing as drainage impact decreased.

The Current Status of Moss Balls and the Growth Conditions of Aquatic Bryophytes in Lake Kussharo, Northern Japan

Yoshi Minami, Tomoko Yoshikawa

Tamagawa University, Tokyo, Japan

Lake Kussharo is a caldera lake located at the headwaters of Kushiro Marsh, the largest Ramsar Convention wetland in eastern Hokkaido, Japan. Moss balls primarily consist of bryophyte species that grow near the water's surface or within lakes. The moss balls in Lake Kussharo are among the most well-known. However, in recent years, concerns have arisen regarding their endangerment due to water pollution and the impact of pleasure boats on the lake-bottom environment. Although the local government has designated the moss balls as a Natural Monument of the town, detailed research has not been conducted in the past five decades. The purpose of this study was to contribute to habitat conservation by investigating the distribution and environmental conditions of the moss balls and their constituent species. We also examined the distribution of bryophyte species within the lake-bottom community.

The survey was conducted using an unmanned aerial vehicle to determine the distribution of aquatic plants. Moss balls and drift materials were collected, and their constituent species were identified. Water quality (nitrogen and phosphorus), as well as temperature, and surface water flow were measured.

Our findings indicate that the bryophyte community at the bottom of the lake forms in areas with abundant substrates, such as rocks and coarse woody debris, which facilitate plant growth. The distribution of moss balls has declined over the past five decades, and changes in their constituent species have also been observed compared to past records. Given that the decline of moss balls is associated with environmental changes. The exact reasons for this are unclear, but the marked changes in species composition are assumed to be due to alterations in the aquatic environment, particularly the spring water from the lake bottom. Further detailed research on the bryophyte composition and surrounding conditions in moss ball habitats is essential.

Session 5:
Tropical wetlands

30 June
18:35-20:00

Seasonal Variation in Mound Shape of *Thalassina Anomala* Within a Subtropical Mangrove Forest, Southern Japan

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Thalassina anomala is a mud shrimp that excavates soil sediments to form mounds nearly 1 m high in mangrove forests. The associated soil disturbance and microtopographic changes may influence organic matter cycling and mangrove forest dynamics. However, little is known about its ecological characteristics and seasonal variations in excavation activity. This study investigates the distribution and shape variation of mounds in relation to the ecological characteristics of *T. anomala* within a subtropical mangrove forest, southern Japan. The study was conducted in a mangrove forest dominated by *Bruguiera gymnorhiza* and *Rhizophora stylosa* in the Gabulmata River basin on Ishigaki Island, Okinawa. Mound distribution was surveyed across three areas (downstream, midstream, and upstream) at varying distances from the estuary. Mound shape was monitored every three months for one year using time-lapse cameras and drone imagery. The number and size of mounds increased from downstream toward upstream. *T. anomala* exhibited high excavation activity in response to tidal fluctuations, primarily during nighttime, leading to mound enlargement. Conversely, mound submersion due to tidal fluctuations caused partial collapse and a reduction in mound size. These effects varied significantly across seasons. These results suggest that *T. anomala* transports deeper soil sediments to the surface, contributing to sediment disturbance and microtopographic changes. On the other hand, tidal influence promotes greater mound erosion in estuarine areas. This implies that excavation activity has distinct impacts on matter cycling between estuarine and upstream regions, potentially affecting mangrove forest stability and regeneration.

Detection of Forest Structure and Dynamics Using an Unmanned Aerial Vehicle in a Subtropical Mangrove Forest

Mitsutoshi Tomotsune, Seikoh Sekikawa, Tomoko Yoshikawa

Tamagawa University, Tokyo, Japan

Mangrove forests play a crucial role in atmospheric carbon cycling and contribute organic matter to the hydrosphere in tropical and subtropical coastal regions. However, monitoring mangrove forest structure and detecting dynamic changes over time remain challenging due to their complex canopy and limited accessibility. This study aimed to assess mangrove forest structure (canopy coverage, species composition, and stand density) and dynamics (changes in canopy cover and gap formation) using aerial imagery captured by an unmanned aerial vehicle (UAV) in the Fukido River basin on Ishigaki Island, Okinawa. The mangrove canopy was clearly distinguishable from other evergreen vegetation based on differences in shape, color, and size, allowing for precise calculations of forest coverage. Two dominant mangrove species, *Bruguiera gymnorhiza* and *Rhizophora mucronata*, were identified based on crown characteristics. Stand density estimates derived from UAV imagery were approximately 10% lower than actual values obtained from field surveys, likely due to limitations in detecting young and small trees beneath the canopy. Observations along the forest margin revealed no young or dead trees, suggesting that the forest structure has remained stable over the past five years. However, three distinct types of canopy gaps were identified, likely caused by lightning strikes, sediment accumulation on the forest floor, and typhoons. These findings demonstrate that UAV-based aerial imagery is a valuable tool for detecting mangrove forest structure and monitoring its dynamics. Furthermore, the observed changes suggest that the dynamics of the mangrove forest may be affected by the characteristics of coastal environments in tropical and subtropical regions.

Links Between Greenhouse Gas Cycling, Nitrogen Fixation and Microbiomes Within the Canopies of Tropical Trees in the Peruvian Amazon Wetlands

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Tropical wetland forests are significant carbon reservoirs, which can serve as both sinks and sources for the greenhouse gases methane (CH_4) and nitrous oxide (N_2O). Despite the importance of these ecosystems, and their vulnerability to the climate change, they are relatively poorly described. One component, the tropical trees, is particularly understudied, although these plants may play a role in the CH_4 and N_2O cycles via multiple recently discovered mechanisms.

We focused on the tree canopies and explored the greenhouse gas cycling dynamics on two peat swamp forest sites in the Amazon (Iquitos, Peru): a natural protected palm swamp reserve, Quistococha, and as a reference, Zungarococha, a secondary peatland forest. Two campaign trips took place in November 2023, and in May 2024. Experiments included branches/leaves from 3-4 tree species. Potential CH_4 and N_2O production and/or oxidation was evaluated on site in an aerobic, 48-h bottle incubation with daily gas sampling to GC-vials (analyzed in Helsinki, Finland). In addition, nitrogen fixation was tested via 15N-isotope labeling (72 h, 12-ml vials). From the same branches/leaves, samples were collected for a metagenomic analysis of the epi-/endophytic microbiomes.

