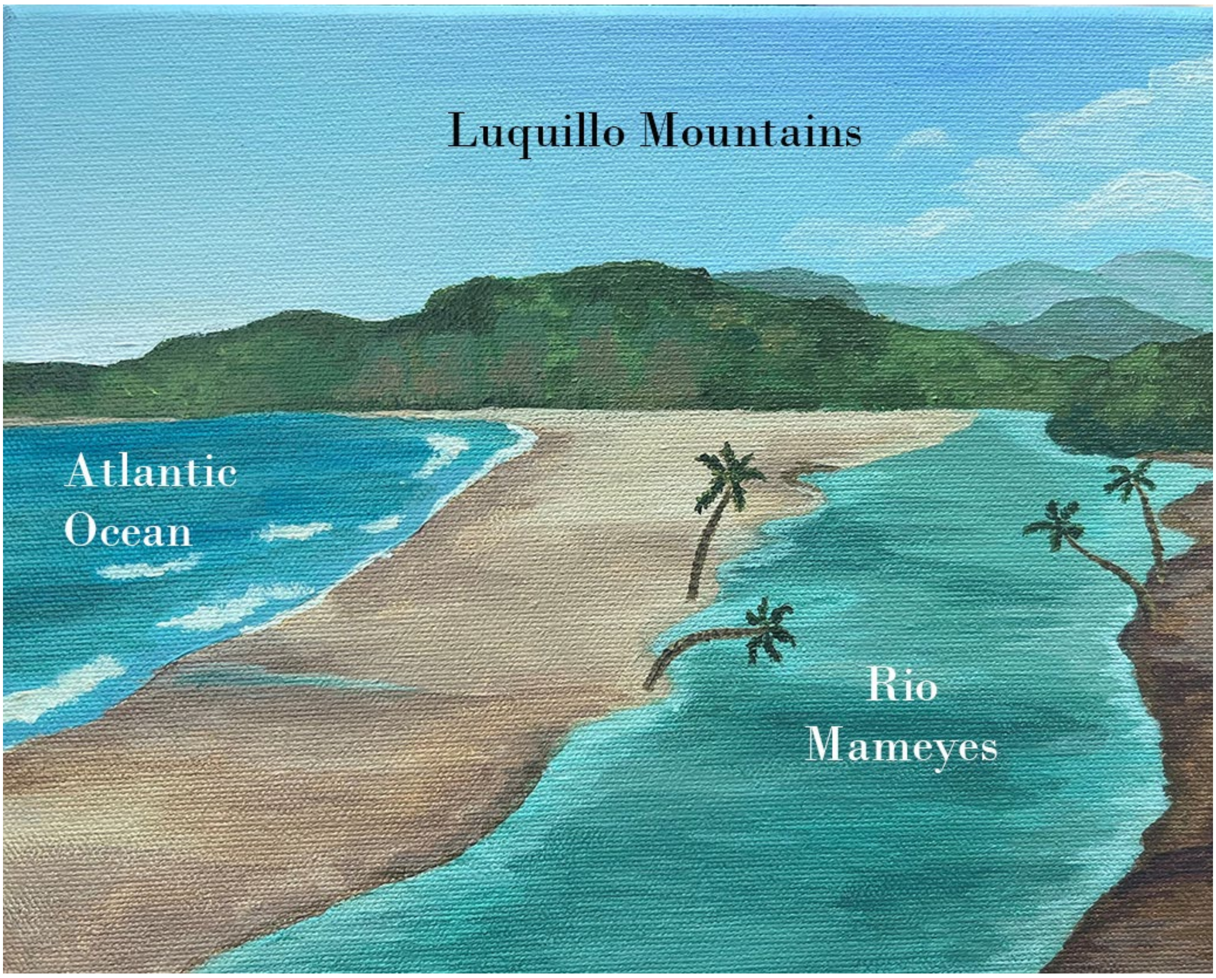
BIOGEOMON 2024

11th BIOGEOMON International Symposium on Ecosystem Behavior

San Juan, Puerto Rico

BOOK OF ABSTRACTS



BIOGEOMON 2024 Book of Abstracts

This publication contains abstracts submitted for the BIOGEOMON 2024 Symposium

Edited by James B. Shanley, Miguel Leon, Willam H. McDowell, Amanda A. Olsen, Thomas Korstanje, Juan G. Garcia-Cancel and Pavel Kram

Cover artwork of Ava Shanley shows Rio Mameyes flowing through the Luquillo Experimental Forest (destination of the BIOGEOMON field trip) and into the Atlantic Ocean in northeastern Puerto Rico.

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Conference sessions, presentations and posters

<u>**Plenary Speakers, workshop** (no accompanying abstracts)</u>

Monday January 8, 8:45. Plenary 1 -- Nancy Dise (Center for Ecology and Hydrology, UK), Melanie Vile (West Chester University), and Martin Novák (Czech Geological Survey) - From Acid Rain to the Anthropocene: 37 years of BIOGEOMON.

Monday January 8, 9:30. Plenary 2 -- Ariel E. Lugo (International Institute of Tropical Forestry)- The biogeochemical history of Puerto Rico in five acts.

Monday January 8, 10:45. Plenary 3 -- Whendee Silver (University of California, Berkeley)- Playing with chutes and ladders: the slippery slope of redox in terrestrial biogeochemistry.

Monday January 8, 11:30. Plenary 4 -- Becca Barnes (NSF/AAAS/Belmont Forum) - Rethinking the scientific enterprise: How to make the biogeosciences more welcoming and just.

Tuesday January 9, 8:45. Plenary 5 -- Irena Creed (University of Toronto) - Changes in catchment dissolved organic matter export fuel unforeseen freshwater cyanobacterial blooms in the Anthropocene.

Tuesday January 9, 12:00 -13:30 **Lunchtime workshop: Decolonizing Biogeochemistry.** *Justin Richardson,* University of Virginia*; Pedro Matos Llavona,* University of Massachusetts; *Bryan Rodríguez Colón*, The University of Kansas [leaders] .

Tuesday January 9, 15:30 Plenary 6-- Eve-Lyn Hinckley (University of Colorado, Boulder) - Our changing manipulation of the global sulfur cycle.

Tuesday January 9, 16:15 Plenary 7 -- Amy Burgin (University of Kansas) - The Biogeochemical Redox Paradox: How do we make a foundational concept more predictive of biogeochemical state changes?

Thursday January 11, 8:45. Plenary 8 -- Sara Vicca (University of Antwerp -- remote) - Enhancing silicate weathering to promote soil carbon sequestration.

Thursday January 11, 9:30. Plenary 9 -- Kevin Bishop (Swedish University of Agricultural Sciences)- Unraveling the fate of mercury in peatlands with the help of micrometeorology, isotopes, paleoecology, genomics, an ice-age and of course some duct tape.

Session 1: Tropical biogeochemistry – Monday January 8th starting at 1:45 PM in Auditorium 3

Session 2: Aquatic Carbon Cycling in the Anthropocene: from Molecules to Meta-Analyses – Tuesday January 9th starting at 9:30 AM in Auditorium 3

Session 3: Soil carbon stabilization and C sequestration – Monday January 8th starting at 1:45 PM in Auditorium 2

Session 4: Change in the Anthropocene: Nutrient cycling — Eutrophication to Oligotrophication – Tuesday January 9th starting at 1:30 PM in Auditorium 2

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S4.P5 – Marketa Stepanova – Contribution of Rime to Atmospheric Sulfur and Nitrogen Deposition in Central Europe (page 113)

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S5.T6 – Jessica Tipton (presented by Stefanie Whitmire) – Assessing the Impacts of Sargassum Brown Tide to Nearshore Water Quality and Seagrass Beds in Jobos Bay, Puerto Rico (page 117)

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S6.T4 – D. Cardace – Elemental Cycling Recorded in Fracture Zone Minerals in Metal Rich Bedrock (15)

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Building a processed-based understanding of discharge-driven variability in CO_2 and CH_4 emissions

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Streams and rivers are important players in global carbon cycles. They simultaneously transform and transport terrestrially and locally fixed carbon, and some of this carbon is released to the atmosphere as carbon dioxide (CO_2) and methane (CH_4). Emissions of these climate-relevant gases from streams and rivers are significant to both greenhouse gas budgets and carbon cycle models. Emission estimates have improved over the last ~10-15 years and are now spatially explicit to the reach scale, but only temporally resolved to the monthly or seasonal scale. Overall, temporal variability in emissions is relatively less understood than spatial variability, in part, due to limited observation and documentation of controls acting at the sub-monthly scale. This talk will focus on the importance of building a process-based understanding of hydrologic controls on CO_2 and CH_4 emissions. Emissions are driven by two factors: 1) the air-water concentration gradient of the gas of interest and 2) the gas transfer velocity, or a physical parameter controlling the rate of emission. Results show that both factors can be strongly modulated by river discharge, sometimes in divergent ways. As more extreme hydrologic conditions (both floods and droughts) are predicted with climate change, discharge-driven variability in CO_2 and CH_4 emission is important to consider for more accurate carbon cycle models and greenhouse gas budgets.

Elemental and Mg-Cu-Zn isotopic features of bay bolete (*Imleria badia)* mushrooms collected over the extended period from the contrasting substrates

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Mushrooms may serve as a determinant of environmental response to various extreme events on both elemental and isotopic levels. We studied elemental and Mg-Cu-Zn isotope compositions of the *I. badia* mushrooms collected during the two consecutive harvesting seasons from three forested sites in the Czech Republic. The sites were almost unpolluted by recent human activities, and are underlain by contrasting bedrock (granite, amphibolite, and serpentinite). Elements such as Ag, Cd, K, P, Rb, S, Se, and Zn were enriched in the mushroom's fruiting bodies relative to substrates of any type. Concentrations of most elements were not site-dependent, with only Ag, As, Rb, and Se concentrations depending on the bedrock composition. No systematic temporal variations were observed for individual elements. Most analyzed elements were distributed unevenly within the mushroom's fruiting bodies, with apical parts enriched in mobile elements. Soils were depleted in the ^{26}Mg isotope ($\delta^{26}Mg$ = -0.78 to -0.30‰) and displayed a wide range of the $\delta^{65}Cu$ values (-0.85 to +0.67‰). Values of $\delta^{66}Zn$ were mostly negative for the granite-based soils (-0.33 to +0.07‰), positive for the amphibolite-based soils (+0.03 to +0.12‰), and slightly deviated from zero for the serpentinite-based soils (-0.09 to +0.09‰). The studied mushrooms fractionated isotopes of Mg, Cu, and Zn both at the soil-to-mushroom interface and within the fruting bodies. Mushrooms preferably uptake lighter Mg isotopes ($\Delta^{26}Mg_{mushroom\text{-}soil}$ = -0.19 to -0.79‰), heavier Zn isotopes ($\Delta^{66}Zn_{mushroom\text{-}soil}$ = +0.43 to +0.61‰), and both lighter and heavier Cu isotopes ($\Delta^{65}Cu_{mushroom\text{-}soil}$ = -0.33 to +0.60‰). For copper, significant isotope fractionation on the soil-to-mushroom interface could be explained by redox reactions, both reduction (negative fractionation) and reoxidation (positive fractionation). Isotope fractionation of Mg (only negative) and Zn (only positive) can be due to preferable incorporation of the heavier Zn and lighter Mg isotopes mobilized from the substrate. The mushroom samples were characterized mostly by the $\delta^{26}Mg_{stipe} < \delta^{26}Mg_{cap} < \delta^{26}Mg_{sporophore}$ and $\delta^{65}Cu_{stipe} > \delta^{65}Cu_{cap} > \delta^{65}Cu_{sporophore}$ isotope fractionation schemes whereas Zn always displayed a $\delta^{66}Zn_{stipe} > \delta^{66}Zn_{cap} < \delta^{66}Zn_{sporophore}$ isotope fractionation scheme. Within-mushroom isotope fractionation was not season- or annual-dependent. This study may offer a new perspective for understanding partitioning of elements between biologic and mineral geochemical reservoirs. The studied sites may serve as a reference point for unpolluted environment for further studies dealing with biogeochemical response to various environmental events. Funded by the Czech Geological Survey (Grants # 311040 and 311450).

Geomicrobiology trends with depth across varied sites: Initial results from the CZNet GeoMicro Project

Dr. Emma L. Aronson

The Critical Zone (CZ) is defined as the Earth's upper, dynamic skin, situated between the highest treetops and the lowest groundwater. Within the CZ, soil microbial communities perform a wide variety of biogeochemical functions, and can vary greatly between sites and with depth. The CZ Network Geomicrobiology (CZNet GeoMicro) project is investigating microbial community variability across 5 former CZ Observatories, including sites in tropical rainforest, Southeastern piedmont, Southwestern Desert, Northeastern steppe and Western mountains. Across sites we are sampling seasonally, down to 2 meters or refusal, investigating the connections between surface and deeper soils, and the influence of these connections on the biogeochemistry of these deep soils.

Initial analysis of the amplicon sequences showed that soil microbial communities in about half of the sites varied greatly with depth, while the others showed remarkable similarities, even down to 2 meters. In particular, the tropical soil samples from sites in the Luquillo rainforest were similar with depth, in contrast to other locations. While previous studies have seen important changes in overall microbial communities with depth, this research suggests that greater connectivity between the surface and depth drives reduced differences in microbial communities with depth. Further, this research strengthens evidence that microbial community composition is driven more by ecological setting than by variances of depth within soil profiles. Further research across this set of soil profiles can provide important insights into the environmental factors that drive the distinction between more connected and more variable profiles. The drivers of connectivity, including pore size, particle size, soil root density, and other factors, must be accounted for in studies that seek to examine how microbial communities are structured by depth.

The Amazon and Tropical Forests: Its Global Implications and Needed Urgent Actions

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The functioning of tropical forests has global implications. Funding the generation of new knowledge or the synthesis of existing knowledge is urgent for the Amazon and the world's tropical forests through recognizing local communities and Indigenous Peoples' differences in governance, cultural diversity, ways of knowing, practices, stewardship, and territorial configuration. The Amazon and Tropical Forests Collaborative Research Action (CRA), launching in 2024 through the Belmont Forum is led by the InterAmerican Institute of Global Change Research (IAI) and São Paulo Research Foundation (FAPESP). The CRA aims to coordinate actions and projects with a transdisciplinary approach to address the similar challenges faced in Amazonia and other tropical forests including climate change, deforestation, alternative agricultural practices, land tenure, illegal activities, water contamination, recovery of indigenous peoples and local communities' knowledge and practices to develop transdisciplinary solutions with local impact.

The transdisciplinary approach that the Belmont Forum promotes starts with the construction of the CRA in itself. The strategy encompassed six scoping workshops with participants worldwide but focusing on the regions with tropical forests and with targeted audiences. As a result, ten thematic areas were identified and consolidated into four primary themes for the call text: 1) Reduce deforestation, sustainable development, and bioeconomy; 2) Ecosystem Functioning and Services, and Health; 3) Violence and Essential Services; and 4) Climate Change Science and Climate Justice. The scoping process also yielded thirteen key recommendations to ensure effective and equitable CRA implementation; spanning coordination, the promotion of transdisciplinary research, the necessity for research permits, or contingent scenarios that may hamper the execution of the proposals. In response, the application process includes specific requirements of both the applicants and funders (e.g., deconstructing "participation" in application materials and including non-academic experts within the review process). This talk will introduce the Belmont Forum and an overview of the upcoming funding opportunity around the Amazon and tropical forests.

Abstract Title:

From volcanic ash to abundant earth: Understanding Andisol soil health and organic matter dynamics across an environmental gradient on Hawaiʻi Island

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Abstract:

While research on the mechanisms of carbon stabilization in Andisols is ongoing, the role of soil organic matter (SOM) dynamics in (sub)tropical Andisol soil health, and its variation across landscapes, has largely been unexplored. High concentrations of poorly and noncrystalline minerals favor greater organic matter accumulation in Andisols than phyllosilicate-dominant soils. Nevertheless, SOM quantity and quality vary greatly across volcanic natural and working lands. Therefore, a systems-level understanding of SOM composition and function is critical for climate change mitigation and adaptation, especially for vulnerable tropical and subtropical islands. Soil health, a soil's capacity to sustain biological productivity and maintain environmental quality, connects management practices to social-ecological vitality and resilience. In this study, we measured the effects of moisture regime and current land use on SOM fractions and soil health in Andisols. We collected soil samples from 24 sites across two moisture regimes (Udands and Ustands) and three land uses (cropland, pasture, forest) on Hawaiʻi Island. We quantified the carbon (C) and nitrogen (N) concentrations of three SOM components, including mineral-associated organic matter (MAOM), heavy particulate organic matter (HPOM), and light particulate organic matter (LPOM), separated by size and density. Additionally, we measured ten dynamic soil properties which were integrated into a soil health score. We used multiple linear regression to determine which SOM pools best predicted the soil health score and semi-partial analysis to understand the amount of model variability uniquely accounted for by each predictor. We found that land use influenced SOM fraction mass proportion ($p < 0.05$), but its effect on mineral-associated (MAOM) and heavy particulate organic matter (HPOM) proportions depended on the moisture regime ($p < 0.01$). Further, pastures had greater HPOM-C and N concentrations than forests and croplands ($p < 0.01$). Soil health scores ranged from 0.05 to 0.91. The highest scoring systems included Udand forests, Udand pastures, and Ustand pastures. Multiple linear regression revealed that MAOM-C ($sr^2 = 0.41$), HPOM-N ($sr^2 = 0.05$), and LPOM-N ($sr^2 = 0.07$) best predicted the soil health score ($R^2 = 0.82$), indicating that N mobilization from particulate fractions may be an important process to overcome the high mineral sorption potential of poorly and noncrystalline minerals and maintain N bioavailability in Andisols.

The changing climate and landscape mosaic means more but less labile organic carbon exports from glacierized watersheds.

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Glaciers can provide highly labile dissolved organic carbon (DOC) to downstream freshwater and marine ecosystems. In contrast, the surrounding watershed is a source of more humic, less labile DOC. As climate change progresses, glaciers will continue to rapidly melt and retreat, while vegetation type and distribution on the surrounding landscape will shift, particularly in high latitude and altitude regions such as Alaska. This will likely be coupled with shifts in the timing, form, and intensity of precipitation and snowmelt, which will alter seasonal patterns in the degree and pathways of DOC mobilization to streams and rivers. While the general characteristics of DOC quality and export are established in glacierized watersheds, less is known about how these characteristics may be changing as the entire landscape changes, particularly in late fall through early spring when access to sites is challenging. To characterize current and expected future DOC quality and export characteristics, we established monitoring sites in a series of watersheds representative of the range of landscape types in South Central Alaska including lowland forests, mid-elevation alder, and high-elevation tundra and talus. At each site, we collected grab samples for nutrients and 15-minute water-quality data with sondes over 3 years (2021-23). We found that during winter and prior to the onset of snowmelt, streamflow is largely derived from high conductance groundwater and subglacial drainage. Fluorescent dissolved organic matter (fDOM, a proxy for DOC), from sonde measurements, is at a high baseline relative to other times of year and undergoes an initial snowmelt flush in all watersheds. Forested and shrub-dominated watersheds have the highest concentrations of DOC (computed from fDOM measurements) during the summer melt season, with high DOC peaks during precipitation events, which increase in frequency and magnitude in the fall. While DOC concentrations are low in the glacier dominated locations, the DOC flux is high due to high melt volumes, and the DOC is much more labile than the other watersheds as suggested by fluorescence index (FI). In the future we might expect increased concentrations of lower lability DOC from glaciated watersheds as well as increased DOC flushing events in fall and winter as high intensity rain and rain on snow events become more frequent. The organic carbon delivered from the glacierized landscape may thus become less available to the marine food web as glaciers recede.

Living on the edge: Mediterranean streams as natural laboratories for understanding the impact of extreme hydrological events on biogeochemical transport and cycling.