Preliminary incubation results showed distinct gas exchange patterns from the two sites: small but significant emissions of N_2O in Quistococha and emissions of CH_4 in Zungarococha. Variability was high between the tree species, but also within the same species between the sites. Nitrogen fixation was active in three of the four tree species tested. Microbiome analyses are still in progress.

This study will give valuable information on the potential role of tropical tree canopies in the cycling of CH_4 and N_2O. Analysis of the tree microbiomes will likely reveal novel microbial groups responsible for the related processes, and even for other functions imperative to the ecology of tropical ecosystems.

Comparative Assessment of Soil Properties and Isotopic Signatures in Rainforest and Oil Palm Plantation on Tropical Peatland

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Despite the importance of tropical peatlands as globally significant ecosystems for carbon storage and nutrient cycling, widespread drainage and conversion to oil palm plantations have raised critical concerns. This study presents a comparative assessment of soil physico-chemical properties, microbial N-cycling gene abundance, nitrous oxide (N_2O) fluxes, and nutrient dynamics in a rainforest and an oil palm plantation on tropical peatland in Sarawak, Malaysia. A total of 24 sites were established: 12 within four forest transects comprising four different forest communities (Mixed Peat Swamp [MPS], Alan Batu [AB], Alan Bunga [ABA], and Padang Alan [PA]) across a peat dome with its natural hydrological gradient, and 12 within three transects in an oil palm plantation. Key parameters analyzed included soil moisture, C:N, nitrate (NO_3^-) and ammonium (NH_4^+) concentrations, N_2O fluxes, and abundance of microbial nitrogen-cycling genes. ^{15}N isotope signatures in foliage and soil were also analyzed to infer nitrogen cycling processes such as mineralization, leaching, and gaseous losses. Preliminary results showed that oil palm sites had significantly an order of magnitude higher NO_3 concentrations than forest soils, which is probably due to the input of fertilizers. In contrast, the forest soils had a higher NH_4^+:NO_3^- ratio and consistently higher moisture contents, indicating more anaerobic conditions. Soil C:N tended to increase along the forest gradient (MPS>AB>ABA>PA), reflecting differences in organic matter composition and decomposition rates. Among the forest sites, MPS had the highest nutrient concentrations, probably due to lower elevation and potential nutrient accumulation. Anticipated $\delta^{15}N$ isotope data may reveal differences in nitrogen dynamics between forest and plantation sites, indicating different nitrogen transformation and loss pathways. Such an integrated assessment highlights the profound impact of land-use change on peat soil and nitrogen cycling and provides insights into sustainable management and restoration of peatland ecosystems.

Iron-Polyphenol Complexes from Mangrove Sediments Promote the Growth of Zooxanthellae

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To clarify the effect of iron-polyphenol complex eluted from the mangrove sediments to coastal sea on the growth of zooxanthellae, photosynthetic marine organisms, that is able to live in symbiosis with marine invertebrates such as coral, the effects of the iron-polyphenol complex made from water-soluble phenolic compounds extracted from two mangrove species leaves (*Rhizophora stylosa* and *Bruguiera gymnorhiza*) and ferric chloride on the growth of three species of zooxanthellae (*Symbiodinium* sp., *Breviolum minutum*, and *Effrenium voratum*) were tested. The contribution of the iron(III) complexes to the growth of each zooxanthellae was evaluated by measuring the iron use efficiency by calculating the amount of 1 mmol iron and phosphorus fixed per day (P mol/1mmol Fe/day), as well as the growth rate. As the results,it was indicated that the iron(III)-polyphenol complex contributes significantly to the growth and iron utilization of the two zooxanthellae species (*B. minutum* and *E. voratum*).

Session 6:
Use of wetland ecosystems

3 July
18:15-20:00

Local Cooling Effect of an Artificial Buffer Wetland Estimated by Satellite Land Surface Temperature

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Artificial Buffer Wetlands (ABW), such as the Rampillon's in France, are effective Nature-Based Solutions (NBS) for mitigating the impacts of climate change, particularly by reducing local land surface temperatures (LST). As part of Alfawetlands HORIZON project (www.alfawetlands.Eu) ABW of Rampillon is monitored to assess water quality improvement, biodiversity refuge and Green House Gases emissions. This study assesses the cooling effect of the Rampillon ABW during summer periods, using satellite-based LST data –Landsat 7 and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)– alongside in situ temperature measurements. The results show a significant temperature reduction, with a maximum cooling effect of 5.43°C (-13.7% variation) within a 100-meter radius of the Rampillon's ABW. This localized cooling is most significant during the hottest months, suggesting that artificial wetlands can behave as thermal buffers in agricultural landscapes. However, the cooling effect decreases with distance, becoming less pronounced beyond a 500-meter radius, likely due to surrounding agricultural activities.

In this study, a +1.25 °C increase in air temperature and a -4.7% decrease in relative humidity was also observed during the July-September period over the 25-year time span, which highlights the growing risk of heat stress in the region in the climate change context. Overall, this study reaffirms the potential of artificial wetlands as valuable tools for climate adaptation in agricultural areas.

Rewetting Peatlands: Carbon Farming on Organic Soils

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Peatland is an area of land with a naturally accumulated peat layer on its surface. Peat is a sedentarily accumulated material consisting of at least 30% (dry mass) of dead organic material. Organic soils are soils with a high carbon density, holding near-surface carbon and nitrogen stocks with a high emission potential for CO_2 and other greenhouse gases. While peatlands are distributed across all European countries, the majority concentrated in the northern regions. When they are drained, they become strong CO_2 emitters. This is what happens when degradation of organic soils continues. Peatlands are drained for agriculture and other purposes. Average soil emissions from arable lands on drained peatlands is 40t CO_2 eq/ha/y. The deeper the drainage, the higher are emissions. Every 10 cm decrease in the depth results in an additional 5 t CO_2 eq/ha/y. The solution could be rewetting. These degraded areas could still continue to be productively cultivated but in permanently wet conditions. Such paludicultures bring various possibilities, for example cultivation of reed, cattail, peat mosses, growing water buffaloes. Most importantly rewetting organic soils stops CO_2 emissions.

Scoping the Impacts of Paludiculture on the Natural Environment

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Paludiculture – the productive land use of wet and rewetted peatlands – is gaining traction as a land use option that can extend the commercial life of drained lowland peatlands while simultaneously reducing greenhouse gas emissions. To inform land use decisions and management, it is important to understand how paludiculture affects the wider natural environment, but this aspect tends to be relatively overlooked.

Through a combination of literature reviews, interviews and a workshop, we carried out a scoping exercise to identify: (a) observed and potential impacts of paludiculture on the natural environment, specifically soils, hydrology, water quality, and landscape character and heritage, and (b) management options to minimise negative and maximise positive impacts. We focused on lowland peat landscapes in England, but many of the ideas will be applicable to other geographies.

This poster highlights the mixed effects paludiculture can have on the natural environment, depending on the outcome considered and precisely how it is implemented. Many intrinsic features of paludiculture could lead to desirable or undesirable impacts, depending on the context.

For example, a high water table could preserve peat, conserve or create wetland habitats, and hydrologically buffer existing wetlands. But rewetting could flood valuable dry habitats. The impacts of rewetting on soil and water chemistry are heavily dependent on how it is carried out, site history, and the time horizon. New paludiculture crops can contribute to habitat and resource diversity, remediate soil and water pollution, and preserve or restore cultural values, but could diminish landscape character. Paludiculture will likely have telecoupled impacts through displacement of food production and increased domestic production of certain crops.

We encourage further research to fully understand the risks to the natural environment, both positive and negative, associated with paludiculture. Our full scoping report highlights some specific open research questions and knowledge gaps.

Session 7:
Wetland restoration

3 July
18:15-20:00

Research on the Varied Development of Historically Abandoned Peat Extraction Sites in Latvia

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Since the early 20th century peat has been a significant resource for agriculture and energy production in Latvia. However, peat extraction experienced a decline in the 1990s leading to the abandonment of numerous areas where remaining layers predominantly consisted of fen-type peat. In the following years natural self-renewal processes have occurred in several abandoned areas, although many continue to be classified as degraded.

Research was done as part of project "Development of proposals for the creation of protected nature areas and the restoration of habitats in degraded peatlands". It involved a comprehensive assessment of 31 abandoned historical peat extraction site conditions using field studies, cartographic evaluation and remote sensing.

Thirteen scenarios for post-extraction development of these areas were identified. In certain territories, particularly in quarries, self-renewal processes have been notably successful. The conformity of these areas with EU protected habitats was evaluated revealing that 25% of surveyed territories met criteria. The most prevalent outcome of self-renaturalization is the formation of reed beds, observed in 33% of the sites, specifically in 15 peatlands characterised by wet or periodically overflowing conditions. Biologically valuable species-rich grass fens which are significant both as habitats and for CO_2 accumulation were identified. Potential renewal and peat formation processes were not observed in the abandoned peat milling fields, which constitute around 10% of the sites and exhibit variable hydrological regimes. Most water bodies at historical peat extraction sites can be regarded as part of the natural succession of peatland development and, therefore, should not be classified as degraded areas.

Many areas that have undergone renaturalization or other forms of restoration have been classified as degraded. Therefore, it is imperative to develop uniform criteria that can determine whether an area is degraded in accordance with both expert opinions and political documents.

Comparing Wetland Placement Land Use Scenarios for Streamflow Dynamics Agricultural Catchment Using SWAT+

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Wetlands play crucial role in regulating the hydrology of catchments, influencing water levels, streamflow, and overall ecosystem health. Furthermore, wetlands have a significant capacity to reduce agricultural nutrient runoff, acting as natural filters that remove excess nitrogen and phosphorus from water before it enters downstream ecosystems. Despite their significance, wetlands are often overlooked in hydrological studies aimed at estimating water balance components. While various approaches, including in-situ measurements, laboratory experiments, and hydrological models, have been employed to study wetland impacts on streamflow, many are limited in spatial scope. Process-based hydrological models offer considerable potential to assess wetland effects at larger spatial scales, including the evaluation of their nutrient retention capabilities and the impact on downstream water quality.

We aim to quantify the effect of wetland inclusion on streamflow dynamics, providing valuable insights for future catchment restoration efforts. We utilize the SWAT+ model, a well-established tool capable of incorporating wetlands as distinct spatial units, to evaluate the impact of wetland placement in Porijõgi catchment, Estonia on streamflow. The model uses Digital Elevation Model (DEM), soil data, land use, climate data, and flow measurements. The modelling system will be applied on 24,153.12 ha catchment, which is subdivided into 37 subbasins, 325 channels, 649 landscape units (LSUs), and 2,157 Hydrologic Response Units (HRUs). For wetland placement land use scenarios, we used geospatial analysis-based suitability analysis to find potential suitable locations for wetland placement. We test two alternative scenarios: (1) numerous small wetlands distributed across the upper catchment and (2) a single large wetland located downstream. These scenarios were compared against a baseline scenario that is the current land use.

The findings will help inform strategies for optimizing wetland restoration to enhance hydrological resilience in the region.