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Climate warming is inducing more frequent and intense precipitation events and extended periods of droughts in many regions of the world, which alter the hydrological regime of streams and rivers by increasing the probability of extreme hydrological conditions. Mediterranean-climate regions are used to experience extreme hydrological events on a seasonal basis, and thus, fluvial ecosystems in this region can be used as natural laboratories for understanding how future climate will impact ecosystem structure and functioning in other biomes. In this talk, we will use empirical and modelling approaches to illustrate how the alternance of large floods and intense droughts influence the transport and processing of nutrients and organic matter in Mediterranean fluvial networks. Specifically, we will show how intense floods and droughts can impact stream microbial assemblages and associated biogeochemical processes. We will also discuss how extreme droughts can magnify point-source contamination in Mediterranean streams draining urban landscapes, and to which extent in-stream biogeochemical processes can contribute to mitigate water contamination and nutrient excesses in the receiving streams. Ultimately, we aim to share the lessons learned from ecosystems naturally experiencing multiple extreme hydrological events, to discuss how we can better cope with climate change and mitigate its impacts on hydrological flow paths and the transfer and cycling of matter in stream ecosystems.

Recent Pb soil pools and comparison of long-term Pb mass balances in headwater catchments with different pollution loads

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Lead is toxic for the environment and human health. Its natural geochemical cycle has been substantially changed by human activities. In Central Europe, Pb emissions reached a maximum during the 1980s, due to coal burning, use of leaded gasoline, base-metal smelting and chemical industry. Pb is removed from the atmosphere via dry and wet deposition to the hydrosphere and pedosphere. In Central Europe, forested headwater catchments are an important source of drinking water.

Twelve small forested catchments of the GEOMON monitoring network are situated along a north-south pollution gradient and include different bedrock types. At each site, three soil pits were sampled at the depths of 0–10, 10–20, 20–40 and 40–80 cm, and analyzed for water-soluble, bioavailable, and total Pb concentrations (H_2O extracts, EDTA, and HF digestions, respectively). Across the sites, the overall mean water-soluble Pb pool was 0.17 kg/ha (with a minimum of 0.04 and a maximum of 0.32 kg/ha), the mean bioavailable Pb pool varied from 22 to 84 kg/ha, with the mean of 42 kg/ha, and the total Pb storage ranged from 65 to 481 kg/ha, with the mean of 210 kg/ha. On average, almost half of the water-soluble Pb storage and more than 40% of bioavailable Pb pool were located in the uppermost layer of the mineral soil (0-10 cm). On the other hand, more than 40 % of the total Pb pool were in the deepest sampled layer (40-80 cm).

Pb mass balances (atmospheric Pb input minus Pb output) based on long-term hydrochemical monitoring of open-area precipitation, throughfall and runoff water were evaluated for 24 consecutive years (1996-2019). Sites exhibited a wide range of mean annual atmospheric Pb input (4.3–49.5 g ha^{-1}) with the mean of 14.8 g ha^{-1} across the sites, as well as output (0.6–30.4 g ha^{-1}) with the mean of 6.2 g ha^{-1}. Moreover, the mean annual output/input ratios varied substantially among the sites (7–180%). All the sites showed decreasing trend in Pb atmospheric input, however only at half of the sites significant decrease in Pb output was detected during the monitoring period. Analysis of hydrochemical and soil parameters controlling Pb retention/release is under way.

Principal drivers of organic carbon stocks in forest soils of the Czech Republic

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Forest soils represent a very important pool of soil organic carbon (SOC) and proper management of these soils can thus mitigate climate change. In this study, we analyzed the major drivers influencing the SOC stocks in temperate forests at national scale of the Czech Republic. We used data from the aggregated database of forest soils of the Czech Republic, containing standardized soil properties compiled from several national-scale soil surveys done in the years 2000-2020. We selected data on locations where the SOC was really determined, i.e. where soil bulk density was measured in the mineral soils and where quantitative sample collection was done for the organic horizons (namely fragmented and humified horizons, F+H). Most of these data originated from the ICP-Forests and Biosoil projects. In total, data on 200 sites were analyzed, with total SOC stocks determined to the depth of 30 cm; in addition, at 169 locations the SOC stock to the depth of 80 cm was also determined. Basic (ANOVA, correlation and regression) and advanced (factor analysis, principal component analysis) statistical methods were employed.

Tree species composition, altitude and forest vegetation zones were found to be the most important drivers of forest SOC stocks. Generally, the total carbon stocks are higher under deciduous forests than under the coniferous ones. Under coniferous forests, the contribution of forest floor (F+H) to the total SOC stock to the depth of 30 cm is higher (around 40%) than under broadleaved and mixed forests (around 20%). Nevertheless, the mineral part of the profiles is still the most important SOC pool. Bigger accumulation of SOC in soil profiles is related to lower temperatures and higher precipitation at higher altitudes, and lower pH reducing the decomposition rate. The strongest effect of pH on SOC accumulation was found in forest floor. In this layer the high SOC stock is generally connected also with lower organic matter quality indicated by higher C/N ratio. Some effect of soil classes was also shown; the highest SOC stocks were in Podzols and Histosols, the lowest in Luvisols and most Cambisols.

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Scaling of stream organic matter stoichiometry across the world's forest biomes

The geographic distribution and climate-dependency of terrestrial organic matter processing across Earth's forest biomes is generally well understood. However, the emergent consequences for the chemistry of streams that permeate these biomes are less clear. As stream chemistry is notoriously variable through time, it is well known that long-term data are essential for characterization of mean field conditions that are critical to evaluation of global change effects. In contrast, bulk soil properties are known to vary greatly through space but remain relatively constant over decades or more. Here, we synthesize stream water chemistry distributed across 250 undisturbed watershed streams in boreal, temperate, and tropical forests worldwide. Most of the >30,000 samples examined were collected regularly over the last four decades or more at Long-term Ecological Research sites. We focused our analyses on dissolved organic C (DOC) and N (DON) cycling and exports. We compare these patterns to an independent global data set on soil chemistry to evaluate the degree of stoichiometric coherency between soils and streams. By examining power-law scaling relationships across space and time we find remarkable coherency within and across biomes in the CN stoichiometry of soils and streams. After normalizing for mass-volume relationships between soils and streams, we derive soil-stream transfer functions and power law scaling between C and N that show increasing relative N enrichment per unit C in soils and streams from boreal to tropical forest watersheds. We demonstrate stoichiometric symmetry between soils and streams made possible via long-term stream chemistry data that reveal the time-integrated averaging effects of watershed ecological and hydrological processing. Our findings offer insight into how stoichiometric pattern emerges at the ecosystem level over space and time.

Unlocking plant-microbial interactions in deep soils: Linking depth gradients in roots, microbial activity, and soil carbon

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Abstract

Growing deep-rooted plants may offer the potential to build soil carbon (C). However, most research has focused on shallow soils. This focus on shallow soils neglects deep soils which account for at least a third of all soil C. Thus, our objectives were to: (1) link depth gradients in root biomass with microbial activity and soil C stocks down to 1 meter and (2) examine differences between depths in the ability of simple C inputs, as a proxy for root exudates, to prime or build soil C. For a model system, we used the deep-rooted perennial bioenergy crop, Miscanthus, which has been shown to build soil C in the top 30cm. To meet our objectives, we dug five, quantitative soil pits under 20-year-old Miscanthus plots in Champaign-Urbana, IL. We excavated soils from a 1m x 30 cm x 1m volume and separated them into five depths. Observationally, we measured fine root biomass, total soil C, mineral associated organic C (MAOC), particulate organic C (POC), microbial respiration, net nitrogen cycling, and enzyme activity. Experimentally, we added ^{13}C labeled glycine to soils from each depth in a lab incubation and followed the fate of the carbon into different soil C fractions.

We found strong significant declines with depth in fine root biomass, total soil C, MAOC, POC, and microbial activity. POC declined more rapidly with depth than MAOC leading to an increase in the ratio of MAOC-to-POC. When we examined linkages between total soil C and root and microbial measurements, we found that fine root biomass, n-acetyl-glucosaminidase (NAG) activity, and microbial respiration explained 98% of the variability in soil C. Both fine root biomass, representing inputs, and NAG, representing microbial recycling of dead cell walls, had positive effects on soil C. By contrast, microbial respiration had a negative effect. MAOC mirrored these results, but POC was only dependent on fine root biomass. In our experiment, we found that all depths had similar ability to transfer simple C inputs into MAOC. However, this transfer led to net MAOC losses in shallow soils, and net MAOC gains in deep soils. Collectively, these results suggest that soil C represents a balance between inputs, decomposition, and the recycling of microbial necromass. Moreover, in deeper soil horizons with low decomposition rates, increases in root C inputs may have the potential to build soil C.

Greenhouse gases production in open-pit mines

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The Czech Republic belongs to largest soft-coal producers in Europe. Lignite is mined in CR today only at the surface, in the North Bohemian Basin and in the eastern part of the Sokolov Basin. The opencast Bilina coal mine (North Bohemian basin) produces eight million tons of subbituminous coal per year.

Open-pit coal mines are significant sources of methane (CH_4) and carbon dioxide (CO_2) emissions into the atmosphere. We studied the chemical and isotopic ($\delta^{13}C$-CH_4, $\delta^{13}C$-CO_2, δ^2H-CH_4) composition of gases from three opencast mines in the North Bohemian lignite basin, Bilina, CSA, Libous and Jiri in the Sokolov Basin. The release of greenhouse gases from a coal mine starts with coal seam degasification during the initial removal of overburden, continues during coal mining, crushing, pulverization and ends with CH_4 being released from abandoned mines.

Gas samples were collected at two locations in one mine at several distances from the coal bed. Coal samples were taken at the same locations, directly from a freshly excavated seam.

Using the canister method, we measured gas emissions from fresh coals as a function of time until equilibrium was reached, then the coals were crushed into pieces about 1 cm in diameter and the released gases were analysed. Finally, the samples were crushed into powder (particle size less than 1 mm) in a closed mill with a gas septum to analyse the residuals. We monitored the amount of methane and CO_2 released, the dependence of the amount and isotopic composition of the gases on time and subsequently on the particle size during gradual erosion of the coal structure (effect of coal treatment). The surface size, the amount of pores and their distribution were also monitored (BET) since the ability to retain gases is influenced by the volume of the pores and their surface area.

The isotopic composition was used to determine the origin of the emitted gas from coal samples collected in the Bilina open-pit mine. The $\delta^{13}C$ values of the released methane (CH_4) and carbon dioxide (CO_2) indicates their biogenic origin ($\delta^{13}C$ (CH_4) −70 ‰ to −55 ‰ vs. VPDB, δ^2H −275 ‰ to -260 ‰ vs. VSMOW, $\delta^{13}C$ (CO_2) -10 ‰ to -16 ‰ vs. VPDB). We assume that the secondary biogenic gas production replaced original coal bed gases and the excavated coal is rich in CO_2, but very low in CH_4. Additionally, most of the secondary CH_4 was released before excavation.

Tracing carbonaceous emission in an industrial conurbation in Central Europe using ^{13}C data.

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Ostrava, the third largest city in the Czech Republic, has been for more than a hundred years part of the most industrialized region of the country. Heavy industry, coke production and ironworks are the main polluters here, along with local and mobile sources.

Organic carbon (OC) is a significant component of particulate emissions below 10 µm (PM10). One component of OC is black carbon (BC) or elemental carbon (EC), which is formed by incomplete combustion of various forms of OC. The isotopic composition of $\delta^{13}C$ OC and EC varies according to the origin of the OC and can be used to identify OC in PM10 or in deposition (e.g. soil).

Atmosphere was sampled three times per year (February, July and December) for 30 days, at five sampling sites, with known to daily airflow trajectories.
Atmospheric aerosol particles PM10 were collected using the automatic high volume samplers with quartz filters (QF). The effect of long-time PM deposition was monitored by soil analysis on all sites. Contents and $\delta^{13}C$ OC and BC were determined on QF and in the soil.
Sources of emissions were identified through their typical $\delta^{13}C$ values: for the Polish Silesian coal it is -24.5 ‰, for the local coal -25.5 ‰, for traffic input it is -26.5 ‰ and for biological residua -28.0 ‰. Most of the time (75 to 82 %) the wind direction was from S to N and from N to S.

The results showed that coal use and combustion are the dominant emitters in winter (from 55 to 74 %, the rest originates from traffic, biogenic input is not important). In summer, biogenic input forms from 40 to 50% of OC in PM, the rest originates from traffic (with exception of site 1 with additional 20% emission from the coal use). Site 8 (close to the Polish border) has a significant contribution (from 60 to 70 % in winter) of OC from the combustion of the Silesian coal coming from the Czech-Polish borderline.

BC $\delta^{13}C$ values in the topsoil of Ostrava soils present narrow range between -24.5 and -25.5 ‰ corresponding to a mixture of Polish and Ostrava coal.

Nutrient and streamflow fluxes in the Espiritu Santo River, a tropical watershed in the Luquillo Mountains

The Espiritu Santo River is located in Northeast Puerto Rico, an ecological diverse region of different land uses, protected lands, developed lands, and minor agriculture that connects the Luquillo Mountains, floodplains and coastal ecosystems. Also mountain wetlands, a tropical rain forest, coastal forest, and a mangrove forest cover the basin. Gradients in temperature and rainfall are created by the steep elevational relief (McDowell et al., 2021) on the upper watershed. El Yunque National Forest receives between 5,000 and 6,350 mm of precipitation annually but water extraction for human consumption is extensive. Nutrient export in tropical streams is influenced by a variety of factors, including the local geology. This poster analyzes nutrients export and streamflow patterns over 3 years in the Espiritu Santo River.

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Abstract title: Elemental Cycling Recorded in Fracture Zone Minerals in Earth's Metal-rich Bedrock

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Some of Earth's naturally metal-rich bedrock units, tectonically upheaved from the subseafloor and stranded on continents, are essentially mantle samples, characterized by high Fe and Mg rock compositions and sometimes mobile Cr, Ni, and other metals in advecting groundwater systems. Reactions with water drive pervasive alteration of primary materials to serpentine clay mineral assemblages. These rock units are of high interest to research in atmospheric carbon drawdown strategies and evaluations of mineral controls on microbial activity in/beyond the critical zone. Core samples of serpentinites from the Coast Range Ophiolite were obtained at the UC-Davis administered McLaughlin Natural Reserve in Lower Lake, CA. Shallow samples were collected from Coast Range Ophiolite Microbial Observatory (CROMO) cores, deeper samples were from Homestake Mining Co. archives. Questions asked were: (1) do bulk core samples reflect changing redox status with depth below ground surface? (2) how do Fe-containing vein fill minerals exhibit redox differentiation with distance from vein centers to edges, and (3) do different fracture sets (relatively dated based on cross-cutting relationships) exhibit the same or different redox characteristics? Implications for metal release and trapping within the mineral assemblages are considered as the system trends towards equilibrium.

THE BEDROCK AND DOMINANT TREE SPECIES CONTROL THE FOREST RESPONSE TO NITROGEN DEPOSITION

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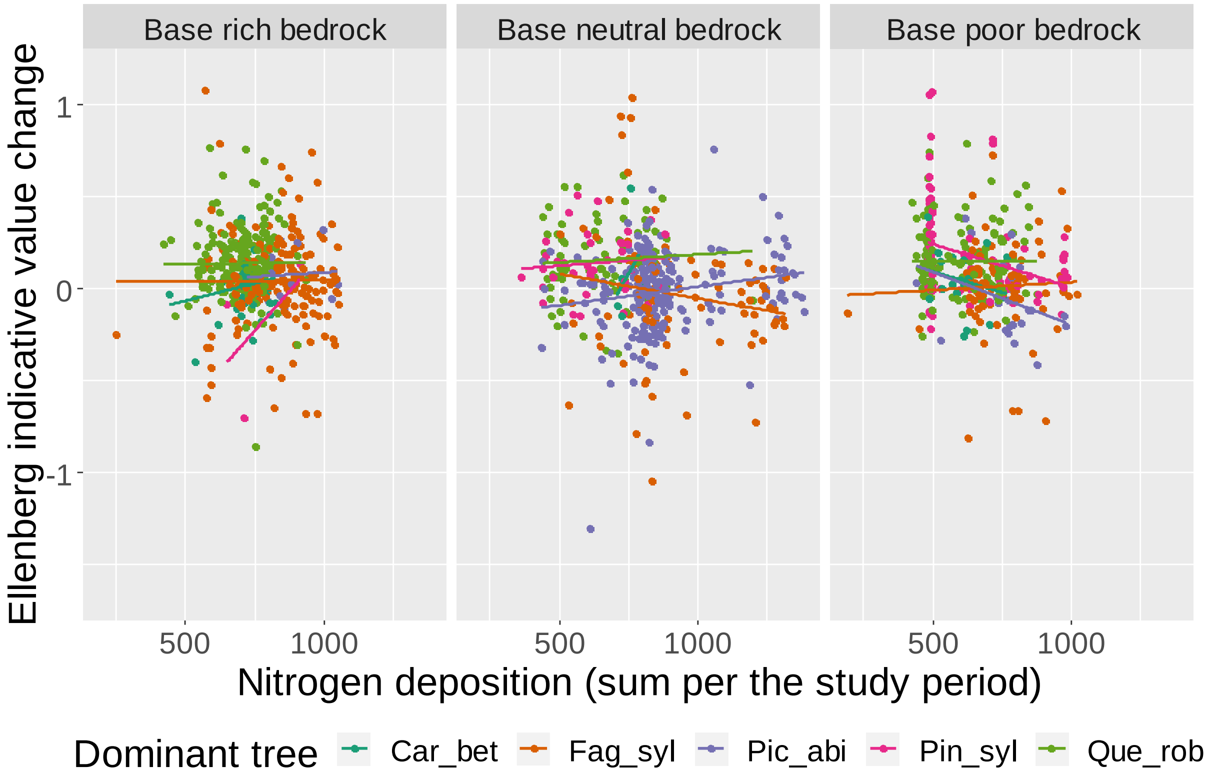
Many studies show that excessive nitrogen inputs to terrestrial and aquatic ecosystems are one of the environment's most severe problems, leading to a decline in species biodiversity. Species loss through increased nitrogen inputs is a global issue, although it is most prominent in the temperate zone and well documented in Europe and the U.S. In terrestrial ecosystems, nitrogen is often a limiting nutrient for primary producers; however, since the industrial revolution, due to fossil fuel combustion and increased fertilisation, its inputs in the reactive form have increased unprecedentedly. Increased input of nitrogen (eutrophication) results in increased biomass production and a shift from nutrient limitation to light limitation and thus to the dominance of a few species, so-called strong competitors. Most weak competitors are plant species from oligotrophic and mesotrophic habitats adapted to nutrient-poor conditions. The spread of nitrogen-demanding species leads to a decline in plant species of nutrient-poor sites (oligotrophs). However, there are still some gaps in our understanding of the species' response to nitrogen deposition. One such research gap is in understanding the interaction of nitrogen deposition and the bedrock, representing potential nutrient supply other than nitrogen. Other nutrients, such as phosphorus or base cations, may be limited at specific bedrock, modifying the response to nitrogen deposition and not allowing expansion of the strong competitors. Therefore, we analysed the response of temperate forest understory plant species to nitrogen deposition on different bedrock. We used data from resampled forest plots and analysed how the Ellenberg indicative value for nutrients has changed over time. We found a negative relationship between the Ellenberg indicative value for nutrients and nitrogen deposition across all sites, not considering the lithology, indicating that forests have generally experienced slight oligotrophication rather than eutrophication. However, the response to nitrogen deposition further depends on the bedrock and dominant forest tree species. This relationship was the most prominent for the Spruce forest, where we can see oligotrophication on base-poor bedrock and eutrophication on base-rich and base-neutral bedrock.