Insect Biodiversity as a Bioindicator for Conservation and Restoration Management in Mediterranean Peatlands

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Wetlands fragile ecosystems are threatened by land-use change, pollution, and the advance of invasive species, thus requiring pressing conservation and restoration action. To study the impacts of these factors, we focused our study on a recently designated local nature reserve, a lowland peatland in Alpiarça, Portugal. Our research interest was focused on studying the impact of several management practices on butterfly and carabid populations and community to contribute to design the reserve management plan. Using groups as bioindicators, we assessed habitat health and diversity in five habitats of the nature reserve with different degrees of human intervention and agricultural practices. For butterfly populations, 30 minutes randomized free-walking transects were used, while for the carabids, 10 sampling points were installed with 10 pitfalls distanced at least 2.5m. Biodiversity indices (Shannon and Simpson) revealed significant inter-habitat variability. Open, managed areas (e.g., Horse Pasture and extensive cattle-grazed Wetlands) exhibited higher diversity (Shannon: 0.060, 0.051; Simpson: 0.76, 0.78, respectively) when compared to less disturbed sites. The habitat used for monoculture of ryegrass cultivation, and the habitat inside of the Wetland revealed lower diversity (Shannon: 0.033; Simpson: 0.46 and 0.45, respectively). Our findings diverge from extant literature on European wetland butterfly communities, which typically report higher biodiversity in hydrologically stable habitats. This discrepancy may be due to the lack of specialists in peatland on the Iberian butterfly fauna. Notably, restored habitats demonstrated elevated α- and β-diversity relative to non-restored areas and were close to the two habitats up mentioned. Nevertheless, the maintenance of this mosaic of habitats seems to increase the presence of abundance and promote ecosystem services locally. Our findings underscore the importance of habitat heterogeneity and effective management practices in maintaining local

insect biodiversity within Mediterranean wetlands, contributing to EU Nature Restoration Law promoting sustainable land-use practices in these vital and understudied ecosystems.

New Coastal Lagoons, New Carbon Fluxes: Insights from Two Recently Created Mediterranean Coastal Lagoons

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Natural coastal ecosystems play a crucial role in biogeochemical cycles, particularly in the carbon cycle, functioning as important carbon sinks. However, they are among the most degraded ecosystems. While creating new coastal wetlands could help restore this function, carbon fluxes in these newly created ecosystems remain unexplored. Our goal was to quantify carbon gas fluxes and identify key factors driving their variability from these newly created coastal lagoons. We selected two coastal lagoons created in 2017 in the Mediterranean basin (Tarragona, NE of the Iberian Peninsula). We measured monthly fluxes of carbon dioxide (CO_2) and methane (CH_4) in both lagoons from February 2023 to February 2024. The lagoons differed significantly in their physico-chemical and biological characteristics, primarily due to differences in confinement and seawater exchange during storms. CO_2 and CH_4 fluxes were considerably higher in the more confined lagoon, which had lower conductivity and high macrophyte coverage, compared to the more connected lagoon, characterized by higher conductivity and phytoplankton dominance (EC = 7.7 ± 0.5 and 24.5 ± 8.2 mS cm^{-1}, respectively). Both lagoons were net carbon sources to the atmosphere throughout most of the study period. Peak fluxes for both CO_2 and CH_4 occurred in September, when water temperature was highest. However, CO_2 uptake periods varied between lagoons. The macrophyte-dominated lagoon absorbed CO_2 in spring, while the phytoplankton-dominated lagoon showed CO_2 uptake in winter. CH_4 emissions in the macrophyte lagoon were an order of magnitude higher than in the phytoplankton-dominated lagoon, particularly during the warmer months (July to September). Our study sheds light on the carbon dynamics in shallow newly created coastal lagoons and emphasizes the crucial role of hydrology in the carbon budget of these ecosystems.

Session 8:
Wetlands monitoring

3 July
18:15-20:00

Assessing SAR-Derived Water Table Estimates in Forested Peatlands: A Case Study from Red Bog, Lithuania

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The hydrological regime is the driving force behind raised bogs, as it controls peat accumulation and ecosystem stability. A key aspect of this regime is the dynamics of the water table, which is directly linked to water table depth (WTD). This, in turn, affects peat decomposition, carbon storage, and vegetation composition. While WTD measurements are typically taken in situ, studies in peatlands often face challenges due to factors like size, complex topography, hydrological characteristics, and dense vegetation cover. To address these limitations, remote sensing techniques, particularly Synthetic Aperture Radar (SAR), can provide a solution for large-scale WTD monitoring.

Research shows that in situ water table measurements in open, treeless raised bogs shows a relatively strong correlation with SAR-derived estimates. However, there has been limited research on the relationship between in situ and SAR data in forested peatlands, where vegetation may interfere with remote sensing signals. To fill this gap, in situ water level data collection began in the Raudonoji bala peatland in Lithuania during the 2024 vegetation period. This study aims to assess the correlation between SAR-derived data and in situ water table measurements in a forested peatland environment.

The correlation between VV and VH polarization SAR images and in situ data demonstrates varying strengths across different measurement points. In some locations, particularly in more open areas, VH polarization showed a stronger relationship than VV polarization.

Further data processing and analysis are needed to enhance the accuracy of hydrological regime assessments in forested peatlands. The interaction of SAR signals with vegetation can distort reflectance values, making it necessary to apply data filtering and correction methods, such as noise reduction and minimizing vegetation impact. Additionally, analyzing the spatial relationships between different well locations and environmental parameters can provide better insights into the distribution of water level fluctuations across the area.

Bias Reduction for Airborne LiDAR Derived Elevation Models in Wetland Ecosystems

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Flow of water, water depth, and inundation times are important variables for understanding ecological processes in wetlands. Ecological models often require high-accuracy elevation information at resolutions that capture landscape features that drive biotic and physical processes at the scales at which they interact. Digital terrain models (DTM) derived from airborne LiDAR data are regarded as the most accurate data, however, in densely vegetated and partially inundated wetland terrain they exhibit high and variable error due to attenuation in the plant canopy and water column.

We developed a modeling framework that estimates and reduces bias in LiDAR-derived DTMs. Bias was estimated by subtracting the lowest LiDAR return within 2m grid cells from kinematic GNSS elevation surveys (accuracy ~ 2 cm) at 73,055 locations within Florida Everglades National Park marsh and prairie ecosystems. Elevation bias was then modeled as a function of vegetation-induced point cloud distribution metrics and applied to the entire study area. An independent accuracy assessment for 893 randomly sampled locations within the 3,320 km^2 study area estimated an overall root mean square error (RMSE) of 21 cm for the non-adjusted DTM with a relative root square error (RRSE) of 31.5%. The RMSE of the bias-adjusted DTM was 8 cm with an RRSE of 12.3%. This bias reduction of 13 cm is a substantial improvement for elevations in a wetland environment. The largest reduction in RMSE (24 cm) and RRSE (58%) was observed for dense tall graminoid species (mostly *Cladium* and *Typha*). Despite an 87% reduction in relative absolute error (RAE) this vegetation type still had the largest remaining RMSE of 12 cm (RRSE ~ 30%). Bias-adjusted DTMs deliver much improved high-resolution elevation information, and consequently, more accurate location-specific inundation depth and dry period estimates, supporting the decision-making processes in wetland management and restoration.

Distribution of Peatlands in the European Union – Data Acquisition and Harmonization

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Peatlands are one of the fastest-declining ecosystems in the world. The issue of their protection and restoration is raised in both international and national policies. Drained peatlands emit greenhouse gases (GHGs), accounting for around 4% of global emissions and 5% in the European Union. Preventing further degradation of these ecosystems requires hydrological stabilization, which ensures suitable conditions for peat accumulation. Nevertheless, these actions must be preceded by the delineation of peatlands, their characterization, and status assessment. Harmonizing datasets on European peatlands will improve the protection and management of organic soils, including the sustainable use of peatlands. The research team of the Faculty of Civil Engineering and Environmental Sciences of Bialystok University of Technology coordinates this task as part of the Europe-LAND project.

This presentation will provide an overview of databases obtained on peatlands' distribution in European Union member states. It includes an introduction to peatland terminology and an indication of discrepancies in defining these ecosystems. It also compares national datasets on peatland coverage with two international datasets – the European Soil Database (ESDB) and CORINE Land Cover (CLC). We found that the distribution of peatlands based on EU-wide datasets is inaccurate and generalized. Thus, their area may be at least 30% smaller than the area presented in national databases. Using the ESDB and CLC for resource characterization, threat assessment, and wetland conservation planning would involve a significant error. It is also unreliable for estimating greenhouse gas emissions, which is the final stage of our team's task under the Europe-LAND project.

Session 9:
Peatlands

3 July
18:15-20:00

Can-Peat: Canada's Peatlands as Nature-Based Climate Solutions

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Canadian peatlands and their function as carbon (C) sinks are under threat of permafrost thaw, wildfire, and anthropogenic disturbances such as mining, drainage for agriculture and forestry, urban development, and peat extraction. Managing and protecting peatlands from these disturbances may greatly reduce greenhouse gas emissions (GHG) in Canada. However, there are uncertainties in peatland GHG emissions and removal estimates and research gaps in C stock mapping, and disturbance regimes. The Can-Peat project aims to address these uncertainties and gaps to determine the potential of peatland management as a nature-based solution to climate change. The Can-Peat project is a 5-year long project that started in 2022 and is funded in part by the Government of Canada's Environmental Damages Fund. Administered by Environment and Climate Change Canada, the project represents an over $7 million partnership between academics, governments, environmental non-governmental organizations and private enterprise to advance peatland knowledge in Canada. Can-Peat includes multiple research activities led by internationally recognized Canadian experts in peatland sciences working together to support the building of a sustainable net-zero emissions economy by 2050. The specific goals of Can-Peat are to (1) create a Canadian peatland research network, (2) compile a peatland C database, (3) advance models of peatland C cycling and use these models to evaluate future peatland GHG uptake or emission, (4) investigate mechanisms to implement peatland nature-based solutions in Canada and develop a decision-support framework for peatland management, and (5) communicate findings to partners and provide the tools needed for climate-friendly peatland management and GHG emission reporting.

Two Decades of Phenological and Meteorological Observations in a Pristine Boreal Peatland, Siikaneva Fen, Reveal Increasing Leaf Area

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Boreal peatlands provide extensive carbon (C) uptake and storage capacity, stabilizing the climate system. However, global change threatens this function. As vascular plants regulate the peatland C cycle, understanding their responses to climate change is vital. Experimental and palaeoecological studies reveal that warming and drying alter vegetation and C cycling. With this study we address the lack of *in situ*, long-term assessments of these dynamics by examining ongoing change in leaf area phenology in a boreal peatland.

We combined two decades of automated *in situ* observations (meteorology) and field measurements (leaf area index, LAI and water table depth, WT) from Siikaneva fen, central Finland. To identify long-term ecosystem changes (total and plant group specific LAI, temperature, Ta; vapor pressure deficit, VPD; photosynthetically active radiation, PAR; and WT) we applied trend analysis. To quantify the role of different variables for annual LAI development we used non-linear mixed effects modeling.

The study revealed increasing LAI, especially maximum LAI, that was achieved earlier in a slightly shorter peak vegetation season. We also observed rising Ta, declining WT, and decreasing VPD, with no significant PAR changes during the growing seasons. Most plant groups benefited from changing conditions, except ombrotrophic Sedges, which declined. Current-year weather explained much of the LAI variability, as did cumulative LAI conditions from the early or previous growing season. While Ta, PAR, and WT were key LAI drivers, the negative VPD trend and its strong influence on LAI were unexpected.

Significant alterations in LAI, plant group composition and local meteorology point out ongoing changes in vegetation and its phenology, with functional implications. To better understand potential implications for large-scale earth system dynamics, cycling of C, water and energy in response to the identified ecosystem dynamics should be further studied.

Carbon Certification and Paludiculture: Assessing the Baseline for Greenhouse Gas Mitigation in a Drained Peatland

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Voluntary carbon markets provide opportunities for private companies, public institutions, and individuals to develop CO_2 removal projects in peatlands, reducing their overall carbon footprint. However, effective implementation requires alignment with appropriate rewetting targets. Establishing a baseline assessment of the peatland's condition is crucial for informed decision-making.