Base rich bedrock
Base neutral bedrock
Base poor bedrock
Ellenberg indicative value change
1
0
-1
500
1000
Nitrogen deposition (sum per the study period)
Dominant tree
Car_bet
Fag_syl
Pic_abi
Pin_syl
Que_rob

Wood frog tadpoles (*Lithobates sylvaticus*) significantly contribute to nutrient cycling and enhance litter breakdown in wetland ecosystems

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Animals play a pivotal role in the structuring and functioning of ecosystems. For instance, animal waste can contribute substantially to nutrient cycling and ecosystem productivity in lotic environments. However, little is known of the biogeochemical impact of animal excretion in wetland environments. Here we investigate the effects of wood frog (*Lithobates sylvaticus*) tadpole aggregations on nutrient recycling, microbial metabolism, and carbon cycling in geographically isolated wetlands. We used a paired mesocosm and field study approach that utilized measurements of tadpole excretion rates, microbial extracellular enzyme activities, and litter degradation. Tadpoles displayed a strong relationship between development and nutrient excretion demonstrating that ontological changes impact tadpole mediated nutrient cycling in wetland habitats. Further, the interplay between per capita excretion rates and hydrologic conditions in wetlands increased ambient nutrient concentrations in wetlands through time. Within our mesocosm study tadpole derived nitrogen elicited a strong microbial response, decreasing extracellular enzyme activities associated with nitrogen acquisition by a factor of 5. In addition to microbial metabolic response, tadpole presence enhanced litter breakdown in both mesocosms and wetlands by 7% and 12%, respectively, in comparison to reference conditions. These results provide evidence for the functional and biogeochemical role of tadpole aggregations in wetland habitats, with important implications for ecosystem processes, biodiversity conservation, and ecosystem management.

BIOGEOMON Invited Abstract 2023

Title: Seasonal and Experimental Drying Effects on Soil Carbon and Nutrient Cycling across Four Distinct Panamanian Forests

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Climatic drying has been predicted and documented in many tropical regions, but its consequences for belowground dynamics remain unclear. Tropical forests hold some of the largest carbon (C) stocks globally, with the largest and most long-term storage occurring in soils, yet little is known about how these C stocks will respond to drying at an ecosystem-scale. The Panama Rainforest Changes with Experimental Drying (PARCHED) experiment was developed to address this gap by investigating seasonal and experimental chronic drying effects in four lowland Panamanian forests that vary in background precipitation and soil fertility. We hypothesized that drying would alleviate anaerobic conditions in wetter forests to increase soil respiration, but suppress soil respiration in drier sites because of decreased decomposer connectivity to fresh C inputs and nutrients. We also hypothesized that microbial communities would be more resistant to chronic drying in drier sites compared with wetter sites, reflecting adaptation to longer, stronger dry seasons. Finally, we hypothesized that drying would promote root mortality and suppress root production most in wetter, following dry season trends. We predicted that soil fertility would be less important than background rainfall in predicting forest responses to chronic drying.

The first five years of results suggest that chronic drying will substantially alter tropical forest soil C cycling, with the largest effect differences according to soil fertility. We found that all forests initially had suppressed soil respiration with drying, but by the third year of the experiment the most fertile forest developed a positive drying effect on soil respiration. The suppression of soil respiration in infertile forests was characterized by proportionally larger losses of older soil C,

as characterized by radiocarbon measurements, potentially indicating reduced connectivity of fresh organic C inputs or nutrients to decomposers. Suppressed soil respiration with drying was also accompanied by nutrient accumulation in surface soils during the dry season. In these infertile forests, chronic drying shifted the microbial community toward a common "drought microbiome," but there were no changes in the fertile soils. Finally, chronic drying suppressed fine root turnover across sites, with fine roots contributing ~50% of soil respiration during the wet season. Together, these results indicate that chronic drying in tropical forests on infertile soils could reduce both inputs of root C to soils, and reduce soil respiration losses of C, such that net effects on soil C stocks remain unclear. The recent positive drying effect on soil respiration in the fertile forest, together with decreased root C inputs, suggests that declines in soil C stocks might be more likely in fertile tropical forests. Ongoing measurements in this experiment are being integrated with soil biogeochemical models to improve predictions of tropical forest-climate feedbacks.

The mass balance of base cations (Mg, Ca and K) and P at 14 small catchments, Czech Republic

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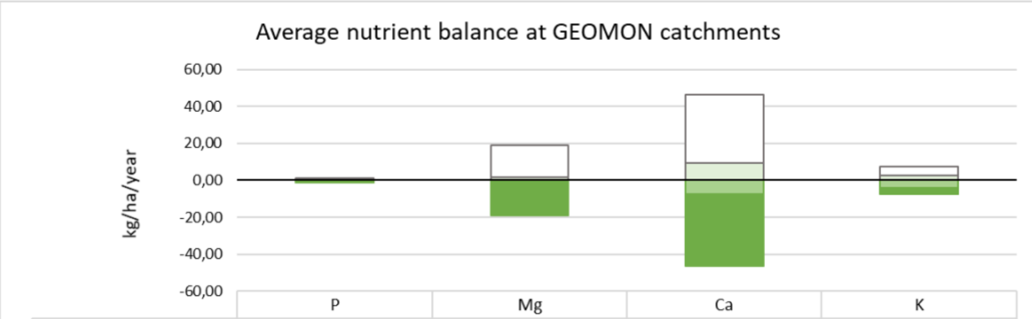
The mass balance of base cations (Mg, Ca and K) and P was assessed in the 14 long-term monitored GEOMON catchments in the Czech Republic (Oulehle et al., 2017). Measured fluxes of atmospheric deposition (average deposition for years 1994 - 2019), streamwater runoff (average for years 1994 - 2019) (Oulehle et al., 2021) and estimated annual uptake of nutrients by forest biomass were compared among the catchments and the net balance was calculated. The net balance was compared with pools of nutrients in the forest-soil profile down to 80 cm (extraction with $BaCl_2$).

Results show that runoff and uptake of studied nutrients significantly exceed atmospheric deposition. Base cations in catchments were therefore mainly supplied from rock weathering and soil sorption complex. Based on the mass balance approach, the mean soil supply accounted for 17 kg/ha/yr for Mg, 37 kg/ha/yr for Ca, 4.7 for K and 0.03 kg/ha/yr for P. The phosphorus balance is close to zero in all monitored catchments, with the exception of the LYS and MOD catchments, where there is higher soil supply demand for P (0.45 kg/ha/yr for LYS and 0.54 kg/ha/yr for MOD).

The highest soil supply demand was recorded for calcium of all studied elements. The highest required soil supply of Ca was observed at JEZ (67 kg/ha/yr) and at CER (63 kg/ha/yr). Extremely high soil supply demand of Mg is at PLB catchment with serpentinite as prevailing bedrock (81 kg/ha/yr). The second highest soil supply demand of Mg was detected at CER (27 kg/ha/yr). The highest soil supply demand of K is calculated at extremely acidic LYS catchment (13 kg/ha/yr).



	P	Mg	Ca	K
Net balance	0,03	17,21	36,89	4,71
Runoff	-0,11	-17,96	-38,69	-3,38
Atmospheric deposition	0,50	1,64	9,48	2,71
Nutrient uptake	-0,58	-0,89	-7,67	-4,05

Literature

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Effects of experimental warming and drought on gaseous carbon fluxes and the carbon balance of a Welsh raised bog

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Peatlands are important carbon sinks and stores, however this function is threatened by climate change. Experimental field studies are used to examine peatland responses to climate manipulations, but most studies are short-lived, few manipulate both temperature and hydrology, and those that do usually simulate a permanent water table change. Here we report the results of a ten year, fully-factorial climate manipulation experiment on a Welsh raised bog. We used open top chambers to passively warm plots by an average of 0.8 °C all year, and we simulated four one-month droughts (water table approximately 15 cm lower than controls) by subsurface water pumping during the summers of 2010, 2011, 2014 and 2019. We measured fluxes of CO_2 and CH_4 and calculated multi-year annual gaseous carbon budgets for each plot.

Net ecosystem exchange in the control plots averaged -221 g CO_2 m^{-2} yr^{-1}, similar to that reported from other ombrotrophic bogs. Ten years of warming combined with episodic summer drought caused the plots to switch from a net CO_2 sink to a source of 14.3 g CO_2 m^{-2} yr^{-1}. This change was due to a large increase in the rate of ecosystem respiration in the warmed+droughted plots. The warmed-alone and drought-alone treatments showed declining trends in CO_2 removal and increasing trends in respiration, but these were not significant. Methane emissions accounted for only about 5 % of total annual gaseous carbon fluxes and decreased in the warmed+droughted plots. This may relate to increases in surface aeration and small but significant increase in ericaceous shrubs, potentially affecting the soil microbial community. Since CH_4 fluxes were very low, random fluctuations in CH_4 production and consumption also cannot be ruled out.

Our study indicates that peatlands may shift from a long-term carbon sink to a carbon source in response to a moderate climate change driver of approximately 1 °C warming and summer drought at a recurrence frequency of ca 2-4 years. This expands the zone of likely negative impacts on peatland carbon storage to regions where climate change is expected to be less severe than at high latitudes. This work also emphasizes the value of long-term experiments for simulating realistic environmental change to detect cumulative and non-linear effects of environmental drivers.

Potential mobility of Cr from heavily contaminated soil

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Abstract

Soil on the territory of Buzuluk Komárov, Czech Republic, contains elevated level of chromium. This study focuses on assessing the leaching potential of this potentially toxic element (PTE). It identifies the "near total", available and leached out content of chromium and main factors affecting its mobility.

At first, basic soil properties (pH, CEC, mineralogy, organic carbon content) were determined. Two leaching experiments (batch and column) were performed in order to determine the effects that deionized water as well as citric and oxalic acids have on the dissolution of chromium from soil. Ion chromatography was used to determine the ions present in the leachates from citric and oxalic acids. Four step sequential extraction (BCR) procedure was carried out to obtain information on fractional distribution of this element in sampled soil. The investigation of soil samples showed high 2M HNO_3 extractable ("near total") content of chromium but low available content. There was a slight increase in chromium content in deionized water leachates and an observed trend of overall increasing PTE concentration in both citric and oxalic acid leachates. Organic matter content and pH appeared to be important factors affecting chromium mobility. The decrease in amount of organic matter and lower pH values seem to cause more intensive leaching of this PTE from analysed soil. Deionized water showed to be the least efficient extracting agent when compared to oxalic/citric acid. Citric acid appeared to be more effective in dissolution of chromium than deionized water as evident from Kruskal – Wallis statistics. Oxalic acid also proved to have high affinity for chromium. Fractional distribution of chromium in analysed soil was significantly changed after the column leaching experiment, however, major amount still was bound to reducible and oxidizable fractions.

Dynamic condition of the solvents appeared to enhance leaching of the PTE as opposed to the static condition in batch experiment. Concentrations of chromium in leachates are exceeding water guideline values.

Exploring Multiscale Variation in Concentration-Discharge Patterns

Jonathan Duncan, Melinda Marsh, Peter Groffman, Tony Buda

Concentration (c) -discharge (Q) analyses allow inference of catchment-scale processes that combine aspects of streamflow generation and water quality genesis, including solute source areas, flowpaths, and biogeochemical processing. Here, we explore differences in c-Q patterns at long-term watersheds thru time and at nested spatial scales. Watersheds span agricultural, forest, and urban land uses, including Mahantango Creek and Conewago Creek, Long-Term Agroecosystem Research (LTAR) watersheds, the Penn State Leading Ridge Experimental Watersheds, and the Baltimore Ecosystem Study watersheds. C-Q patterns reveal changes thru time and across spatial scales. Additionally, we find differences in c-Q slopes between composite analysis and individual events in sites with high-frequency water quality data. Multi-decadal grab sampling at Mahantango Creek's WE-38 subwatershed, conducted three times per week, reveal a clear enrichment pattern over a 36-year record (1983-2019). The long-term composite data show a decrease in peak concentrations over recent decades and that slopes across all time periods are impacted by both low and high flow conditions in wetter vs. drier years. We also analyze dissolved inorganic nitrogen c-Q patterns at Conewago Creek, a larger, mostly agricultural watershed. Conewago Creek has two gaging stations that have been less intensively sampled between (2012-2022). Temporal trends in c-Q patterns diverge between upper and lower stations. Baltimore Ecosystem Study watersheds were sampled weekly (1998-2018) and span an urban gradient. Seasonal patterns of c-Q patterns change with increasing scale. While land use change has been minimal in these urbanized watersheds, sewer infrastructure and stormwater controls have increasingly been implemented. Leading Ridge, PA is a forested watershed that has been sampled approximately weekly from 1972-2007 and from 2018-current. In the forested watersheds, including Pond Branch, MD and Leading Ridge, PA, changes in c-Q patterns are notable thru time and are poorly correlated with reductions in atmospheric deposition. In sum, these results suggest other controls beyond hydroclimatic variability on the temporal dynamics of c-Q relationships, including watershed management effects. Changing cQ patterns thru time and across spatial scales have implications for process level inference and future water quality sampling design.

Geochemical fingerprints of flood dynamics from an artificial extreme event on the Allegheny River

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Extreme events are important components of natural river flow regimes as they maintain the health of river ecosystems. For example, extreme high flows are necessary for maintaining aquatic habitats by flushing fine sediments from mussel beds. Moreover, flood inundation of riparian ecosystems is essential for the exchange of water, sediment, nutrients, and biota between the aquatic and terrestrial environments during floods. These floods are also essential to the health of riparian ecosystems which rely on frequent disturbance to prevent the over-growth of woody plants and maintain riverscour habitats. However, human alteration of rivers for flood control, including the installation of dams, homogenizes downstream flow regimes by preventing extreme high and low flows.

In this study, we evaluate the biogeochemical fluxes stemming from the first experimental spring flood conducted by the U.S. Army Corps of Engineers on the Allegheny River (Pennsylvania, USA). Flooding was initiated on March 30, 2023 by sustained releases of 450 cms for 17 hours from the Kinzua Dam and the Allegheny Reservoir. We hypothesized that the spring pulse would initially release organic rich sediment and nutrients stored behind the Kinzua Dam, and that the "geochemical fingerprint" of water will change as the flow eventually scours the channel and riparian areas. To quantify the impact of the pulse event on downstream biogeochemistry, we collected hourly grab samples from a site 5 km downriver of the Kinzua dam over a 48 period that spanned pre- and post-pulse. Grab sample chemistry including fluxes of dissolved, organic and total nutrients, as well as total suspended sediments and nitrate isotopes, are evaluated here. Our results are put in the context of flood events and material fluxes reported for extreme events in other river systems.

Microbial community dynamics and N2O-related genes responses to short-term flooding in riparian forest soil

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The growing interest in the impact of short-term floods on various ecosystems is driven by climate change and the increasing occurrence of extreme rainfall events. The control of nitrogen quantity and distribution relies on complicated biogeochemical processes. Yet, our understanding of the microbial processes governing nitrogen cycling needs to be improved, hindering our ability to estimate the effects of climate change on forests.

This study aimed to evaluate the influence of short-term flooding on bacterial, archaeal and fungal communities and nitrogen cycle processes with nitrous oxide (N_2O) emissions in riparian alder forests.

Topsoil peat samples were collected from riparian alder forests in 2017 and 2018. Real-time polymerase chain reaction (qPCR) and sequencing techniques were employed to assess processes and communities, while physicochemical parameters and in-situ N_2O emissions were concurrently measured. Genetic potential of nitrogen transformation processes was evaluated by targeting the following functional genes: *nirS*, *nirK*, *nosZ* clade I and *nosZ* clade II (denitrification); *nifH* (N2 fixation); *nrfA* (dissimilatory nitrate reduction to ammonium, DNRA); bacterial, archaeal and COMAMMOX (complete ammonia oxidation) *amoA* (nitrification); and n-damo(nitrate/nitrite-dependent anaerobic methane oxidation)-specific 16S rRNA.

The results indicated a significant impact of short-term flooding on the abundance of bacteria, particularly those harbouring archaeal *amoA*, n-damo-specific 16S rRNA, and *nosZII* genes. Furthermore, several associations were observed between marker genes of the nitrogen cycle and N2O emissions. The bacterial and fungal communities showed a shift in the community because of the short-term flooding. Sudden changes in soil moisture influenced the patterns of marker genes of nitrogen cycle processes and microbial communities.

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Title: How disturbing: The effects of anthropogenic disturbance on soil health, productivity, and plant community makeup in tropical and subtropical systems

Early humans started farming about 6000 ya, which many consider the start of the Anthropocene, a new era defined by human influence on natural systems. Today, the climate is changing faster than ever, yet we still need to feed the growing population and conserve land to coexist with other species. Is there an achievable balance between both of these objectives? Here, we applied the community ecology concept of the intermediate disturbance, which hypothesizes that moderate disturbance levels can increase species richness and soil health. In this study, we created an anthropogenic disturbance index (0-100) by compositing multiple disturbance indicator ratings (e.g., land use history, tillage intensity, vegetation removal, etc) measured across a range of land uses in the Kula region of Maui, Hawai'i. We then evaluated the relationship between anthropogenic disturbance on soil health, measured using the Hawai'i Soil Health Index (ranging from 0-1), across the different land uses. We found that disturbance levels and soil health varied, with disturbance index scores ranging from 0 to 72 while soil health scores ranged from 0.02 to 0.88. Our findings do not fully support our intermediate disturbance hypothesis given that health scores decreased dramatically after a certain level of disturbance was reached, which was all associated with annual croplands. Overall, we found that disturbance levels were

dependent on the land use types (shrubland, high-elevation pastures, low-elevation pastures, and croplands) in our study ($p<0.001$)--with croplands having the highest level of disturbance; shrublands, the lowest; and no statistical difference between the two pasture types. Better understanding of the impact of specific disturbance indicators might help us determine what actions separate this intensive land use from others and better understand the implications of disturbances made through our management and conservation efforts on soil health. This will help us identify management practices that may establish resiliency, safeguard the soil and plants we work with from the effects of climate change, and provide ecosystem services such as nutrient cycling and carbon sequestration.

Title:

Methane Dynamics in the Illinois Waterway from Lake Michigan to the Confluence of the Mississippi River: Contrasting Seasonal Patterns of Methane in Urban and Agricultural Environments

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Abstract:

The 541-kilometer-long Illinois Waterway is a highly managed, navigable system of rivers, canals, and series of locks that connect Lake Michigan with the Mississippi River. Its watershed encompasses densely populated urban areas (e.g., Chicago, Illinois) and intensively managed agricultural regions of the Midwestern United States. Using a boat-mounted, mobile-sensor platform, dissolved methane (CH_4) and related water-quality physiochemical properties were sampled at a frequency of 1 hertz, and a spatial resolution of approximately 1 sample every 12 meters, along the entirety of the Illinois Waterway. In total five different field sampling campaigns were completed from May 2022 to July 2023. Dissolved CH_4 concentrations were consistently elevated in the upper Illinois Waterway within the urban areas of greater Chicago, ranging from 1.14 micromoles per liter (µmol/L) to very high levels reaching 11.9 µmol/L. Elevated dissolved CH_4 (2.69 µmol/L) at relatively low water temperatures (<10 degrees Celsius) measured during the March–April sampling indicates a fluvial ecosystem that is more responsive to its watershed and lateral inputs than to internal drivers such as water temperature. This persistently elevated CH_4 in an urban waterway is likely heavily influenced by population density, human activities, and urban infrastructure. While CH_4 concentrations tended to decrease below outfalls of treated wastewater effluent, untreated wastewater released during combined sewer overflows resulted in elevated CH_4 concentrations in the waterway. In contrast, CH_4 concentrations in agricultural reaches had a discernible seasonal pattern, with concentrations peaking during the summer months aligning with elevated water temperatures and lower discharge conditions. This seasonality indicates fundamentally different controls of CH_4 in agricultural landscapes, potentially linked to agricultural practices. Other influences include tributaries, and the hydrologic connectivity of wetlands and backwater sloughs adjacent to the Illinois Waterway. The divergent CH_4 concentration patterns observed across the Illinois Waterway highlight the importance of anthropogenic influences, internal controls, hydrology, and land management practices in influencing CH_4 concentrations and emission to the atmosphere. These spatial-temporal data can be used to identify and quantify distinct sources of CH_4 and aid modeling of

greenhouse gas emissions from riverine ecosystems and the resultant contributions to the carbon budget in the Illinois Waterway.

Disentangling nitrogen's role as a limiting nutrient and acidifier: how does nitrogen availability affect soil respiration?