This study follows carbon certification program standards, specifically the Verified Carbon Standard (VCS) and MoorFutures® methodologies, to assess reference conditions in a drained peatland targeted for paludiculture and carbon credit certification. A 16.4 ha extracted peatland in Latvia was selected as a case study to quantify greenhouse gas (GHG) emissions and evaluate potential mitigation measures. We conducted a baseline evaluation, including peat thickness mapping, groundwater monitoring, water chemistry analysis, vegetation classification using the Greenhouse Gas Emission Site Type (GEST) approach, and photogrammetry-based land cover assessment.

Our results indicate that restoring the site through rewetting and paludiculture could prevent 60.17 t CO_2 emissions annually while capturing 80.31–120.11 t CO_2 per year. Continued drainage poses a significant risk, potentially releasing 52,653.64 t CO_2 from residual peat deposits over time. Hydrological monitoring revealed substantial groundwater fluctuations, reinforcing the need for targeted water management strategies to optimize carbon sequestration potential.

This study demonstrates that rewetting and paludiculture can be implemented without large-scale EU funding when both conservation and economic interests align. Such efforts represent a practical climate mitigation strategy by transforming degraded peatlands into carbon sinks while maintaining economic viability.

This project is supported by SIA "Mikrotīkls" through a donation administered by the University of Latvia Foundation.

CH_4 Production and Oxidation Potentials in a Boreal Drained Peatland Forest

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The fertile forestry-drained peatland soils act as sources of carbon to the atmosphere. This is because the low water table level (WTL) enhances the surface peat decomposition, leading to high CO_2 emissions. Also, the oxidation of methane (CH_4) in oxic peat layers causes CO_2 emissions. Rewetting (by ditch blocking), however, elevates WTL and increases CH_4 emissions. CH_4 oxidation and production rates vary along the soil profile and are affected by several environmental factors, such as WTL. It is still not fully understood, how these processes are affected by rewetting in different peatland soils.

A fertile peatland forest in Southern Finland was rewetted in 2024. With various measurements, such as by using the eddy covariance technique, closed chambers and soil incubation experiments, we investigate how rewetting affects greenhouse gas (GHG) fluxes both at the ecosystem and at the soil level. Here, we focus on the soil incubation experiment we conducted before rewetting (summer 2022), and will repeat after rewetting (summer 2025). First, we took peat samples and divided them in several depths: 10-60 cm for CH_4 oxidation, and 10-75 cm for CH_4 production experiment. Then, the peat was extracted into production (anoxic conditions) and oxidation (oxic conditions with 10 000 ppm CH_4 for targeting low-affinity oxidation) bottles. The gas samples were taken regularly during the experiment and analysed with a gas chromatography system (Agilent Technologies 7890B GC System).

In 2022, the CH_4 oxidation potentials were on average 114–254 nmol g^{-1} h^{-1} and CH_4 production potentials 0–0.63 nmol g^{-1} h^{-1}. CH_4 oxidation potential was highest close to the surface, and close to the WTL. CH_4 production potential was highest in the deepest layers. We expect that the next experiment during the summer 2025 will shed light on the early effect of rewetting on the CH_4 oxidation and production rates.

Greenhouse Gas Emissions on Peat Extraction Impacted Areas in Hemiboreal Region

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Hemiboreal region has vast peatland areas, many of those are affected by forestry drainage and agriculture, but in smaller extent also peat extraction. Although the spatial coverage of peat extraction sites in the region is minuscule, the region is an important provider of horticultural peat to the global market. The study aimed to estimate greenhouse gas fluxes on near-natural or excavated peatlands in different stages (excavated, abandoned, various types of after-use (afforestation, agriculture, grasslands, bioenergy crop and berry cultivation, rewetting, restoration with moss-layer-transfer technique)) in hemiboreal region based on meta-analysis.

The global database was compiled during the summer of 2023 including 951 items from which 10% satisfied the quality and climate criteria. The data was homogenized to same units and different site and year combinations were extracted for quantitative analysis and grouped into land-uses. Also, LULUCF Wetland category emissions in National Inventory Reports in relevant region are analyzed and summarized and used for comparison purposes.

Our meta-analysis results generally support the Tier 1 data of IPCC Wetland supplement, whereas some variations occurred. CH_4 emissions were generally larger with higher temperatures and annual precipitation, N_2O emissions in reverse decreased in such conditions. There were no significant correlations between annual climate conditions and the CO_2 fluxes. The data availability is heterogeneous between the countries, land-use types, and measurement methods in hemiboreal region. The data is available for the peat extraction sites, abandoned extraction sites, and rewetted sites but for many other after-use options the published greenhouse gas measurement data are scarce in the region. The abandoned peat extraction sites have the highest greenhouse gas emissions in CO_2 equivalents, even larger than from active extraction sites. The available data supports the prompt restoration actions after the end of the peat extraction to mitigate the climate impacts of this economic sector.

Spatially-Explicit Marginal Abatement Cost Curves for Developing Cost-Effective Peatland Restoration Pathways

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Restoring degraded peatlands back to their (near) natural conditions, while identifying new ways of increasing their environmental and economic benefits is becoming both a necessary action to address the climate emergency and a political priority. The restoration efforts are often complex projects consisting of several phases and require application of a combination of measures that bring on substantial implementation, opportunity, and maintenance costs. Understanding the distribution and drivers of variation in these costs is critical in determining the feasibility and appropriateness of future restoration efforts and post-restoration use. The marginal abatement cost curves (MACC) are frequently used to produce an applicable cost-effectiveness rank of available and relevant abatement measures in context of their total abatement potential, aimed at maximising value for money. In the case of peatland restoration, a set of site-specific environmental, economic, and technical conditions drive the choice, as well as the total cost and abatement potential of selected measures. The applied measures need to work in accord in order to deliver the desired results. For these reasons, a novel method for constructing a MACC is developed, with a focus on the underlying conditions that drive the variation of restoration costs. Applying this approach to a case study in Scotland, a clustering algorithm was used to create a discrete set of condition groups, for each of which cost-effectiveness values (in terms of cost per unit abated) were calculated. Further, a spatial model for determining the allocation of all degraded peatland into the condition clusters was applied. The results show a distribution of both costs and abatement potentials for restoring all the peatlands in each cluster, and thus allow for scenario modelling of future potential restoration pathways with focus on the most cost-effective avenues for scaling up of such efforts.