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Soil respiration (Rsoil) is the second largest terrestrial carbon flux, vastly exceeding fossil fuel emissions. It is composed of two separate fluxes: autotrophic respiration (Ra), driven by plant respiration, and heterotrophic respiration (Rh), which comes predominantly from microbial decomposition. Many studies have demonstrated that increasing nitrogen (N) availability can suppress Rsoil, but the mechanisms underpinning this response are difficult to discern, because each component flux can respond differently to changes in N availability, through its roles as a limiting nutrient and as an acidifying agent. As a limiting nutrient, increasing N availability could reduce plant belowground carbon allocation to roots (Ra) and microbial symbionts; however, supplying N to nutrient-limited soil microbes inhabiting carbon rich soil layers could offset this effect by increasing saprotroph biomass (Rh). Alternatively, as an acidifying agent, N may decrease soil decomposer biomass and increase belowground carbon allocation if acidification reduces availability of other nutrients. Here, we test these hypotheses by measuring respiration fluxes from fixed collars (Rsoil) and from lab-incubated soils separated by depth (Rh) in a replicated, ten-year N x pH manipulation (+N, +pH; +N, -pH; -pH; control) study in mixed temperate forests in central New York, USA.

Acidifying N additions led to large reductions in Rsoil (19%, 2.2 t C ha-1 yr-1), and decreased forest floor Rh (per unit soil mass). In contrast, acidification alone had no effect on Rsoil, but produced large increases in Rh in mineral soils. De-acidifying N additions did not significantly affect Rsoil or Rh, but effects trended towards suppression rather than enhancement. When considered per unit area, both Rh and Rsoil decreased sharply with increasing soil N availability, but showed little response to soil pH across all treatments. However, within acidification treatments, Rsoil and mineral soil Rh decreased with increasing acidity. We anticipated that acidification would impact Rsoil by reducing Rh and increasing Ra, but surprisingly found that acidification alone stimulated Rh in mineral soil, perhaps reflecting long-term accumulations of carbon in surface mineral soils. Overall, our findings suggest that increased N availability suppresses Rsoil through nitrogen's role as a limiting nutrient for both plants and heterotrophic microbes and that N-driven acidification can contribute to this effect by suppressing microbial activity in surface soil layers.

Using FALCON an array of artificial catchments to study the role of surface heterogeneity on erosion and other ecosystem procese in early stages of ecosystem development

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This study combines results from a series of artificial catchments FALCON and two chronosequences of rehabilitated and unrehabilitated post-mining landscapes near Sokolov (Czech Republic). All study sites were formed by the deposition of post-mining overburden consisting of Miocene clays impregnated with carbonates and fossil organic matter (kerogen). Each chronosequence consists of four sites and covers the first 65 years of ecosystem development. FALCON was established in 2019 and allows the first stages of ecosystem development to be studied in detail. It consists of four parallel catchments (0.25 ha each) that are completely isolated hydrologically. Two catchments are rehabilitated and two are not, as is common in the region, copying the approaches used at the sites of the rehabilitated and unrehabilitated chronosequences. The remediated areas were leveled and planted with alders, while no action was taken in the non-remediated areas where the longitudinal undulations created by the fill remain. In the remediated areas, alders formed a closed canopy in the 10-15 year old areas. In unrehabilitated areas, sheath willow, birch, and aspen are the predominant trees colonizing the areas and forming a closed canopy in the 15-25 year old areas.
Detailed surface change studies using erosion pins and 3D terrain models created using drones show that the surface area in the undulating areas is decreasing more than in the apartment areas, while sediment loss measurements show no difference between the apartment and undulating areas. In wavy areas, there is a great heterogeneity in the erosion process. The upper part of the undulations is heavily eroded, while the eroded material accumulates in the depression. The depressions contain more silt and clay material, have higher water retention and lower infiltration rates, while the opposite is true for the elevated wave tops. Studies along the chronosequence also show that the elevated portion of the waves retain portions of the original mudstone that are more resistant to weathering, such as pelocarbonates. These stone-like parts of the mudstone provide the safe spaces for woody vegetation to colonize. In contrast, the vegetation in the depressions between the waves is dominated by grasses. The study shows that vegetation establishment depends on the formation of microsites with specific soil conditions created by surface processes in the initial phase of ecosystem development. Surface heterogeneity affect also proportion of surface and subsurface runoff and quality of run off water.

Broadleaf and conifers and their interaction with soil biota play contrasting role in soil C sequestration at various stages of pedogenesis

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Soil has contains three times more C than the atmosphere and biosphere combined. and play an important role in the carbon (C) cycle.
Soil organic mater (SOM) cam be roughly divided into two pools. The first pool is referred as free particulate organic matter (FPOM), the other pool is comprised of microbial necromass, associated with soil mineral matrix, so called mineral associated organic matter (MAOM). It is assumed that MAOM becomes C saturated during soil development because it is limited by the amount of available mineral surfaces. FPOM, on the other hand, does not saturate and can therefore play an important role in later stages of soil development. Supplying easily decomposable litter may support buildup of MAOM when soil is not C saturated. Earlier studies show that in soil in early stages of decomposition more C is stored in soils supplied by easily decomposable litter (namely broadleaf litter with low CN ratio) while in mature soils conifers producing les decomposable litter with high CN ratio stores more C.
We tested hypothesis that MAOM is supported by providing litter with low CN ratio in early stages of pedogenesis while C storage in POM and forest floor is supported by litter with have propose that earthworm bioturbation may support C storage in unsaturated soils only. To do so we analyze forest floor and C storage in soil and amount of C in FPOM and MAOM using two types of soils - spoil heap (immature soil in early stages of pedogenesis) and forest soil in the surrounding area (mature soil). Replicated plots with only one type of tree species (spruce or alder) in 3 replications were present on each of these soil types. Our results show that different tree species have different effects on the amount of C stored in mineral soil and forest floor (Oe layer) in immature and mature soils. In mineral soil more, C was sequestered under alder on immature soil, while in the mature soil more C was sequestered under spruce. In forest floor more, C was sequestered under spruce in both types of soils. Soils did not differ in the amounts of FPOM and MAOM present in soil, but they did differ in the amount of C stored in these fractions. MAOM stored significantly more C in Immature soils than in forest soil but for FPOM no difference was observed between the two types of soils. Separate manipulation experiments show that earthworm bioturbation may support C storage in soils which are not C saturated.

Patterns of stream water N and P concentrations during a high-flow event in northern hardwood forested headwater catchments

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The chemistry of forested headwater streams often changes during high-flow events due to changes in flowpaths that more directly connect shallow soils with the streams. The magnitude and duration of the changes in stream chemistry can strongly affect leaching of nutrients such as nitrogen (N) and phosphorus (P) and may differ based on various factors, including soil factors such as depth and antecedent conditions, and forest factors such as vegetation composition and management. We are collecting and analyzing high-flow event stream water samples from paired headwater catchments at the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire USA. These catchments are similar in terms of their soils, slope, aspect, and northern hardwood species composition, but differ in their age (100+ year-old mature forest vs. a 50-year-old regrowing forest). We will present analyses focused on major solute chemistry, including total dissolved N and nitrate, and total P and soluble reactive P. We expect the data to show increases in N and P concentrations with increasing flow as these nutrients are flushed from the forest floor or shallow mineral soils. We will be investigating whether the concentration-discharge relationships differ between the catchments based on the forest age, with a central hypothesis being that nutrient availability may be lower overall in the soils of the regrowing forest, leading to less pronounced increases in leaching with increasing flow. The importance of understanding controls on nutrient leaching in headwater streams is likely to become increasingly important as downstream systems face ongoing eutrophication issues and work to meet certain water quality targets.

Seasonal Drivers of the Carbon Budget in Lake Erie's Western Basin

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The Western Basin of Lake Erie is highly eutrophic and subject to seasonal harmful algal blooms (HABs), largely driven by nitrogen and phosphorus runoff from the surrounding landscape. While the phosphorus and nitrogen dynamics in Lake Erie have been extensively studied, this region is also a likely hotspot for carbon transformation. To investigate the seasonal and spatial variability in inorganic and organic carbon budgets, we completed three field surveys, in spring, summer, and fall on a transect across the Western Basin from the Maumee River to South Bass Island. In all three surveys we observed higher spatial variability of dissolved inorganic carbon, dissolved organic carbon, and particulate organic carbon within 11 km of the Maumee River mouth relative to sites outside of Maumee Bay, driven by pulses of direct riverwater carbon, steep nutrient gradients, and patchy bloom conditions. Seasonal variability was also greatest within Maumee Bay, with the highest river discharge in June adding particularly large amounts of dissolved inorganic carbon and spurring pCO_2 flux out of the water at sites where the Diatom bloom had not yet transformed the carbon. In August, when and where we observed a dominantly Microcystis bloom, particulate organic carbon increased in concentration and dissolved organic matter chemistry indicated more fresh algal sources. In October, Chlorophyll a concentrations and oxygen saturation were lowest, indicating the seasonal slowdown in productivity, and river discharge is the lowest, resulting in minimal terrestrial input and the lowest observed total carbon. Outside of Maumee Bay seasonal and spatial carbon budget dynamics are much more seasonally stable, but some variation was observed closer to South Bass Island where there is more riverine input, highlighting the importance of riverine inputs on lake carbon budgets.

Spatial and Seasonal Variability of Dissolved Organic Matter and Nitrogen in Lake Erie Tributaries

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Dissolved organic matter (DOM) is an important constituent of the global carbon cycle and plays a critical role in many biogeochemical processes. The biogeochemical function of DOM is dependent on both its concentration and chemistry, which varies between watersheds and over time. For example, watershed characteristics such as watershed area, land use, soil type, and bedrock type can all influence DOM. To better understand how watershed characteristics and seasonality drive the concentration and chemistry of DOM in watersheds that drain into Lake Erie, we synoptically sampled 82 tributaries along the US coast of Lake Erie in fall, early spring, late spring, and summer to target different hydrologic domains. We chose tributaries with a range of watershed sizes and land uses to try to identify watershed controls on DOM exported into Lake Erie. Water samples and sensor measurements were taken near each stream's point of discharge to the lake. We measured the concentration of dissolved organic carbon (DOC), total nitrogen, and anions, and used UV-Vis and fluorescence spectroscopy to measure DOM chemistry. Spatial and seasonal variability were observed between watersheds of individual streams in the eastern and western portions of the broader Lake Erie watershed. Watersheds in the western half are largely dominated by intensive agricultural land use, while land use in the eastern portion has higher forest cover. DOC concentrations were generally higher, with greater seasonal variation, in streams in the agricultural western half of Lake Erie watersheds than eastern watersheds. BIX, a fluorescence index which indicates more freshly produced DOM from autochthonous sources, trends lower with a greater percentage of forest cover in a watershed. This means there is a smaller proportion of microbially created DOM in streams with greater forest cover, potentially due to lower availability of nutrients and light limiting photosynthesis. Samples collected in the western half of Lake Erie watersheds also exhibited highest total nitrogen concentrations in May, followed by March, while samples collected in the east had relatively consistent total nitrogen concentrations regardless of season. These results indicate that land use heavily controls the export of both carbon and nitrogen from watersheds in the Lake Erie basin and could be used to guide predictions of future nutrient export in the changing Anthropocene.

Title: Drying and rewetting of riverbed sediment shifts DOM thermodynamics and influences sediment respiration rates

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Abstract (400 words maximum):
River corridors experience natural and anthropogenic disturbances including floods, droughts, wildfire, land-use changes, and water use and management. With the changing climate, disturbances have increased in frequency and intensity. River corridor biogeochemical processes and dissolved organic matter (DOM) composition are susceptible to changes in flow regimes and variable inundation conditions, yet the mechanisms behind these biogeochemical impacts are rarely studied and are not represented in Earth system models. As over 60% of global rivers experience at least one dry day per year, and intermittent rivers are on the rise in the United States, it is crucial to investigate the mechanisms associated with the effects of drying on key biogeochemical processes like sediment respiration rates and DOM composition across diverse river ecosystems. Here, we apply DOM thermodynamic theory to investigate the effects of drying and rewetting on sediment DOM composition and respiration rates across 53 sites in the contiguous United States. Specifically, we conducted laboratory manipulative experiments with sediments from each site where one treatment was allowed to remain inundated, and the other treatment was allowed to dry over the course of 21 days. Both treatments were then fully saturated with native riverine water and aerobic respiration rates were measured noninvasively using optodes. Samples were collected for ultra-high resolution mass spectrometry analysis post respiration measurements. We investigated the effect of drying on DOM chemistry (i.e., DOM properties, elemental composition, chemical classes) and thermodynamics (i.e., Gibbs free energy and lambda) and the effects of these changes on respiration rates. We hypothesize that DOM thermodynamic metrics in the dry treatments will be lower than the wet treatments and that these shifts in thermodynamics will be linked to cold moments in respiration rates. By understanding how drying affects DOM chemistry and thermodynamics we can generate mechanistic inferences regarding the effects of stream intermittency in global biogeochemical cycles.

Title. Revealing basin-scale metabolism drivers via model-experiment integration

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Abstract (400 words maximum):
Inland waters contribute significant amounts of carbon dioxide (CO2) to the atmosphere. In particular, river corridors generate CO2 emissions larger than lakes and reservoirs combined. Carbon cycling in rivers has been widely studied via two key processes: carbon fixation (Gross Primary Production, GPP) and organic carbon mineralization (Ecosystem Respiration, ER), which together constitute river metabolism. These estimates are commonly derived from diel dissolved oxygen measurements, which encompass the collective aerobic organisms (including autotrophs and heterotrophs) and habitats (such as benthic, planktonic, and hyporheic zones). While river metabolism is influenced by the interaction of several biotic and abiotic factors across habitats, commonly used models like the Networks with Exchange and Subsurface Storage (NEXSS) and the River Corridor Model (RCM) assume that hydrologic exchange is the primary driver of metabolism and thus focus only on simulating riverine sediment (hyporheic) respiration rates across scales. Here we evaluate the role that physical, chemical, and biological processes have on riverine metabolism and sediment respiration via model-experiment integration (ModEx). To do this, we test a hypothesis derived from process-based model results which states that hydrologic exchange is the key driver of sediment respiration at the basin scale. We test this hypothesis by comparing RCM model predictions at the basin scale with measured sediment respiration rates across 48 sites in the Yakima River Basin (YRB). We found no qualitative or quantitative correspondence between our observed respiration rates associated with sediments and the respiration rate predictions from the physical model. One potential reason for the lack of correspondence between observed and predicted respiration rates is that respiration within the physical model is limited to the hyporheic zone. Our measurements of sediment respiration integrate processes from benthic, planktonic and hyporheic zones that are hydrologically connected to the active channel. The field measurements, therefore, include additional processes that are not represented in the physical model. Our observed-predicted comparison does not, therefore, reject the model. Instead, the lack of correspondence indicates there are important processes not represented in the model and the processes that are represented do not strongly drive spatial patterns of in situ respiration. Collectively, our results contribute to the existing conceptual understanding of river sediment respiration by addressing previously unexplored ModEx relationships across scales.

Partial mycoheterotrophy in the understory of a tropical forest in Panama: A multi-element stable isotope natural abundance approach

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Currently, an intensive and controversial discussion about the existence and relevance of common mycorrhizal networks in forests is going on (Karst *et al.*, 2023; Klein *et al.*, 2023). This discussion mostly focusses on the existence or non-existence of an organic carbon exchange between trees mediated by a network of mycorrhizal fungi and completely ignores the existence of several hundreds of fully mycoheterotrophic plant species mostly thriving in forest understories. Fully mycoheterotrophic plants are mycorrhizal, but simultaneously leafless and achlorophyllous and therefore rather obviously require organic carbon supply through their mycorrhizal fungi from neighbouring autotrophic plants. Mycoheterotrophic plants are the ultimate positive control supporting the existence of mycorrhizal networks. Mycoheterotrophic plants developed evolutionary from photosynthetic anchestors. Thus, also a mycoheterotrophic carbon gain by photosynthetic plant species closely related to mycoheterotrophic plants has to be postulated and was, indeed, found among forest orchids (Gebauer & Meyer, 2003) and Ericaceae (Zimmer *et al.*, 2007). This kind of simultaneous carbon gain from own photosynthesis and from a fungal source is now known as partial mycoheterotrophy. Recently, partial mycoheterotrophy was also identified among photosynthetic temperate forest ground plants forming the *Paris*-morphotype of arbuscular mycorrhiza (Giesemann *et al.* 2020; 2021). This latter finding initiated our most recent search for the occurrence of partial mycoheterotrophy among young tree saplings in the understory of a tropical forest in Panama. Using stable isotope and microscopic techniques, we examined whether common shade-tolerant tropical tree and shrub species are partially mycoheterotrophic as saplings. Own observations of fungal morphology within plant species (n=40) disagreed somewhat with the literature (Dickson *et al.*, 2007), indicating the demand for *in situ* determination. Enrichment in the heavy isotopes ^{13}C, ^{2}H and ^{15}N (cf. mycoheterotrophic *Voyria*) relative to surrounding plants reflected a significant partial mycoheterotrophic nutrition of at least one *Paris*-type target species (*Anacardium excelsum*). Some further tree sapling species provided some evidence towards partially mycoheterotrophic nutrition that has to be confirmed with further investigations.

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Soil carbon stock surprises over three decades after liming

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Calcium availability can affect a range of plant, soil, and microbial processes that together can alter carbon storage in forest soils at decadal or longer timescales. A catchment-scale liming experiment initiated in 1989 in the Adirondack Mountains, New York, USA has yielded several surprising long-term responses. Contrary to expectations, twenty years after liming, surface forest floor carbon stocks in limed soils roughly doubled those in unlimed plots, even as liming had no effect on woody biomass production or plant litterfall. Initial indications of suppression of decomposition were supported by subsequent measurements of microbial community composition and function that showed that liming suppressed the abundance of the fungal decomposers associated with lignocellulose degradation, especially woody saprotrophs and the dominant ectomycorrhizal guilds.

New measurements in 2021 examined the long-term responses of fine root dynamics as well as changes in plant and soil carbon stocks. Liming suppressed fine root production across all surface soil horizons (Oe, Oa, 0-10 mineral), even as fine root biomass (live + dead) shifted upward, increasing in Oa horizons and decreasing in 0-10 horizons relative to controls soils. These changes in fine root biomass (live + dead) are best explained by suppressed decomposition rather than changes in fine root production.

Thirty-two years after liming, surface soil carbon stocks in limed soils continue to exceed those in unlimed soils, showing persistent enhancement over multiple decades. However, carbon inventories in both limed and unlimed soils declined by roughly 30% over the twelve years since they were last measured. Similar declines in other temperate forest sites have been attributed to increased soil heterotrophic activity in soils recovering from historic acid deposition. However, the parallel declines of soil C in both limed and unlimed plots suggest that other mechanisms may be more important, such as increased priming of decomposition by plants in need of other limiting nutrients, or warming temperatures.

Soil respiration (Rsoil) is the second largest terrestrial carbon flux, vastly exceeding fossil fuel emissions. It is composed of two separate fluxes: autotrophic respiration (Ra), driven by plant respiration, and heterotrophic respiration (Rh), which comes predominantly from microbial decomposition. Many studies have demonstrated that increasing nitrogen (N) availability can suppress Rsoil, but the mechanisms underpinning this response are difficult to discern, because each component flux can respond differently to changes in N availability, through its roles as a limiting nutrient and as an acidifying agent. As a limiting nutrient, increasing N availability could reduce plant belowground carbon allocation to roots (Ra) and microbial symbionts; however, supplying N to nutrient-limited soil microbes inhabiting carbon rich soil layers could offset this effect by increasing saprotroph biomass (Rh). Alternatively, as an acidifying agent, N may decrease soil decomposer biomass and increase belowground carbon allocation if acidification reduces availability of other nutrients. Here, we test these hypotheses by measuring respiration fluxes from fixed collars (Rsoil) and from lab-incubated soils separated by depth (Rh) in a replicated, ten-year N x pH manipulation (+N, +pH; +N, -pH; -pH; control) study in mixed temperate forests in central New York, USA.

Acidifying N additions led to large reductions in Rsoil (19%, 2.2 t C ha-1 yr-1), and decreased forest floor Rh (per unit soil mass). In contrast, acidification alone had no effect on Rsoil, but produced large increases in Rh in mineral soils. De-acidifying N additions did not significantly affect Rsoil or Rh, but effects trended towards suppression rather than enhancement. When considered per unit area, both Rh and Rsoil decreased sharply with increasing soil N availability, but showed little response to soil pH across all treatments. However, within acidification treatments, Rsoil and mineral soil Rh decreased with increasing acidity. We anticipated that acidification would impact Rsoil by reducing Rh and increasing Ra, but surprisingly found that acidification alone stimulated Rh in mineral soil, perhaps reflecting long-term accumulations of carbon in surface mineral soils. Overall, our findings suggest that increased N availability suppresses Rsoil through nitrogen’s role as a limiting nutrient for both plants and heterotrophic microbes and that N-driven acidification can contribute to this effect by suppressing microbial activity in surface soil layers.

Dissolved Organic Matter Composition in Three Urbanized Streams

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Urbanization has induced rapid physical changes to rivers and introduced novel inputs that have the potential to alter the transport and transformation of nutrients including carbon. Dissolved organic matter (DOM) plays an important role in many biogeochemical cycles and both its composition and chemistry are heavily influenced by watershed characteristics including soil type, climate, and hydrology. DOM is also known to be altered by anthropogenic inputs such as persistent organic pollutants. To understand how urbanization could impact DOM, we chose three urban headwater streams with a range of land cover (ex. suburb, industry, golf course, parkland) and collected monthly baseflow samples from 8-10 locations over the course of one year. Samples sites were chosen based on changes in land cover or water chemistry (i.e.; conductivity, temperature) observed when scouting locations. Water samples were collected for common anions and cations as well as DOM analysis and sonde measurements of conductivity, temperature, dissolved oxygen, and FDOM were taken at each location. DOM composition and concentration was analyzed via fluorescence and dissolved organic carbon (DOC) analysis. The two streams with more intensely urbanized watersheds, including commercial and industrial land use, had higher temperatures and DOC concentrations and greater variability in chemistry across the year. DOC concentrations decreased after ponds and remained more stable than upstream. Total nitrogen in the more industrial/suburban stream jumped during early spring. Streams consisting of shale substrate showed less variability in DOC and conductivity than stream reaches consisting of glacial outwash. Overall, we found that urbanization and anthropogenic manipulation of streams was associated with greater seasonal variability in temperature, conductivity and dissolved organic matter across the streams with constructed ponds acting as a filter on concentrations of dissolved organic matter.

Title: Warming alters solute concentrations and fluxes from peatland streams

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Abstract:
Northern peatlands are high-carbon, nutrient-limited ecosystems that are vulnerable to climatic and environmental change. We examined how warming may affect peatland stream solute concentrations and fluxes within the SPRUCE (Spruce and Peatland Responses Under Changing Environments) experiment. SPRUCE is examining the effects of warming (+0, +2.25, +4.5, +6.75, +9°C) and elevated CO_2 (+500 ppm) over 10 years using a whole-ecosystem manipulation in an ombrotrophic bog in northern Minnesota (USA). Warming is added both above and belowground within ten 12-m diameter, 8-m tall enclosures installed in the peatland. A belowground corral hydrologically isolates each plot, and two lateral, slightly sloped, slotted pipes installed in the near-surface peat allow for lateral, passive drainage of water akin to stream flow. The pipes drain into a subsurface basin, which is equipped with a water-level sensor to estimate stream flow. An automated sampler collects flow-weighted water samples from the subsurface basin (before the water reaches the reservoir where water level is measured). Water samples are retrieved weekly and analyzed for a suite of solutes, including total organic carbon (TOC), inorganic and total nutrients, anions, cations, and metals. After 7 years of warming, the most notable change in stream water chemistry was a large increase in TOC concentrations with warming, from 52 mg/L (+0°C enclosures) to 87 mg/L (+9°C enclosures), likely due to warming-induced increases in peat mineralization and leaching of recently produced photosynthate. While TOC concentrations have increased with warming, stream flow has decreased, likely due to increased evapotranspiration, resulting in an overall decrease in the efflux of TOC from the peatland. In contrast to the response of TOC to warming, the response of nutrients has been minimal, possibly because of rapid microbial and vegetative uptake of mineralized nutrients in this nutrient-limited ecosystem. Our findings to date suggest that climate change may alter the chemistry and volume of stream water flowing from peatlands, with potential cascading effects to downstream ecosystems.

Differences in watershed-level event scale dynamics of stormwater nutrient concentrations with changes in urban forest of Saint Paul, Minnesota, USA

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Concerns surrounding urban water management continue to grow with increasing urbanization and extreme weather events due to climate change. Issues such as flooding, nutrient pollution, and declining water quality of recreational lakes cause concerns for public health and safety and protection of infrastructure. Trees are frequently considered to influence stormwater quantity and quality and have high urban stormwater management potential. Due to urban development and redesign, resident preferences, or the land use history of an area, tree canopy cover and diversity can vary across a city and therefore provide variation in the efficiency of stormwater management. Data and place-based studies focused on the specific, measurable effects of trees on urban watersheds will support more resilient urban planning and further define the benefits and trade-offs of including trees in urban watersheds.

Compared to natural systems, urban areas have a multitude of different contaminants and high variation in contaminant loads. The high density of impervious surfaces and diverse land uses in cities typically elevate contaminants in stormwater. Little is known about how changes in urban forests could affect event scale dynamics of nutrient concentrations in urban watersheds. Current studies are being done as part of long-term ecosystem research examining water and nutrient fluxes associated with urban trees. We aim to further elucidate the tradeoffs of trees in urban systems (eg. leaves filter atmospheric deposition, but can pollute waterways when they fall) through the collection of bi-directional data of water use and nutrient flows.

In this study, we examine if stormwater nutrient exports are sensitive to changes in urban tree canopy cover and the fraction of canopy comprised by street trees in selected watersheds in Saint Paul, MN. Through coupling remote sensing and tree inventory-based estimates of tree canopy cover with historical measurements of urban discharge quantity and quality, we evaluate the relationship between urban tree cover and stormwater quality between the years of 2007 - 2022.

Title: Scenarios assessing the effects of land-use change, forest management, and climate change on Puget Sound hydrologic regimes and freshwater habitat quality.

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Abstract

Across the Pacific Northwest late summer stream temperatures are increasing while stream flows are becoming extremely low. Stream nutrient and contaminant loadings from diverse sources are also on the rise. These environmental shifts have direct impacts on aquatic systems and all pose a rising threat to the health of human communities and aquatic life (e.g., populations of Coho Salmon, Chinook Salmon, and Orca listed under the Endangered Species Act (ESA)). We are applying the ecohydrology model Visualizing Ecosystem Land Management Assessments (VELMA) as an ecosystem services tool to help inform mitigation of these effects. VELMA simulations can estimate impacts from climate change, land-use change, and other increasingly frequent extreme events. Extending from existing regional Tribal and partner experience with VELMA, we are co-developing best management practices (BMPs) through watershed scale simulations that estimate the long-term impacts from changes in land-use change and climate.

A recently initiated multi-institutional modeling effort called Puget Sound Integrated Modeling Framework (PSIMF) has been launched to identify practical, proactive watershed restoration strategies that can be started now to lessen long-term extreme impacts of climate and land-use change on Puget Sound communities. This research includes coupling of the University of Washington's Land Cover Change Model (LCCM) to provide dynamic land-use change inputs to VELMA. VELMA simulations being developed under PSIMF address projected trends for years 2024 through 2100 for landscape scale disturbances including: 1) historic forest management and fires, 2) land-use change (i.e., forestry to agricultural, and agricultural to urban), 3) projected forest fires frequency and intensity and alternative forest management practices, and 4) applies representative concentration pathway (RCP) 4.5 and RCP 8.5 climate change projections out to 2100.

Presented here are Snohomish River watershed (4807 km^2) results comparing simulated to observed watershed discharge and nutrient loadings between 1990 and 2023. Also presented are alternative scenario results aim to assess aquatic systems and human health impacts. This effort aims to inform remediation, restoration, and revitalization (R2R2R) toward all Puget Sound communities but is particularly pertinent to tribal communities and the salmonid populations essential to their sustenance, health, and culture. The broader focus of this work targets 24 Salish Sea salmonid-bearing watersheds that the tribes and State of Washington co-manage for salmon recovery and habitat protection. Through the PSIMF effort we aim to mitigate the impact of these trends and extreme events on Puget Sound aquatic systems and expanding human population.

2024 Biogeomon

Title: Coupled biogeochemistry modeling in the ELM-FATES modeling for understanding tropical forest regrowth dynamics

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Abstract:

Nutrient control of productivity, allocation, and turnover is a critically important issue in tropical forests, which are for the most part located on highly weathered soils that are deficient in essential plant nutrients. Due to the importance of tropical forests in their global carbon sink potential, understanding and correctly representing both nutrient controls and disturbances within ecosystem models is required. However, how plant nutrient availability regulates carbon allocation is a key source of uncertainty in model predictions of tropical forest responses to environmental change.
Most current Earth System Models are limited in ecological detail and realism (e.g., ecosystem structure, demography, and disturbances). Failing to mechanistically represent mortality, recruitment, and disturbance limits the ability of these models to realistically forecast ecosystem responses to future climate stressors. To be able to accurately predict these complex ecological processes we use the vegetation demographic model FATES (Functionally-Assembled Terrestrial Ecosystem Simulator) that is coupled to the land surface model ELM. We present here an overview of the newly implemented representation of nutrient competition, acquisition, and extensible approach of nutrient and carbon allocation within plants, that has coupled the interactions of nutrients between soil biogeochemistry in ELM and plant productivity and carbon in FATES. This presentation will highlight the on-going work from multiple modeling studies located in Puerto Rico from NGEE-Tropics team members. One testing the new nutrient enabled ELM-FATES at Luquillo, another using ELM-FATES to understand hurricane disturbance induced forest recovery using a light demanding and shade tolerant Puerto Rican plant-functional types. Simulation results examine aboveground biomass, leaf biomass, and litter pre- and post-Hugo hurricane compared to observations. This work is important for understanding long-term recovery in an island where hurricanes might become more frequent or intense. Early-stage work also aims to deepen the current understanding of carbon dynamics in secondary forests recovering from abandoned agricultural fields in Puerto Rico, and the influence of degraded lands and soils on forest regrowth and sustained recovery. With two new updates, 1) downscaled DayMet meteorological forcing and 2) updated raw datasets that include land surface and land-use change parameters, the ELM model has the capability to simulate the land surface at high spatial resolutions and heterogeneity at the 1-km scale, making it possible to address fine scale land-use and biogeochemistry questions in Puerto Rico in an Earth System Model.

The Increase in Streamwater DOC Concentrations may not Necessarily Imply the Increase of DOC Fluxes, an Example from Central European Catchments.

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Surface waters recovering from acidification often show an increase in DOC concentrations. This increase is driven by a decline in acidic deposition, leading to a decrease in the soil and surface waters ionic strength and a subsequent increase in the solubility of humic substances. Over 30 years of observations (1993-2022) in the Slavkov Forest catchments (Czech Republic, Central Europe) sulfur deposition declined from 34 kg ha $^{-1}$. yr^{-1} in 1993 to 2.6 kg ha $^{-1}$ yr^{-1} in 2022 and inorganic nitrogen deposition from 13.4 kg ha $^{-1}$ yr^{-1} to 6.1 kg. ha $^{-1}$ yr^{-1} respectively.

Three Norway spruce dominated catchments – Černý potok (CEP), 15.2 ha peaty catchment, Lysina (LYS), 27.3 ha granitic with riparian peats and Pluhuv Bor (PLB) 21.6 ha serpentinite catchment were investigated. Peaty CEP showed lowest relative annual increase (0.013 mg DOC per mg DOC. yr^{-1}), despite having very high concentrations. The annual 3-year average between 1993-1995 was 48.2 mg L^{-1} increasing to 68.3 mg L^{-1} for 2020-2022. The granitic adjacent LYS showed an annual increase of 0.014 mg DOC per mg DOC. yr^{-1} with concentration increase from 16.9 mg. L^{-1} to 25.4 mg L^{-1}. The largest relative increase was observed at PLB; 0.031 mg DOC per mg DOC yr^{-1} with concentration increasing from 15.7 mg L^{-1} to 36.7 mg L^{-1} over 30 years.

Annual runoff declined significantly at CEP and LYS, from 465 to 331 mm as a result of rising air temperature, reduced precipitations and increased evapotranspiration. PLB did not show a statistically significant runoff decline, with an average of 266 mm. PLB experienced significant deforestation during the last years, which likely decreased transpiration and thus increased catchment runoff.

As a result, DOC fluxes did not change significantly from CEP and LYS (average 210 kg ha $^{-1}$ yr^{-1} and 90 kg ha $^{-1}$ yr^{-1}). However, PLB´s flux more than doubled increasing from 44 to 106 kg ha $^{-1}$ yr^{-1}.

The combined effect of geochemically controlled rise of stream water DOC and climatically derived runoff reduction may thus result in limited changes in DOC fluxes.

Sedimentation from widespread mass wasting events in Puerto Rico

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Puerto Rico is especially vulnerable to mass wasting, given its topography, tectonic setting, geology, climate, and land use patterns. In 2017, Hurricane Maria triggered more than 70,000 shallow landslides across the island. More recently, Hurricane Fiona in 2022 reactivated many of the same hillslopes that failed in 2017. Because of the high drainage density in the island, most shallow landslides transition into fast moving debris flows that enter first order streams. This results in remarkably little volumes of sediment being stored as “landslide deposits”.

To track the landslide-derived sediment transport, we have carried out several bathymetric surveys of reservoirs in Puerto Rico that drain mountainous zones that suffered mass wasting in hurricanes Maria and Fiona. Data from these surveys are show that Hurricane Maria caused the equivalent of around 15 years of background 21st century sedimentation in Lago Dos Bocas and Lago Caonillas, both located in the municipality of Utuado in the central interior of the island. This excess sedimentation in each lake is compatible with the LiDAR analysis estimates of volume of material lost at landslide sites in each respective basin. Both lakes are part of the Puerto Rico’s “super-aqueduct” system that provides water to the island’s San Juan metropolitan area. At the time of our surveys, Lago Dos Bocas (2021) was 64% filled with sediment and Lago Caonillas (2020) was 38% infilled. We also surveyed Lago Cerillos in Ponce in 2023. The results from this study show that Lago Cerillos is 10% infilled and that sediment mobilized by hurricanes Maria and Fiona may have accounted for storage loss equivalent to several decades of background sedimentation.

Mitigation of sediment infilling of the fragile reservoir system in Puerto Rico will be important to ensure viable water supply for the future. The research highlighted here shows that sediment influx derived by mass wasting is a major component of reservoir capacity loss. Watershed management strategies must account for this input.

COMPOSITION AND MOLECULAR STRUCTURE OF MICROORGANISMS IN BIOLOGICAL SOIL CRUSTS FROM A DRY, HIGH-ALTITUDE GLACIER FORELAND IN THE EASTERN PAMIR (TAJIKISTAN)

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Biological soil crusts (BSC) constitute an extremely important group of organisms, especially in environments where the conditions for higher plants are unfavorable, such as mountains and deserts. BSCs are formed by cyanobacteria, fungi, lichens, bryophytes, and algae in various proportions. This complex community is responsible for soil formation and nutrient sequestration and constitute a step in a succession of organisms. Especially important role play cyanobacteria which as autotrophs enrich soil with organic carbon and thanks to N_2 fixation are, together with some other bacteria, responsible for nitrogen sequestration. Thanks to secretion of the extracellular polymeric substances, they also play a structuring role in this environment, stabilizing the soil, increasing its porosity and water retention capacity. Still the knowledge on composition and structure of bacterial components in BSC and on relations between them especially in extreme environments is limited.
We studied (10 study plots) biological BSC in the Koksoy River Valley in Eastern Pamir Mountains in July 2018 and in July 2019. This valley was recently characterized as exceptionally poor in terms of organic carbon and with its harsh weather conditions can be considered an extreme environment. In the present study we used amplicons sequence variants (ASV) approach recovered from a high-throughput analysis of hypervariable region V3-V4 of 16S rRNA gene.
The results showed that among bacteria dominated Actinobacteria (18% of ASVs), Proteobacteria (14%), Bacteroidota and Chloroflexi (13% each) and the next phylum was Cyanobacteria with 9% contribution to the bacteria community. However, the most numerous single genus was a cyanobacterium - *Microcoleus vaginatus*. *Microcoleus* is known to have a structure-forming role for BSC and to form "cyanosphere" which attracts bacteria, among which are N_2 fixing taxa. In this way presence and domination of *Microcoleus* influences the nitrogen cycle in the BSC.
A filamentous, green non-sulfur bacteria "AKIW781" from the Chloroflexia class was another dominant taxon followed by Abditibacterium, an oligotroph, adapted to occur in an environment with a very low concentration of nutrients. Also in each sample, though in lower abundance we noticed genus Sphingomonas, a diasotrophic photoheterotroph. Another diazotrophic bacteria belonged to Cyanobacteria: Nostocales and Chroococcidiopsidales present in more developed BSC, in 15 out of 24 samples. Thus, the study confirmed that the BSCs were functionally diverse communities with complex interactions between its components and with cyanobacteria playing a crucial role in its functioning.
This work was supported by the Polish National Science Centre Grants 2015/19/B/NZ9/00473 and 2017/25/B/ST10/00468.

Bioenergy crop *Miscanthus x giganteus* acts as an ecosystem engineer to increase bacterial diversity and soil organic matter on marginal land

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Bioproduct crop cultivation on the world's vast amount of marginal land could foster agroecosystems that not only provide renewable sources of energy and materials but also help to rehabilitate damaged lands and mitigate climate change. However, we lack fundamental knowledge of the microbially-mediated processes that govern biomass crop productivity on and rehabilitation of marginal lands. For example, plant-microbe interactions occurring at the root-soil interface undoubtedly influence plant productivity and soil nutrient cycles, but the underlying mechanisms of these dynamics remain obscure. *Miscanthus x giganteus* (*Miscanthus*) stands out for its propensity to produce large amounts of biomass and accumulate soil carbon even on marginal lands, and emerging evidence suggests the clear role of plant-microbe interactions in facilitating these favorable traits. However, we lack a data-driven, mechanistic understanding of how *Miscanthus* alters soil microbial community structure and function leading to soil organic matter accumulation and high plant yields. This is especially true when considering variation in land management strategies (e.g., fertilization strategy) and disturbance intensity. To fill this knowledge gap, we established *Miscanthus* stands on marginal land in West Virginia, USA across a spectrum of disturbance intensities and fertilization regimes. We measured plant performance, soil properties, and microbial dynamics over the first three years of *Miscanthus* establishment. We determined that plant performance (e.g., aboveground biomass yield) and microbial carbon use efficiency (CUE) increased over time during establishment under all disturbance intensities but remained lower overall at the most intensely disturbed site. Across all sites, bacterial diversity and microbial carbon use efficiency increased over time and were positively correlated with soil organic matter. We also observed increases in the relative abundance of key plant growth promoting microbes (e.g., mycorrhizal fungi and bacterial N-fixers). There was no effect of nutrient addition on plant yield, soil carbon concentrations, or microbial carbon cycling. All told, our results suggest that *Miscanthus* consistently increases microbial diversity and carbon use efficiency, facilitating soil organic matter accumulation across sites despite varying land use histories and soil properties. In this way, *Miscanthus* acts as an ecosystem engineer, improving soil biological and chemical properties such that highly disturbed soils come to resemble less disturbed systems over time.