The Eddy Covariance Fluxes of CO_2, CH_4 and N_2O From a Drained Peatland Forest in Estonia

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Peatlands, covering only about 3% of the Earth's land surface, store approximately one-third of terrestrial carbon (C) and 12–21% of global soil organic nitrogen (N). However, drainage for forestry, which typically involves lowering the groundwater table, alters carbon and nitrogen dynamics, converting these ecosystems from carbon sinks to sources and shifting their nitrogen balance. Forest cover may potentially help to offset these changes, though the extent of this effect remains uncertain. While greenhouse gas (GHG) emissions from drained peatland forest soils have been well documented, the number of studies reporting ecosystem-scale GHG fluxes, particularly in the hemiboreal forest zone, remains low. We present the first years of eddy-covariance measurements of CO_2, CH_4, and N_2O fluxes from a drained peatland forest in Estonia. Gaining a better understanding of GHG fluxes in these ecosystems is essential for their management, as drained peatland forests hold the potential to either exacerbate or mitigate the ongoing climate change.

The Oldest Peat of Estonia: A Multi-Proxy Study from Southern Estonia

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This multi-proxy study presents the first insights from Lake Mäe-Tilga in southeastern Estonia, where the oldest known peat layer in the country has been found. Approximately 10 cm of peat formed during the warm Allerød period (~13,000 cal.BP)—a time when brown mosses and dwarf shrubs began to colonize the surface of a buried ice block. The peat layer is overlain by about 50 cm of limnic, mineral-rich sediment deposited during the subsequent cold reversal known as the Younger Dryas.

Geochemical analyses reveal a transition at 755 cm core depth within the Allerød-period peat: both organic content and the carbon-to-nitrogen (C/N) ratio increase, indicating terrestrial conditions. This shift closely follows a change in the botanical composition. The peat's bottom section (761–755 cm) is highly decomposed, with only a few identifiable mosses, including *Meesia longiseta* and *M. triquetra*. In contrast, the upper part (755–751 cm) shows an increase in bryophyte diversity: we identified taxa such as *Ptychostomum pseudotriquetrum*, *Distichium* sp., *Tomentypnum nitens*, *Campylium stellatum*, *Loeskypnum badium* and *Amblyodon dealbatus.* The mosses suggest persistent alkaline fen conditions and include species now extremely rare in Estonia. Whether the compositional shift resulted from autogenic succession or climate change during Allerød remains to be examined.

In addition to the ecologically informative moss flora, vascular plant remains of *Caryophyllaceae*, *Equisetum fluviatile*, *Carex* spp., *Juncus* spp., *Salix polaris* and *Betula nana* were found. *B. nana*, which persisted on the site throughout the Allerød period, offers a unique opportunity to investigate phenological and growing season changes using a novel microphenological method. Ongoing pollen analysis will enhance our understanding of regional vegetation succession and serve as an independent proxy for past temperature changes.

This study provides a rare glimpse into Late Glacial environmental and climate dynamics at the southeastern edge of the retreating Scandinavian Ice Sheet.

Summer Temperature as the Key Driver of Annual Methane Budgets of a Boreal Peatland

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Boreal peatlands are a major source of methane (CH_4). With increasing temperatures due to climate change, CH_4 emissions may severely rise. Yet, only few longer-term studies to evaluate the effect of climate change on boreal peatland CH_4 dynamics exist. Here, we measured CH_4 fluxes at a boreal fen in northern Finland throughout 13 years (2007-2019) using the eddy covariance technique, accompanied by measurements of abiotic and biotic drivers. Mean annual CH_4 emissions were +21.7 g CH_4 . The CH_4 emissions (+17.3 g CH_4) were smallest in 2015, a relatively cold summer (1.0°C below 2007-2019 mean). The highest emissions (+26.9 g CH_4) occurred in 2018, an exceptionally warm summer (2.8 °C above 2007-2019 mean). Large CH_4 emissions occurred during snowmelt and contributed up to 8.5% of the annual CH_4 budget. Summer fluxes and the warm summer soil temperatures controlled the annual CH_4 budget (45-57%, $p < 0.001$) as CH_4 emissions rose exponentially with soil temperatures ($p < 0.001$). Observed warming in late summer (2.1 °C above 2007-2019 mean) did not increase CH_4 emissions as soil temperatures remained unchanged. This might be due to relatively high water tables that buffered soil temperatures. Our results indicate that with ongoing climate change and higher summer soil temperatures CH_4 emissions of boreal peatlands will likely increase.

Changes of Hydrogenic Soils in Selected Research Site in the Kuwasy Peatland, Biebrza Valley

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The research area is located in the Kuwasy peatland, a lowland fen situated in the central Biebrza Valley in northeastern Poland. This part of peatland has been subjected to intensive drainage since the 1930s, primarily due to the construction of the Kuwasy Channel and the subsequent development of a ditch system. These activities have significantly altered the hydrology and soil conditions of the area. The primary objective of this study is to evaluate changes in the physical properties of hydrogenic soils, particularly in relation to ongoing drainage processes. Detailed studies conducted in the 1950s and 1970s confirmed that the physical properties of these soils—such as structure, porosity, and water retention capacity—had significantly deteriorated due to drainage activities. Similar studies were carried out in this area this year. These included an assessment of the degree of peat humification using a simplified van Post scale and an analysis of organic matter content based on loss-on-ignition testing. Undisturbed soil samples were also collected using Kopecky cylinders, enabling calculations of capillary porosity, bulk density, and soil moisture content. Recent assessments comparing current soil conditions with data from past decades revealed changes indicative of progressive peat mineralization over the past 50 years. Soil cores extracted using an Instorf probe, when compared to data from the 20th century, revealed an increase in the thickness of the murshic layer. These findings underscore the necessity of re-wetting the peatland to prevent its further degradation.