BIOGEOMON Abstract

Multiple Lines of Evidence Elucidate Sediment and Phosphorus Dynamics in Midwestern USA Watershed

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Many agricultural and mixed land use watersheds within the midwestern USA have water quality concerns regarding sediment and phosphorus. Export of both sediment and phosphorus rely on a cascade of catchment and in-stream processes including source, transport and storage, each with their own range of timescales, and, yet events remain critical for solute and sediment export from the watershed at nested scales. We examined stormflow C-Q, hysteresis, and flushing patterns of total suspended sediment (TSS) and soluble reactive phosphorus (SRP) in two stream reaches of a severely impaired agricultural watershed in northeastern Wisconsin, USA. The upper watershed reach— draining a relatively flat, row crop-dominated contributing area with minimal tile drainage— showed predominantly anti-clockwise TSS hysteresis during storms, suggesting that particulate materials were mobilized more from distal upland sources than near- and in-channel areas. In contrast, the incised lower watershed reach produced strong TSS flushing responses on the rising limb of storm hydrographs and clockwise hysteresis, signaling rapid mobilization of near- and in-channel materials with increasing event flows. C-Q relationships for SRP showed complex patterns in both the upper and lower reaches, demonstrating largely non-linear chemodynamic C-Q behavior during events. As with TSS, anti-clockwise SRP hysteresis in the upper reach suggested a delay in the hydrologic connectivity between SRP sources and the stream, with highly variable SRP concentrations during some events. A broad range of clockwise, anti-clockwise, and complex SRP hysteresis patterns occurred in the lower watershed, possibly influenced by in-channel legacy P stores and connection to more extensive tile drainage networks in the lower watershed area.

Carbon emissions from drainage ditches in oil palm plantations on peat soil

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Tropical peatlands contain approximately 17% of the total global peat carbon and are under pressure for deforestation and the formation of oil palm plantations. The conversion of large peatland forests in Malaysia and Indonesia has resulted in these plantations becoming substantial sources of greenhouse gases. While previous research has focused on estimating the C loss from the soil, the impact of drainage ditches on the overall C budget remains largely unexplored. However, on average, drainage ditches with free surface water cover roughly one-third of the total drained land. Hence, these ditches could be significant CO_2 and CH_4 sources and while not considered for C budget calculation it could lead to significant underestimation of total C loss from these ecosystems. Here we represent the CO_2 and CH_4 emissions from drainage ditches in an oil palm plantation located in Sarawak, Malaysia. CO_2 and CH_4 samples (n=107) were collected from a recently created plantation (~5 y.o.) and from the plantation, which is under second rotation using a floating chamber and LI7810 analyzer. The results revealed that the average net CH_4 flux (combining both diffusive and ebullitive emissions) from drainage ditches in the first and second rotations was 10.8 ± 14.3 mg m^{-2} h^{-1} and 13.2 ± 23.9 mg CH_4-C m^{-2} h^{-1}, respectively. The average CO_2 flux from the first and second rotations was 0.16 ± 0.1 g CO_2-C m^{-2} h^{-1} and 0.17 ± 0.1 g CO_2-C m^{-2} h^{-1}, respectively. Consequently, the annual emission from the ditches in the first rotation was 400 kg CH_4-C yr^{-1} and 4198 kg CO_2-C yr^{-1}, while in the second rotation, the emissions were slightly lower, with 118 kg CH_4-C yr^{-1} and 3352 kg CO_2-C yr^{-1}. These results strongly underscore the significant role of drainage ditches in contributing to the overall carbon loss from oil palm plantations. Proper consideration of these emissions is essential for accurate carbon budget calculations and for devising effective strategies to mitigate greenhouse gas emissions in these ecosystems.

Extreme Events Alter the Future of Freshwater Salinization Syndrome

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Human activities have altered the sources, transport, and transformation of salt ions contributing to the anthropogenic salt cycle. A major process in the anthropogenic salt cycle is freshwater salinization. Freshwater salinization is increasing in groundwater, streams, rivers, and lakes around the world due to factors such as irrigation, road salts, sea level rise, groundwater pumping, resource extraction, and human-accelerated weathering of geologic materials. The suite of impacts of freshwater salinization on the natural and built environment is called Freshwater Salinization Syndrome (FSS). One major symptom of FSS is the mobilization of diverse mixtures of chemicals of concern called ‘chemical cocktails’, which can impact aquatic life, infrastructure, and clean drinking water. Although there have been increasing salinization trends over time in many prominent freshwater ecosystems, less is known regarding the impacts of extreme events on watershed-scale FSS responses across space and time. Here, we explore spatial and temporal responses of FSS in watersheds to different weather and climatic events such as: floods, tropical storms, hurricanes, droughts, winter road salt events, and saltwater intrusion in the Chesapeake Bay region. In some cases, salt pollution and associated chemical cocktails increase in concentrations and fluxes along flowpaths in response to hydrologic events, whereas there can also be attenuation and dilution of salt pollution based on land use and management decisions. We develop a typology for predicting watershed-scale FSS responses to extreme events across space and time and discuss implications for anticipating the effects of extreme events on influencing the trajectory, spread, and severity of FSS in the future. We also highlight the potential for ecosystem recovery from FSS and resilience in response to extreme

events. Anticipating responses of FSS to climate change and variability will be critical for developing effective salt restoration and mitigation strategies to protect drinking water, habitat, food production, and infrastructure in the future.

Microbial nitrogen cycle in sub-tropical peatland cloud forest and wetland ecosystems of Reunion Island

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Abstract:
Peatlands play an important role in the regulation of carbon and nitrogen cycles. Nitrogen-rich peatlands under warm and dry conditions can be a source of N_2O, which is a potent greenhouse gas. Research on microbial activity, particularly in relation to N_2O emissions in sub-tropical peatlands and wetlands, is very limited. In the current study, we investigated two peatland cloud forest sites in Reunion Island, namely Plaine des Cafres (characterized by dominant species *Erica reunionensis* and *Alsophila glaucifolia*) and Forêt de Bébour (featuring *Erica reunionensis* exclusively), alongside one RAMSAR wetland site located in Saint Paul. Our objective was to clarify the microbial dynamics associated with the nitrogen cycle in sub-tropical peatland forests and wetlands.

Soil samples were collected from the study sites for physical-chemical and microbial analyses. DNA extraction was performed on soil samples, followed by quantification of genes associated with the nitrogen cycle using quantitative polymerase chain reaction. In addition, soil samples underwent analyses to assess levels of ammonium (NH_4-N) and nitrate (NO_3-N). Soil N_2O fluxes were determined by collecting gas samples from the chamber headspace of static soil chamber systems at 20-minute intervals during one-hour sessions. The concentration of N_2O was determined from gas samples using a gas chromatographer (Shimadzu-2014).

A substantial amount of NH_4-N was found across all sites (mean: 77.2 mg/kg), correlating significantly with the abundance of *nifH* gene ($R^2 = 0.7$, $p<0.01$). This indicates high rates of microbial nitrogen fixation. Soil NO_3-N content varied substantially, with Plaine des Cafres and Forêt de Bébour sites exhibiting notably higher levels (means: 53.67 mg/kg and 139 mg/kg, respectively) compared to the wetland in Saint Paul (mean: 2.5 mg/kg). Archaeal and COMAMMOX *amoA* gene abundances were high across all three sites, indicating archaeal nitrification and complete ammonia oxidation. The *nir*:*amoA* ratio was highest in wetland soil, explaining the low NO_3-N content. The *nir*:*nosZ* ratio was less than 1 in all sites indicating the dominance of N_2O consumers in soil, with wetland exhibiting the lowest ratio. The high abundance of denitrifiers and dominance of *nosZ*-type denitrifiers in the peatland forests and the wetland of Reunion Island can explain the observed low N_2O fluxes in all sites with no significant variation.

Beavers as Arctic Carbon Cycle Engineers: The Impacts of Beavers on Organic Matter Cycling in Permafrost Landscapes

In the Arctic, rising temperatures have led to longer growing periods and the expansion of shrubby vegetation. Wildlife, including beavers, that require this shrub environment have begun to colonize these Arctic tundra regions. Beaver engineering plays a significant role in controlling surface water dynamics, which can increase the rate of permafrost thaw, releasing stored carbon, and thereby exacerbating the effects of climate change. This study examined the influence of beaver activity on regional carbon cycling in Nome and Kotzebue, Alaska. Water samples collected from above, below, and within beaver ponds were analyzed to characterize and quantify the export of dissolved organic matter (DOM) and assess the impact of beavers on regional carbon cycling. UV-visible absorbance spectra and DOM fluorescence excitation-emission matrices (EEMs) were measured to assess DOM composition and fate. Lignin biomarkers were characterized to quantify the input of terrestrial DOM. Fluorescence EEMs were used to identify the molecular changes to the DOM pool and the unique impacts of beavers on the sources, cycling, and fates of DOM in permafrost landscapes. The concentration and composition of DOM varied widely across sites above and below beaver ponds. Across the landscape and gradients of permafrost thaw, we observed changes in the composition of fluorescent DOM indicating that beavers likely are altering the export of terrestrial carbon through these systems. These results suggest beavers have a significant impact on regional carbon cycling and need to be considered when examining recent changes to Arctic tundra landscapes.

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8. Biogeochemical response to extreme events

Increasing frequency of heavy rains accelerates recovery of the Tatra Mountain lakes from acidification

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Ongoing changes in climate characteristics can reverse trends of decreasing calcium plus magnesium (Ca+Mg) leaching to surface waters recovering from acidification and increase their concentrations of phosphorus (P) and organic nitrogen (ON) in granitic alpine regions.

Despite decreasing concentrations of strong acid anions (–1.6 µeq/L/yr), the average Ca+Mg concentrations increased (1.3 µeq/L/yr), together with increased terrestrial export of bicarbonate (HCO_3; 2.5 µeq/L/yr) in 25 non-acidic alpine lakes in the Tatra Mountains (Central Europe) during the mid-2000s to 2022. The elevated terrestrial export of Ca+Mg from catchments thus reversed the Ca+Mg trends, which had originally decreased in parallel with decreasing strong acid anions after their continuously reduced atmospheric deposition since the late 1980s. The percent increase of the in-lake Ca+Mg concentrations was significantly and positively correlated with proportion of scree (areas of broken rocks and gravel without any vegetation except lichen) in the lake catchments and negatively correlated with extent of vegetated soil cover.

Leaching experiments with 12 freshly crushed samples of granodiorite (the dominant bedrock in the study area) showed that accessory calcite was an important source of Ca, Mg, and HCO_3. Moreover, fresh apatite [$Ca_5(PO_4)_3(F,Cl,OH)$] in the crushed granodiorite was a P source under acidic soil conditions, especially in the presence of chelating organic acids. Increasing soil pH due to liberated HCO_3 and decreased acidic deposition decreased soil ability to adsorb phosphate. The elevated P input from catchments stimulated biological activity in lakes and increasing ON concentrations. The increasing ON concentrations then represented the most sensitive indicator of the changes in the lake water nutrient composition.

We hypothesize that elevated terrestrial export of Ca+Mg, HCO_3, and P resulted from increased mechanical weathering of rocks due to elevated climate-related forces during the last 30+ years. The forces include increasing frequency of days with > 30 mm day^{-1} precipitation causing more creep of scree and erosion, and more frequent air temperatures fluctuating through 0 °C, creating more mineral and rock fractures.

These climatic effects on water chemistry are especially strong in catchments dominated by scree areas where fragmented rocks are more exposed to weathering, and their position is less stable than in soil.

Kopáček J. et al. Environ. Sci. Technol., 2017, 51: 159–166. DOI: 10.1021/acs.est.6b03575.
Kopáček J. et al. Aquat. Sci., 2019, 81:70. DOI: 10.1007/s00027-019-0667-7

Temporal Chemical Weathering in the Río Yahuecas Watershed

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Silicate weathering is an important process for the consumption of atmospheric CO_2. Chemical weathering in tropical watersheds on volcanic bedrock results in some of the highest weathering rates in the world meaning that these areas are particularly important for CO_2 consumption. Río Yahuecas is a 2nd order stream monitored by NEON in the Adjuntas municipality of Puerto Rico. The 9.5 km^2 watershed is predominantly tropical moist/wet forest with a small agriculture research station. The area has an average annual rainfall of 1168 mm and average annual temperature of 25°C. The watershed experiences a dry season from December through March and a wet season from May through November, with large precipitation events due to tropical storms or hurricanes occurring between June and December. The bedrock in the area is mapped as mainly Anon Formation, a volcanic breccia, tuff, and tuffaceous sandstone; the Lago Garzas Formation, a volcanic breccia, volcanic sandstone-claystones, calcirudite and pillowed basalts; and the Yauco Formation, a siltstone, sandstone, claystone, limestone, and conglomerate; the watershed also includes small areas of porphyritic hornblende dacite. The goal of this project is to calculate bimonthly chemical weathering rates in the Río Yahuecas watershed. NEON has monitored the Río Yahuecas (GUIL) site since 2018 and provides a minute-interval continuous dataset for river discharge. Stream and precipitation chemistry samples are analyzed approximately bimonthly. This frequent and prolonged sampling allows us to calculate approximately 100 chemical weathering fluxes across including data during wet and dry seasons. This will allow us to capture temporal variation in chemical weathering and seasonal differences that are not generally captured in other stream export weathering studies.

Long-term patterns of DOC concentrations in soil water at catchments with contrasting acid-base chemistry

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Surface waters in Europe often shown increase in dissolved organic carbon (DOC) concentrations during the last decades. It could be driven by decline in acidic deposition, leading to a decrease in ionic strength (IS) of precipitation and soil water and subsequently to increase in the solubility of humic substances in forest soils (Monteith et al. 2023, Science Advances, 9, 3491). More than three decades of monitoring at two catchments in the Slavkov Forest documented enormous reduction in atmospheric load, especially of sulfur (S). Deposition of S decreased from 34 kg/ha/yr in 1993 to less than 3 kg/ha/yr in 2022. Two Norway spruce catchments were investigated: Lysina (LYS, 0.27 km^2), with prevailing Podzol developed on acidic leucogranite and Pluhův Bor (PLB, 0.22 km^2), with mostly Cambisol on ultrabasic serpentinite. Acidic streamwater at LYS showed an annual DOC increase of 0.3 mg/L and even larger annual increase was observed in circumneutral PLB streamwater (0.9 mg/L) over 30-year period (Hruška et al., this vol.).

About fourty zero-tension and tension lysimeters were installed in five depths at LYS and PLB during the period 1989-2011. This abstract is focused on evaluation of samples collected by zero-tension lysimeters situated in uppermost mineral soils (E or A horizons) which offer the longest time series, from 1990 at LYS and from 1994 at PLB. DOC was measured there since 1993, later in comparison to inorganic constituents. Most DOC measurements were performed by Techman-Dohrmann Apollo 9000. Changes in soil water quality were driven by decrease of sulfate concentrations at both sites (1.1 at LYS and 1.3 mg/L/yr at PLB, $p<0.01$). Decrease of IS of the soil waters was correlated with SO_4 (R^2 0.82 and 0.87, at LYS and PLB, respectively, $p<0.01$). IS decreased significantly in the uppermost mineral soils, 26 µeq/L/yr (LYS) and 36 µeq/L/yr at PLB ($p<0.01$). Soil water annual mean values of pH increased significantly at PLB, from 5.4 to 6.4 ($p<0.01$) but stayed around 3.5 at LYS due to properties of humic and fulvic acids, which are highly acidic and effectively prevent pH rise. The most pronounced increase of DOC was observed in organic horizon at LYS (1.26 mg/L/yr, R^2 0.61, $p<0.01$). Increase of DOC in uppermost mineral soil was 1.25 mg/L/yr (R^2 0.31, $p<0.01$), from 30 to 70 mg/L at PLB and 0.85 mg/L/yr (R^2 0.15, $p<0.05$, from 50 to 75 mg/L) at LYS. Climate change could be a confounding factor in future DOC trends.

The Response of Lake Nutrients During Treatment of a Harmful Algal Bloom by Nanobubble Ozone Technology

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Anthropogenic changes in land-use have had a large impact on nutrient cycles. In Ohio, nutrient runoff from agricultural fields, mainly of nitrogen and phosphorus, has caused eutrophication in lakes and lead to harmful algal blooms (HABs). There are many proposed methods to either mitigate the nutrients or control algal blooms. One emerging experimental treatment for HABs is Nanobubble Ozone Technology (NBOT). Ozone is used to treat microcystin, an algal toxin, in water treatment plants, and NBOT is a way to deliver ozone to lakes to potentially treat the HABs *in situ*. There is some suggestion it can also mitigate the nutrients which cause eutrophication. Before NBOT can be used, it is important to understand not only how it works with algal blooms but also whether it will alter nutrient cycling in lakes. Grand Lake St. Mary's is the largest inland lake in Ohio and frequently experiences some of the worst HABs in the country. We performed an experimental NBOT treatment at Dog Tail Beach, a protected area of Grand Lake St Mary's, in summer 2022 and 2023. Water samples were collected weekly and consisted of pretreatment, NBOT treatment, and post-treatment samples. In 2022 we observed an increase in dissolved organic carbon (DOC) during initial NBOT treatment, followed by a decline mid-way through treatment and increase in post-treatment samples. Because ozone is known to react with dissolved organic matter (DOM) and any algae treated by the NBOT would release DOM, this suggests a complicated relationship between NBOT treatment and DOM. Total nitrogen increased early on during NBOT treatment, declined, and then continued to increase through treatment and post-treatment. Total phosphorus steadily increased throughout pretreatment, treatment, and post-treatment with the exception of a slight decrease in June. This suggests that NBOT does not remove phosphorus from the water, which it is advertised as doing. Because there are many factors controlling nutrient cycling in this lake, including runoff from agricultural fields, the algal bloom itself, and the treatment, it is difficult to isolate the impact of any individual driver on the nutrient cycling. Further work will involve examining this data with that from experimental NBOT treatments in controlled lab and mesocosm environments.

The Climate Change Imprint: Dynamic Shifts in Spring Yields and Water Quality in the Czech Republic

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Springs are valuable indicators of groundwater quantity and quality. The past few decades have seen a significant rise in air temperatures in Central Europe, impacting the hydrological cycle and altering streamflow patterns. This study examined the annual trends in spring yields from 136 springs across 18 hydrogeological regions (HGR) in the Czech Republic from 1971 to 2020 using Mann-Kendall test. Of these, 56 springs had available mean annual water

quality data, which were analyzed for trends in sulfates, nitrates, dissolved organic carbon (DOC), and ionic strength (calculated using concentrations of major cations and anions: Ca_2^+, Mg_2^+, Na^+, K^+, NH_4^+ , H^+,SO_4^{2-}, NO_3^-, Cl^-, F^-, and HCO_3^-).

A majority of springs (70%) showed no long-term trends in annual yields. Among those with notable trends, declines (28%) were more frequent than increases (2%). Notably, seven HGRs displayed a significant decreasing trend ($p < 0.05$). No region showed an increasing trend. Springs in crystalline bedrock HGRs (4 out of 7) were especially impacted. The decline observed in the North Bohemian Cretaceous Basin region is of particular interest, given its status as a protected water accumulation zone.

In water quality trends, SO_4^{2-} and NO_3^- concentrations exhibited a significant decreasing trend at 46% and 52% of sites, respectively. Conversely, an increasing trend was detected at 21% (SO_4^{2-}) and 16% (NO_3^-) of sites between 1984 and 2020. DOC concentration decreased significantly ($p<0.05$) at 34% of sites from 2002 to 2020. Ionic strength showed a decreasing trend at 16% of sites and an increasing trend at 7% between 2002 and 2020 ($p<0.05$).

Using a linear mixed-effect model, we evaluated the relationships between climatic (precipitation and temperature) and hydrogeological variables (transmissivity) on spring yields. We found a strong positive correlation between precipitation and yields, underscoring that a decrease in precipitation directly contributes to reduced yields ($p < 0.01$). Conversely, an increase in temperature was associated with a decrease in spring yields ($p < 0.01$). The significant negative effect of interaction between temperature and transmissivity revealed that springs, especially in regions with low transmissivity dominated across Czech Republic by crystalline bedrock, are particularly sensitive to climatic variations. These low transmissivity regions already exhibit lower yields compared to high transmissivity areas, such as the Cretaceous basins. Furthermore, our analysis revealed a significant negative correlation between DOC concentrations and temperature ($p<0.001$).

Unraveling processes of atmospheric Hg sequestration by soils over annual to centennial timescales

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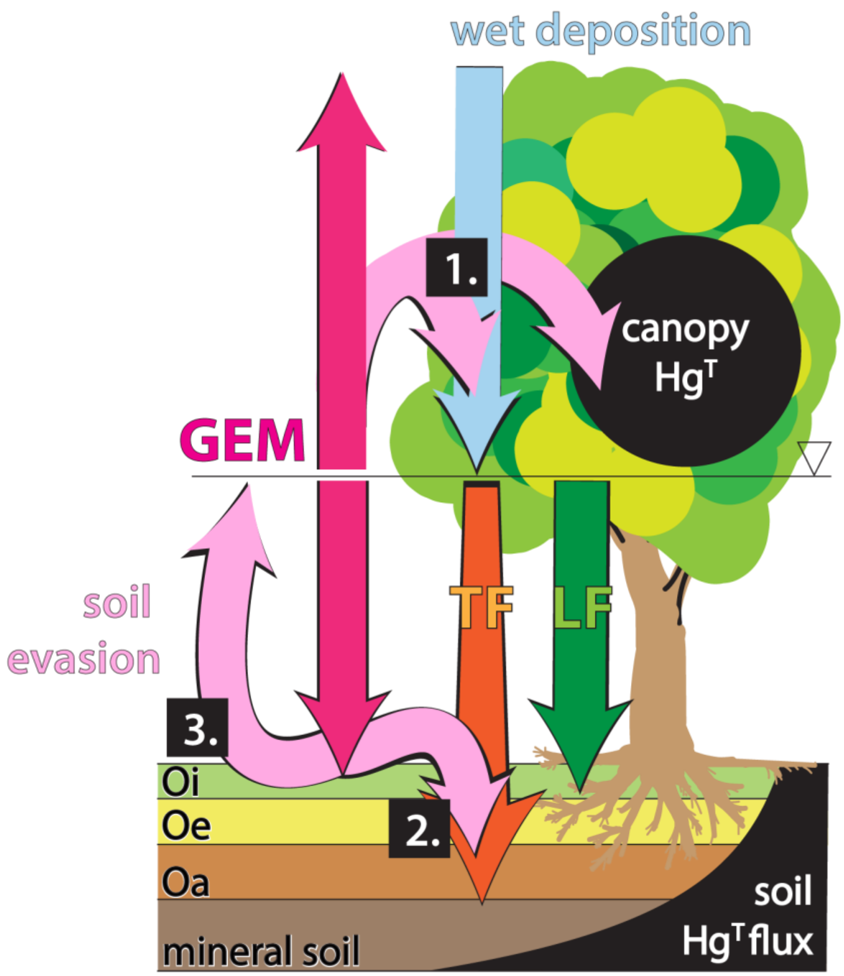
Soils are a principal reservoir of the potent neurotoxin Hg that has accumulated through the history of anthropogenic emissions to the global atmosphere, yet contemporary flux measurements between atmosphere and soil show complex, bi-directional exchange and ambiguous net flux of gaseous elemental mercury (GEM) to soil. This discrepancy reveals fundamental uncertainty regarding how Hg is incorporated into soil, while also underscoring limitations in both modeling the strength of the soil sink in global Hg cycling and understanding the sensitivity of soil Hg to future environmental change. Here we introduce a new bottom-up soil mass balance approach based on fallout radionuclide (FRN) chronometry that allows a direct and independent comparison of Hg soil accumulation rates with measured atmospheric ecosystem flux (sum of litterfall, LF, throughfall, TF, and non-foliar GEM deposition). Through this direct comparison we show that organic soil horizons are typically depleted in Hg, with accumulation rates falling 20-80% short of expected ecosystem fluxes across arctic, temperate and tropical soils. Underlying mineral soils, in contrast, accumulate Hg at rates comparable to contemporary ecosystem fluxes. Moreover, mineral soil accumulation rates increase with depth in a pattern consistent with the decadal-centennial history of atmospheric Hg emissions. We propose that while GEM is mobile in organic soils and may be re-emitted to atmosphere over diel to seasonal timescales, on balance atmospheric Hg is effectively redistributed to mineral soil where it is sequestered to break a cycle of re-emission. We propose that throughfall is likely a key process in soil mass balance, rinsing GEM deeper into soil in a manner analogous to its role in rinsing Hg from the foliar canopy, and thereby delivering GEM to soil depths beyond a surface zone of re-emission. Our ability to reconstruct soil Hg accumulation rates using radionuclide chronometers now poses opportunities to explore environmental factors that regulate both Hg emission and accumulation in soils.



Abstract Art or conceptual figure for Hg accumulation in soil. Key points include (1) rinsing of GEM from canopy by wet deposition (throughfall); (2) rinsing of GEM deeper into soil by throughfall, (3) re-emission of GEM from forest floor

Water and nutrient management in peatland forests under changing climate

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Different climate scenarios agree in predicting rising temperatures to high latitudes, but are contradictory in predictions for the future amount and distribution of rainfall in Fennoscandia. Rainfall is, by far, the most important individual variable determining the fate and the future use of peatland forests. In the case where the summertime rainfall decreases, the management schemes of peatland forests are facing a fundamental change. Lowering water table and increasing peat temperature will enhance organic matter decomposition leading to higher nutrient release and CO_2 emissions from the peat. Improved nutrient supply can increase forest growth, which typically is phosphorus (P) and potassium (K) limited. During rainless periods peatlands can longer maintain the water storage supporting the forest growth better than the upland mineral soils, where the water storage is smaller. Consequently, the relative importance of peatland forests in biomaterial production is likely to increase. Meanwhile, it is imperative to control the greenhouse gas emissions and nutrient exports from forested peatlands. This requires improved water and nutrient management strategies that aim for balanced production of multiple ecosystem services at the same time. This can be achieved with new drainage, forest management and fertilization schemes. Hydrological and biogeochemical processes in forested peatlands are complicated, interlinked and characterized by different feedback mechanisms. In addition, all these are dependent on weather conditions, peat characteristics, drainage dimensions, and stand structure. High-resolution geospatial data combined with process-based ecosystem models provides a solution in searching for new forest management schemes that balance between different ecosystem services. We have developed this kind of ecosystem model, peatland simulator SUSI, and applied it to study how manipulation of drain network, ash fertilization and forest management affect tree growth, greenhouse gas balance and nutrient export to water courses under different rainfall scenarios.

The role of soil health practices on soil organic carbon in managed systems

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It is well known that soil organic carbon can be predicted at various spatial scales based on soil forming factors. In agricultural systems, though, historical land use complicates these predictions. It has been suggested that about half of the original soil carbon has been lost due to management such as tillage. However, the adoption of soil health promoting practices is thought to have the potential to increase soil carbon towards the pre-disturbance values. It can sometime be difficult to isolate the effects due to changes in practices, outside of controlled experiments, because of the spatial heterogeneity of soils and complications of collecting management data. The Soil Health Institute has been working to document the effects on soils of adopting these practices at both long-term research sites and in farmers' fields. At the research sites across a range of soil types and climates North America, we found that the adoption of practices such as reducing tillage, adoption of cover crops, retention of residue, and use of organic sources of nutrients was associated with a 10-25% increase in soil carbon in the top 15cm. The amount of change in soil carbon was in part due to the size of the change in practice. That is, there was a bigger change in soil carbon if the change in tillage intensity or proportion of the year with living roots was bigger. Because it is not feasible to do enough replicated experiments on farmers' fields, we are developing a "benchmarking" approach to determine the magnitude of the effects of management on soil carbon at the regional scale for a cropping system. We compare soil carbon on farms that have adopted soil health practices to those without soil health practices to reference sites with perennial vegetation. We are currently validating this approach in a variety of systems, such as cotton, dairy forage, corn/soy, potatoes, and vegetables in regions throughout the United States. We are also exploring whether it is feasible to collect the management data needed to use quantitative indicators of practice change instead of categorical differences. This approach will allow us to determine the potential for increasing soil carbon, and more broadly soil health, due to changes in practices while controlling for climate and soil texture.

Title: Disturbances drive stream greenhouse gas changes and increased heterogeneity at the reach-scale

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Disturbances, such as droughts and hurricanes, can dramatically alter the structure and function of stream ecosystems. Large inputs of organic matter, riparian canopy opening and sustained impacts on hydrology following a disturbance can result in important changes in biogeochemical processes in small streams such as greenhouse gas (GHG) production.

To explore the impacts of disturbance on GHG dynamics, we conducted longitudinal measurements of dissolved carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) concentrations in two streams before and after a major hurricane. Subsequently, we have experimentally manipulated one of the streams through a stream flow reduction experiment (StreamFRE). We sampled nine pools across ~200m reaches in each stream before Hurricane María in 2017 and at intervals of 1, 4, 6, and 9 months post-hurricane. Experimental flow reduction was initiated three years post-hurricane, and we sampled during two experimental drying periods.

Before the hurricane, concentrations of the 3 gases were stable across the reach with an average of 67.3, 0.07, and 0.01uM for CO2, CH4 and N2O, respectively. Following the hurricane, CO_2 increased on average by 129% and N2O by 10%, while CH_4 decreased by 25%. Heterogeneity for CO_2 increased but N2O and CH_4 remained relatively stable across the two stream reaches. Specifically, CO_2 increased and continued increasing across our sampling periods and did not return to pre-hurricane concentrations during our sampling period. N2O increased post-hurricane and continued to increase until the 4-month mark and was back to

baseline at 7 months. On the other hand, CH_4 decreased and continued decreasing without returning to pre-hurricane concentrations during our study period.

Results from the flow reductions showed a more muted response of greenhouse gases during this experimental drought. During the flow reduction, the experimentally manipulated stream showed small differences in CO_2 concentrations, particularly near the diversion location (ie. higher upstream). CH_4 concentrations remained similar to pre-hurricane concentrations and N2O slightly increased.

Our findings suggest that disturbances can change greenhouse gas concentrations in streams and can also create heterogeneity and hotspots following disturbance. Our understanding of how disturbances change biogeochemistry will be crucial in a future with increased droughts and hurricanes. Moreover, the differences observed between the patterns resulting from natural disturbances and our experimental flow manipulation indicate that other factors may be influencing gas dynamics in small mountain streams.

Wildfires Linked to Oceanic Anoxic Events in Geological History

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Wildfires have the potential to drastically modify the hydrological patterns of a region. These alterations subsequently influence the quantity and type of nutrients exported from terrestrial to aquatic ecosystems, leading to shifts in water quality and fundamental ecosystem processes. Geological records serve as a window into the past, offering an integrated view over both space and time on how aquatic ecosystems have historically responded to massive wildfires. These records can provide information on the long-term consequences of such events and aid in predicting potential future outcomes. We use the Late Devonian period as an example to show how massive wildfires can contribute to widespread degradation of the marine ecosystem. We compiled evidence that showed wildfire events were increasing on a global scale during the Late Devonian. These events were compared to the records of oceanic anoxic events that have been recognized as a direct trigger for mass extinctions. Our results highlight the severe consequences that wildfires can have on aquatic ecosystems at a global scale, including potentially shifting their evolutionary trajectory.

TITLE

The importance of disturbance: hurricanes modify the biotic and abiotic drivers of herbaceous understory plant dynamics in a tropical rain forest

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ABSTRACT

Natural and anthropogenic disturbances mediate the relative importance of biotic and abiotic drivers influencing herbaceous plant dynamics in tropical forest systems. Understanding these interrelated controls requires spatially and temporally explicit data that captures the changing microclimate and environmental landscape surrounding focal plants. In this study, we assessed the combined impacts of hurricanes, historical land use, and environmental covariates on *Heliconia caribbea* distribution in a subtropical montane forest in Puerto Rico.

Using long-term ecological data collected in the Luquillo Forest Dynamics Plot from 1990-2017, we explored the incidence, abundance, and size (shoot abundance) of *Heliconia caribbea* across censuses conducted within this period at approximately five-year intervals. We modeled the probability of sub-quadrat-scale *Heliconia caribbea* presence in each census and probability of survival from census to census as a function of tree abundance, basal area, light availability, elevation, soil type, slope, topography, and historical cover class, considering spatial autocorrelation at the quadrat-scale, using a mixed-effects modelling approach.

We observed greater tree abundance, as well as a wider spatial distribution, abundance, and shoot abundance of *Heliconia caribbea* in censuses following hurricanes that affected the forest plot in 1989 and 1998, followed by consistent declines in *Heliconia* presence and abundance in later censuses. The relative strengths of other biotic and abiotic predictor variables in the models changed significantly across censuses, mirroring the timing of hurricanes and demonstrating the critical role that such large-scale disturbance play in changing the controls on understory plant dynamics and the overall ecosystem equilibrium.

Peatlands occupy about 3% of land surface (Gorham 1991 *Ecol Appl*) but, due to high carbon (C) density, they are a globally important C (Leifeld, Menichetti 2017 *Nat Comm*) and nitrogen (N) store: ~21% of global soil organic C stock and up to 26 Pg N. Undisturbed peatlands are a C sink (~0.1 Pg C y^{-1}), a moderate source of CH_4 (~0.03 Pg CH_4 y^{-1}), and a very weak source of N_2O (~0.00002 Pg N_2O y^{-1}) (Frolking et al 2011 *Envir Rev*). Anthropogenic disturbance, primarily agriculture and forestry drainage (up to 20% of global peatlands) produce net carbon dioxide (CO_2) emissions (~0.1 Pg C y^{-1}), reduce CH_4 emissions (10% below natural conditions), and increase N_2O emissions (>20 times above natural peatlands; Pärn et al 2018 *Nat Comm*).

Man-induced drainage and climate warming-related droughts are the main factors damaging peatlands, causing C losses and increasing GHG emissions. Dry and wet peatlands can be C and GHG sinks while moderately moist peatlands are mostly C and GHG sources. Our global study on the peatlands' N-cycle microbiome indicated a leading role of diverse microbial communities in N_2O emission (Bahram et al. 2022 *Nat Comm*). High abundance of nitrifiers across all studied peatlands shows that they have suffered from drought or drainage at some time in history. Ongoing global warming and intensifying environmental change may boost archaeal nitrifiers, collectively transforming wetland soils to a greater source of N_2O.

Peatland forests, which are the dominant type of wetland in the tropics (Pangala et al 2018 *Nature*) and cover a significant part of boreal peatlands, provide challenges for GHG flux estimation. Although the forests' CO_2 capture is high, the role of trees and their canopy in N_2O and CH_4 budgets is largely unknown (Mander et al 2021 *npj Clim Atm Sci*).

Peatland restoration is the most effective way to facilitate C storage and minimize N_2O emissions (Leifeld, Menichetti 2017 *Nat Comm*). During the first 30–40 years after rewetting or establishment, C sequestration in sediments is offset by the radiative effect of CH_4 emission, however, in a 100-year perspective most peatlands may turn to net climate coolers (Mitsch et al 2013 *Landscape Ecol*).

We need to develop better linkages between time horizons of restored peatlands and the potential for C sequestration by peatland type, as well as to understand how we can sustain C storage in peatlands while continuing of human development.

Drainage and drought increase greenhouse gas fluxes in global peatlands

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The origin of atmospheric lead in urban air of three European cities: Lead isotope approach

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Abstract

Atmospheric lead pollution has adverse health effects on humans. Identification and characterization of Pb pollution sources are crucial for better understanding and evaluation of risks associated with air pollution. We have analyzed concentrations of trace elements (Pb, Zn, Cu, Ni, Cr, Cd, Sb, As, and Zn) and Pb isotopic composition of aerosols in fine particulate matter ($PM_{2.5}$) in three industrial cities (Hradec Králové, Olomouc and Brno), located in the Czech Republic. Sampling was performed in 12 hours intervals in winter and summer. Trace element and $PM_{2.5}$ concentrations were higher in winter in all studied cities, on average by 47 %. Across the sites, $^{206}Pb/^{207}Pb$ ratios ranged from 1.142 to 1.178 in summer and from 1.143 to 1.173 in winter. The mean $^{206}Pb/^{207}Pb$ ratios were statistically indistinguishable in all three studied cities (1.165 in Hradec Králové, 1.163 in Olomouc, and 1.160 in Brno). In the $^{206}Pb/^{207}Pb$ vs. $^{208}Pb/^{207}Pb$ graph, isotopic composition of aerosols sampled in summer lay on a straight line, whereas isotopic composition of samples collected in winter was shifted toward higher $^{208}Pb/^{207}Pb$ values. Increased winter PM and sulfate concentrations points to primary role of coal processing/combustion in Polish and Czech coal-fired power plants and household heating as winter season requires higher electricity production. However, our data showed that coal combustion was not the only Pb pollution source. Lead isotopic composition in aerosol

samples exhibited values that closely corresponded to Pb isotopic composition of Variscan ores. Pb recycling and waste incineration could explain these values and could also explain the shift in $^{208}Pb/^{207}Pb$ ratio of $PM_{2.5}$ to higher values. Such explanation, however, is questionable, because these industrial pollution sources do not exhibit seasonality. Since, we also observed lower $^{206}Pb/^{207}Pb$ isotope composition of urban air, we suggest that these samples could contain traffic-related Pb. It either originated from remobilized alkyl-Pb that was used as gasoline anti-knock additive (banned in 2000) or from currently sold unleaded gasoline and diesel (EU limits Pb content less than 5 mg Pb L^{-1} for currently sold fuel).

Acknowledgements

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Using ^{15}N isotope analysis to understand N_2O production and consumption processes.

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Nitrous oxide is a potent greenhouse gas which is involved in stratospheric ozone depletion. Even though nitrogen cycle has been studied for a long time, it is still challenging to understand specific N_2O production and consumption processes. This is due to the complexity and heterogeneity of soil, wherein multiple processes can take place simultaneously. Isotopic composition of N_2O can help us solve this and provide useful information on evaluating N_2O sources and calculate global budgets. N_2O is a linear molecule and its understanding at molecular scale can provide major insights into partition of its source processes. The N_2O site preference (SP), which is the difference in $\delta^{15}N$ between N_2O molecules substituted with ^{15}N at the central and the peripheral position, has proved to be a major tool to tackle this problem. The objective of this study is to use isotopic research for N_2O sources and process partitioning. We will bring some examples from our recent studies in the lab and in a drained peatland forest.

During our lab study based on peat soil from a floodplain fen, we observed bacterial denitrification was a major source of N_2O emissions under flooded conditions. We observed this using ^{15}N isotopic mapping technique, which helped separate multiple active processes. We applied a similar method in-situ on a drained peatland in southeastern Estonia and described hybrid N_2O formation, where one N atom of the N_2O molecule was taken from NH_4 and the other N molecule from another source such as organic N, was the dominant source of N_2O emissions. The isotopic mapping and molecular enrichment of ^{15}N during our experiment showed that. The isotopic mapping initially suggested nitrification as a major source, but on further investigation of ^{15}N enrichment, we found the presence of hybrid processes (^{15}N nitrogen from two pools or processes). Furthermore, we studied the genetic potential for major N_2O processes (denitrification, nitrification, dissimilatory nitrate reduction to ammonium (DNRA)) and combined these with the isotope results, and this integrated approach is an important tool to partition N_2O processes. When using ^{15}N tracers, the isotopic technique can partition the sources (nitrate or ammonia) of N_2O. Hence, using the isotopic mapping of natural abundances and ^{15}N tracers to partition the source, we can get initial insights into N_2O sources and processes together. Isotopic mapping is still under development and further research is required as it also has a problem of overlapping of processes.

Investigating mycorrhizal type impacts on coupled C and N cycling at the soil aggregate scale in an experimental reforestation site

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Mycorrhizal fungi play a crucial role in biogeochemical processes that impact nutrient cycling and soil structure. The mycorrhizal-associated nutrient economy (MANE) framework has guided in identifying differences in the coupled C and N cycling that occurs in arbuscular mycorrhizal (AM) and ectomycorrhizal (EM) dominated forests. AM forests tend to have an inorganic nutrient economy due to their rapid rates of C mineralization, and EM forests tend to have an organic nutrient economy owing to their more persistent forms of plant organic matter. Due to their role in the formation and stabilization of soil aggregates, mycorrhizal fungi also influence the residence time of below-ground C and N by promoting soil structures that occlude organic matter from decomposition within aggregates.

It is unclear how AM and EM fungi differ in their contributions to aggregate formation and how aggregation may relate to differences in their respective nutrient economies. The goal of this study is to examine C and N cycling at the soil aggregate scale in an experimental reforestation site in Oregon's Willamette Valley, USA. The site was previously a pasture dominated by AM grasses, which now serve as control plots in contrast to plots where EM tree saplings were planted 3 years ago. Preliminary results from wet sieving and calculation of the mean weight diameter (MWD) of soil aggregates revealed that aggregates from control plots were more stable than those from EM trees at the site ($p = 0.08$).