Carbon Balance and Component Fluxes of Drained Hemiboreal Peatland Forests

Muhammad Kamil-Sardar[1], Reti Ranniku[1], Joosep Truupõld[1], Ivika Ostonen[1], Gristin Rohula-Okunev[1], Veiko Uri[2], Kristiina Aun[2], Ülo Mander[1], Kaido Soosaar[1]

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Knowledge about the fate of peatland's C storage and management due to drainage activities is imperative for addressing climate change. This study examines long-term accumulation rates by measuring the existing carbon budget as the sum of all fluxes flowing in and out of the forest ecosystem. The research was conducted in Estonia during 2022-2024, representing two forest types in four tree stands. A drained bog (DBF), dominated by Scots pine (Pinus sylvestris), and three transitional fens (DTF), dominated by downy birch (Betula pubescens), Norway spruce (Picea abies), and Scots pine, respectively. Above- and below-ground net primary production estimated through field measurements. Soil heterotrophic respiration (Rhet-CO_2) in trenched plots was measured biweekly during the growing season, and soil-methane (CH_4) and non-vegetation period CO_2 exchanges were measured around the year. Organic C loss through leaching water was measured every month. Additional soil environmental parameters were recorded continuously using CR1000 data loggers. The Rhet in DBF was 5.33 ± 0.98 t C ha^{-1} y^{-1} and reached twice as high in DTF-spruce- and -birch (10.2 ± 1.8) stands. DBF site was a CH_4 source of 4.9 ± 1.4 kg C ha^{-1} y^{-1}, while the DTF stands were sinks. The water table depth and soil temperature variability influenced both Rhet and CH_4. Carbon accumulation in the understory vegetation and fine root production was higher in DBF than in DTF sites, with a similar trend in DOC losses. The estimated net ecosystem production showed that bog pine was a more significant carbon sink (2.9) than DTF-spruce 1.1 t C ha^{-1} y^{-1}. The DTF-birch was a significant source of C to the atmosphere, 3.9 t C ha^{-1} y^{-1}. In conclusion, drained peatlands' carbon sink and source strength mainly depend on the soil nutrient status, followed by vegetation dominance.

Symposium 10:
Ecosystem service benefits and valuation of wetland restoration: from case studies to a broader understanding of societal benefits

3 July

18:15-20:00

Conservation and Restoration of Urban Wetlands: Policy-Driven Approaches for Ecological Rehabilitation

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Urban wetlands have undergone varying degrees of transformation due to historical land-use change, urban expansion, and limited integration of ecological knowledge into past urban planning practices. This research focuses on conserving urban wetlands in Helsinki by developing applied restoration strategies that incorporate both the environmental histories and ecological conditions of specific wetland sites.

To investigate this, the study analyzes historical planning documents, governance practices, and spatial transformations over time. This approach allows for an understanding of how planning decisions, urbanization patterns, and ecological degradation have interacted to shape the current condition of urban wetlands.

The results reveal a persistent disconnection between ecological values and planning priorities, with wetlands often treated as remnant patches within urban development. The analysis shows how short-term development goals and legacy land-use decisions have prevented coherent and conservation efforts. These findings highlight the need for policy responses that are not only adaptive but also grounded in the environmental history of each site.

The study concludes by advocating for a shift toward context-based and adaptive wetland management approaches that align ecological restoration with urban planning systems. By integrating ecological restoration into broader urban policy frameworks, this research provides practical recommendations for enhancing the ecological value and resilience of urban water landscapes. Ultimately, it seeks to bridge the gap between ecological science, urban planning, and policymaking to support sustainable urban wetland restoration in the face of continued urbanization.

Symposium 13:
Restoration of wetlands: pathways, trade-offs and co-benefits

3 July
18:15-20:00

Wetland Restoration for the Future – ALFAwetlands Project

Liisa Ukonmaanaho[1], Tuula Larmola[1], Tuula Aalto[2], Erik Andersson[3], Kaido Soosaar[4], Alex Barthelmes[5], Marina Abramchuk[5], Juraj Balkovic[6], Iryna Shcoka[7], Maud Raman[8], Kris Decleer[9], Emmi Haltia[1], Andis Lazdins[10], Josep Penuelas[11], Adria Descals[11], Jose-Miguel Sanchez-Perez[12], Odette Gonzales[13], Julien Tournebize[14], Francesc Sabater[15]

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Wetlands cover 5-8% of the Earth's land area. Apart from harbouring significant biodiversity, they also currently store around 225 billion metric tons of carbon (C). Their waterlogged nature creates ideal conditions for highly stable C volumes. Healthy wetland environments therefore have a major role in tackling the climate crisis. Their restoration would provide a nature-based solution to reducing greenhouse gas emissions (GHGE) and thereby mitigating the severe effects of climate change (CC). The European Union aim is to cut GHGE at least by 55% already by 2030.

"ALFAwetlands - Restoration for the future" (www.alfawetlands.eu) is a Horizon Europe funded project (2022-2026), coordinated by Luke and conducted at local to European levels with 15 partners across Europe. Its main goal is to mitigate CC while supporting biodiversity and ecosystem services (BES) and being socially just and rewarding. This includes expanding knowledge on C storage and release in peatlands, floodplains, coastal wetlands, and artificial wetlands, particularly following restoration. ALFAwetlands research focuses on both already restored wetlands and those set to be restored during the project. The project's measures extend beyond ecological restoration to include e.g. rehabilitation and re-vegetation efforts aimed at improving ecosystem conditions.

Our 9 Living labs (LLs) encompass a total 33 sites, locating in European wetlands from North-to-South. At the local level, LL's support and integrate interdisciplinary and multi-actor research on ecological, environmental, economic, and social issues. Experimental data from local sites are scaled-up and will be utilized e.g., modeling. To achieve ALFAwetlands goals, 5 workpackages are implemented to 1)improve geospatial knowledge base of wetlands, 2)co-create socially fair and rewarding pathways for wetland restoration, 3)estimate effects of restoration on GHGE and BES, with the data from field experiments, 4)develop policy relevant scenarios for CC and BES, and 5)study societal impacts of wetland restoration.

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