This study will build upon this investigation by examining if there has been a shift from an inorganic AM to an organic EM nutrient economy in the rhizospheres of EM Oregon White Oaks (Quercus garryana) at the site. We collected soil samples (0-10 cm, $n = 20$) from 3-year-old Oaks in addition to control plots. We will analyze organic and inorganic C and N concentrations within bulk samples and within soil aggregate size fractions after separation by wet sieving. These fractions include macro (> 2 mm), meso (2 > 0.25 mm), and micro (0.25 > 0.053 mm) aggregate sizes. To our knowledge, this study will be the first to test the MANE framework at the aggregate scale. With these new results, we intend to identify the temporal and spatial scale at which AM and EM nutrient economies may emerge in addition to how these differences may relate to biogeochemical processes within stable aggregates.

Occurrence, sources and fate of nitrate in groundwater of agricultural watersheds in southern Alberta, Canada

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Providing high-quality drinking water is of key importance for supporting an increasing global population. While shallow groundwater is often a key source of water for domestic and livestock use in many regions, nitrate contamination of shallow aquifers is a widespread problem in many countries with the potential for adverse health effects if the water is used for drinking water purposes. We have investigated the quality and geochemical evolution of groundwater in agricultural watersheds of southern Alberta, Canada. A key objective was to determine the occurrence, the sources and the fate of nitrate in groundwater in agricultural watersheds using a combination of geochemical, isotopic and microbiological approaches.

Groundwater samples were collected from hundreds of domestic and monitoring wells completed in shallow aquifers (< 150 m) in agricultural regions of the province of Alberta, Canada. For all groundwater samples, concentrations of major and minor ions, total dissolved solids (TDS), water types, and redox states were determined. Nitrate concentrations above the detection limit were found in 35% of the groundwater samples. Only in 3 % of the samples did nitrate exceed the maximum allowable concentration for drinking water of 10 mg/L NO_3^--N. The isotopic composition of nitrate revealed that high nitrate contents in groundwater are frequently the result of cattle manure applications. Chemical, isotopic and microbial data revealed that denitrification was an important nitrate removal process in some aquifers that frequently contain moderately to highly reducing groundwater. The commonly reducing conditions explain why most groundwater samples had low, negligible or non-detectable nitrate concentrations.

In summary, this study revealed that the combination of geochemical, isotopic and microbiological approaches is a powerful tool to investigate the occurrence, origin and fate of groundwater contaminants such as nitrate with health implications for humans, livestock and ecosystems.

Session targeted: 4 – Change in the Anthropocene: Nutrient cycling.

Title: Centuries-old land-use changes influence contemporary biogeochemical groundwater behavior in headwater streams

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Abstract:
Before the era of fossil fuel use, water provided power for industrial processes in the USA through a ubiquitous network of dams and mills. This infrastructure was constructed concurrently with widespread deforestation and sedimentation during the 18th through 20th centuries causing wide-spread transformation of streams and buried floodplains with so-called legacy sediments. These centuries-old changes lead to stream incision and decoupled hydrological and biogeochemical processes causing excess transport of sediments and nutrients. In a pilot study, floodplain restoration involving legacy sediment removal was implemented at an intensively studied stream, Big Stream Run in Pennsylvania, USA. We sought to understand how restored hydrologic connection between floodplains and streams would influence biogeochemical processing of nitrogen and carbon in this landscape. Using variability in the oxygen isotope composition of catchment waters, we examined how groundwater contact times and flowpaths influenced seasonal nitrate and carbon concentrations in an 8-year, pre- and post-restoration study conducted at Big Spring Run. Denitrification potential was lowest in legacy sediments and significantly higher in the restored portion of the floodplain. Furthermore, greater nitrogen transformation occurred along more active paths of groundwater flow, especially where carbon concentrations were seasonally stable. Our study showed that even centuries-old extreme events can affect biogeochemistry of streams and that restoration can have a positive effect on sediment and nutrient fate and transport. (Disclaimer: The views expressed in this paper are those of the author and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency)

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Effects of hydrologic connectivity on greenhouse gas evasion from small tropical rivers

Small freshwater coastal ecosystems link uplands and nearshore environments. Despite the disproportionately high rates of terrestrial primary productivity and greenhouse gas production thought to occur in the tropics, the biogeochemistry of small coastal creeks and rivers with intermittent connections to the ocean is poorly studied. We sampled a range of coastal systems over several years along a connectivity gradient in northeastern Puerto Rico. The connectivity gradient spanned from creeks with continuous freshwater delivery to the sea, to those with infrequent (annual or less) connectivity to marine environments. Our results show that concentrations of greenhouse gases (CO_2, CH_4, N_2O), dissolved oxygen, and nutrients vary dramatically in concert with the extent to which these freshwater systems are hydrologically connected to marine environments. Systems with low connectivity are highly reduced, with the entire water column anoxic and containing extremely high levels of methane. These hot spots of greenhouse gas production represent a potentially important and under-estimated source of greenhouse gases that is driven by the high productivity of tropical mangroves and other wetland systems.

Impacts of acid deposition and lake browning on organic carbon storage in Canadian northern forest lakes

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Lake sediments are an important carbon (C) sink as they can accumulate C over very long time periods (centuries to millennia), and thus remove C from the short-term C cycle. Yet little is known about the sensitivity of this sink to anthropogenic disturbances. During the 20th century, atmospheric acid deposition disrupted terrestrial-aquatic C cycling by drastically lowering dissolved organic carbon (DOC) loads in many lakes across NE North America and northern Europe. Recovery from acid deposition has, in turn, led to widespread DOC increases (i.e., lake browning). To date, it remains unclear how acid deposition and lake browning have altered the role of lakes as long-term C sinks. We present organic carbon accumulation rates (OCAR) over the past ~150 years, and other supporting infrared spectroscopic, isotopic and elemental geochemical proxies, for eight lakes in and around Sudbury, Ontario, Canada – an area heavily affected by acid deposition from smelting activities in the late-19th and 20th centuries. Sediment-inferred trends in lake-water DOC showed a strong response to the effects of acid deposition during the past century, which is corroborated by increasing observed lake-water DOC concentrations since the 1980s. Despite these changes in DOC, as well as changes in water acidity, only lakes with direct physical watershed disturbances (i.e., vegetation loss and soil erosion following acidification and metal contamination) showed short-lived increases in OCAR, whereas OCAR changed little in remote Sudbury region lakes with minimal direct human disturbances (mean OCAR: 14.3±8.7 g/m^2/yr). This is in stark contrast to many other northern forest lakes with minimal direct catchment disturbances that experienced significant increases in OCAR during the 20th century. It has been suggested that lake browning may increase C burial by promoting the flocculation and sedimentation of additional DOC. Our results caution that lake browning alone may not be a dominant driver behind the recent widespread increase in organic C burial in northern lakes, and that additional DOC is instead mostly exported downstream or mineralized and released as greenhouse gases to the atmosphere.

Title: Recovery of plant communities and soil biogeochemistry following high-intensity fire

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Abstract:

To restore oak savannas in the Midwestern US, ecosystem stewards and managers cut invasive brush and thin trees, creating woody debris brush piles. Brush pile burning is the top strategy for dealing with this debris. Though individual piles are generally small (2-5 m in diameter), burning them can produce extreme soil temperatures that adversely affect soil processes and biota beneath the piles. Brush piles are often produced at high density in small management units undergoing ecological restoration, which may have consequences for ecosystem functioning and regional biodiversity conservation; approximately 5,000 brush piles are built and burned annually throughout the Chicago region. However, the ecological effects of these “burn scars,” which may include long-term changes in plant communities and soil biogeochemistry, are virtually unexamined. Furthermore, burn scars represent a unique study system for examining plant and soil successional dynamics following high-intensity fire. Burn scars can be used to evaluate plant and soil responses to high-intensity fires, characterize recovery trajectories, and identify possible remediation solutions. In this study, we used a unique chronosequence of burn scars created between 2015 and 2023 at The Morton Arboretum (Lisle, IL, USA) to evaluate the effects of brush pile burning on plant communities and soil biogeochemistry and track their successional recovery dynamics.

Brush pile burning had dramatic effects on plant communities and soil biogeochemistry, much of which persisted for at least eight years following burning. Recently-produced brush pile scars contained an average of 94% bare ground. It took seven years for scar vegetation cover to approximate that found in unburned areas ($P<0.001$). While plant communities overlapped between burn scars and control plots, burn scars had reduced variation in their plant communities compared to unburned controls ($P=0.001$). Additionally, older burn scars harbored distinct and more variable plant communities than younger burn scars ($P=0.001$). Belowground, nitrate and phosphate concentrations approximated values observed in unburned controls over time while pH and microbial biomass effects persisted for at least eight years. Brush pile burning increased soil nitrate and phosphate concentrations for one and four years respectively before returning to control levels ($P<0.001$). In contrast, brush pile burning increased pH from an average of 6.1 to an average of 7.9 and dramatically decreased microbial biomass – effects that persisted throughout the chronosequence ($P<0.001$). Collectively, our results suggest that while nutrient dynamics may recover unaided, soil pH, microbial populations, and vegetation communities likely require active remediation following high-intensity fires.

Putting a Whole System Approach for ecosystem, critical zone and socio-ecological research into praxis at the European scale: From triggering long-term N impact studies to interoperable standards and sustainable eLTER research services.

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We present recent site and cross-site evaluations of the drivers of long-term total (TIN) and dissolved inorganic N (DIN) concentrations and fluxes from catchments. In a global study, long-term, cross-site data shows that although N deposition is declining over time, atmospheric N inputs and precipitation remain important predictors for inorganic N exported from forested catchments. Despite decreased N deposition in Europe, TIN output fluxes and retention rates showed a mixed response with both decreasing and increasing trends. We put these trends in context using a karst catchment in the Austrian Alps (LTER Zöbelboden) from 27 years of records, where the study area was exposed to increasing N deposition during the 20th century, which are still at high levels of around 20-25 kg N ha-1 y-1. Albeit N deposition was close to or exceeded critical loads for several decades, 70–83 % of the inorganic N retained in the catchment. Exploring and interpreting the long-term dynamics of matter fluxes and stocks suggests cross-disciplinary collaborations, sharing, aligning and multiple usage of long-term operated Research Infrastructures. We will report on recent advancements in building a common theoretical base between major communities that is – inter alia - underlying the ongoing implementation of the Integrated European Ecosystem, critical zone and socio-ecological Research Infrastructure (eLTER RI). The “Whole System Approach for in-situ research on Life Supporting Systems in the Anthropocene” (WAILS) will be outlined. We will also expand on the potential of such unifying approach in theory-guided integration and division of tasks amongst related environmental RIs. Practical implications like Standard Observations will be addressed, which result from research teams driven (bottom-up) needs, but require centralistic RI design and operations for their implementation.

Ruckus in the rhizosphere: connecting exudation, microbial growth, and carbon cycling in forest soils.

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Elevated atmospheric CO_2 concentrations are predicted to increase plant productivity and the release of exudates in the rhizosphere. However, the interplay between rhizosphere exudation, microbial activities, community dynamics, and soil carbon biogeochemistry remains unclear. Here we used $^{18}O–H_2O$ quantitative stable isotope probing to investigate the effects of synthetic root exudate inputs (250, 500, and 1000 µg C g soil^{-1}) on microbial growth traits and carbon biogeochemistry in rhizosphere soils of trees associated with arbuscular mycorrhizal (AM) and ectomycorrhizal (ECM) fungi. Soil respiration increased proportionally to the amount of exudate addition in both AM and ECM soils. However, microbial biomass responses differed, increasing in AM but decreasing in ECM soils. Enhanced exudate inputs increased the relative growth rates of individual taxa, leading to enhanced community level growth and more microbial biomass production in AM rhizosphere soils. In contrast, microbes in the rhizosphere soils of ECM trees were less responsive to exudates and estimates of microbial biomass turnover increased with increasing exudate inputs. Aggregated microbial growth was predictive of soil respiration in AM rhizosphere soils, but this relationship was not observed in ECM soils, possibly due substantial microbial biomass turnover. The distinct responses of AM and ECM rhizosphere communities suggest that the impacts of enhanced rhizosphere exudation expected with higher atmospheric CO_2 may depend upon mycorrhizal association. Specifically, our results suggest future increases in rhizodeposition in response to global change may lead to greater soil organic carbon gains in AM soils than in ECM soils.

Mercury cycling during acid rain recovery at the 14 forested catchments of the GEOMON monitoring network, Czech Republic

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Cycling of mercury within the temperate forest ecosystem was studied at 14 forested catchments included within the GEOMON monitoring network managed by the Czech Geological Survey. The catchments have variable size, elevation, bedrock and forest composition, and were monitored a monthly time step for mercury (Hg) inputs (bulk, throughfall, litterfall) and outputs (runoff) for more than two hydrological years (2021-2022). Air Hg concentrations at all the sites were assessed using passive samplers,

Across the 14 GEOMON catchments, the volume-weighted Hg concentration in bulk precipitation was low, averaging 1.8±0.3 ng L^{-1}. Mean bulk precipitation Hg deposition across the GEOMON catchments averaged 1.7±0.4 µg m^{-2} yr^{-1}, ranging from 1.1 to 2.3 µg m^{-2} yr^{-1}. Mercury concentrations in throughfall were elevated, averaging 6.7±1.8 ng L^{-1} and site means ranged from 3.3 to 11.1 ng L^{-1}. The mean spruce throughfall Hg deposition from the 14 catchments was 4.5±1.5 µg m^{-2} yr^{-1}. Site-specific mean volume weighted spruce throughfall Hg concentrations correlated positively with those of DOC ($r=0.86$, $p<0.001$; $n=14$). Both site-specific annual bulk precipitation and throughfall Hg deposition were positively correlated with annual precipitation amount (r= 0.83 and 0.74, $p<0.001$; $n=14$).

Gaseous elemental mercury (GEM) in air varied little at the monitored catchments; it ranged from 1.25 ng m^{-3} at a background catchment to 1.66 ng m^{-3} at a catchment affected by the emissions from a coal-fired power plant.

The main pathway of Hg input into the 14 forested catchments was litterfall. Across the 14 GEOMON catchments, mass-weighted Hg concentration in spruce litterfall was relatively high, averaging 89.9±20.6 µg kg^{-1}. At catchments LES and JEZ, site-specific average mass-weighted Hg concentrations in beech litterfall were 49.6 and 47.3 µg kg^{-1} and Hg in birch litterfall at JEZ averaged 40.3 µg kg^{-1}. The mean spruce litterfall Hg deposition across the GEOMON catchments averaged 44.5±15.7 µg m^{-2} yr^{-1}, ranging from 23.4 to 72.9 µg m^{-2} yr^{-1}. Hg in beech litterfall at LES and JEZ amounted 32.5 and 26.8 µg m^{-2} yr^{-1} and litterfall Hg deposition in the JEZ birch stand was 14.2 µg m^{-2} yr^{-1}.

The stream Hg output from the forest ecosystems averaged at 1.5±1.7 µg m^{-2} yr^{-1}, ranging from 0.2 to 6.9 µg m^{-2} yr^{-1}. The average retention rate calculated by comparing Hg inputs (throughfall + litterfall) and outputs (stream runoff) of the 14 catchments representing the central European forest ecosystems was 97%.

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Modelling the Influence of Subsurface Geology on Northern Peatland Hydrology

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Peatlands are complex wetlands that play an important role in global carbon cycling as both carbon sinks and sources they contain over one third of all global soil carbon but cover <3% of all land surfaces. The hydrology of a peatland exerts a significant control on overall carbon cycling as the position of the water table directly impacts carbon sequestration and emission while circulation within the peat basin will influence nutrient availability. Hydro-geophysical studies of northern peatlands over the last two decades have identified the presence of eskers buried beneath some peat deposits in Maine. These studies have hypothesized that eskers drive vertical groundwater flow within these systems and may act as hotspots for methane emissions. However, only conceptual hydrologic models have been developed to support this claim. Using the results of these studies along with new hydrologic and geophysical datasets, a USGS MODFLOW 6, finite-difference groundwater flow model was developed for Caribou Bog near Bangor, ME. Caribou Bog is a multi-unit, ombrotrophic, domed bog with a patterned pool system. Groundwater flow simulations were run at regional and local scales by inserting a fine-scale model encompassing a single peat unit into a coarser-grid, watershed area. The PEST parameter estimation package was used to calibrate the model and MODPATH 7 was used to identify flow paths within the model. Simulation results will be used to show that these esker deposits enhance vertical flow through the peat and potentially connect the peatland to the regional aquifer system. These results challenge the traditional viewpoint that ombrotrophic peat systems in boreal regions are relatively disconnected from groundwater flow. Furthermore, they may provide insights into the spatial variability of carbon cycling within peatlands, particularly to assess hydrologic response caused by changing precipitation patterns and warming temperatures expected due to climate change.

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Adsorption to Al-, Fe-, and Mn-oxyhydroxides dominates rare earth element (REE) and P mobility in a headwater stream in Vermont, USA

Sleepers River watershed W-9, a U.S. Geological Survey site in Vermont USA, is underlain by Waits River Formation carbonaceous schist with impure rusty-weathering limestone beds. Quartz, feldspar, two micas, garnet, calcite, and pyrite dominate. Trace apatite, monazite, and possibly calcite are sources of REEs. Till, containing abundant local bedrock and erratics of granite, ranges up to 4 m thick. We evaluated REE and P mobility for three discharge events. Events included eight samples, distributed from baseflow to peak(s) to nearly baseflow, and speciated for **Total** (unfiltered and acidified) and **Dissolved** (0.45 µm-filtered and acidified).

E1 (large Fall rainstorm; 0.014 to 3.696 mm/h): **Total** Al, Fe, and Mn increased from 0.21, 0.83, and 0.85 µmol/L, respectively, to 376(1790X), 161(194X), and 38(45X) µmol/L; **Total** Al/Fe≈2. **Total** Ca **(≈Dissolved**) was diluted, as Mg and K increased slightly (leaf senescence). **Total** Na (**≈Dissolved** Na) remained low and relatively constant. Concurrently, **Total** La, Ce, Pr, and Nd increased from 0.15, 0.17, 0.04, and 0.13 nmol/L, respectively, to maxima of 87(580X), 114(671X), 15(375X), and 53(408X) nmol/L, nearly concurrently. At or near peak discharge, **Dissolved** La, Ce, Pr, and Nd were <3% of **Total**. **Total** La, Ce, Pr, and Nd during events had negative hysteresis, suggesting that particulates of Al, Fe, and Mn were mobilized from the stream bed, while precipitation of fresh Al-, Fe-, and Mn-oxyhydroxides occurred during higher discharge of groundwater, higher pH (degassing of excess CO_2), and higher PO_2. **Total** export for E1 was Ce>La>Nd>Pr for the light REEs while four heavier REEs were typically Dy>Ho>Er>Tm, also with negative hysteresis.

E2 (snowmelt; 0.407 to 0.941 mm/h): Maximum **Total** Al was 10% of **Total** Al for E1 and constant, while maximum Al/Fe was ≈0.10. Base cations (Ca>Mg>K>Na) remained nearly constant with **Total≈Dissolved**. **Total** La, Ce, Pr, and Nd increased 33X, 27X, 25X, and 24X, respectively, while **Total** Mn increased 80X, greater than Al(≈0X) or Fe(12X) during the first peak.

E3 (small Fall rainstorm; 0.006 to 0.073 mm/h): As discharge increased from 0.006 to only 0.013 mm/h, mobilization of most REEs surged 3X-5X. Base cations remained nearly constant (Ca>Mg>K>Na), with **Total≈Dissolved**. During E3, **Total** Al/Fe≈0.67-1.59, consistent with base flow dominated by weathering pyrite. Maximum **Dissolved** P declined from 0.89 (E1) to 0.27 µmol/L (E3); **Total** P declined from 15 (E1) to <1 µmol/L (E3). REEs and P are dominantly exported adsorbed on particulate Al-, Fe-, and Mn-oxyhydroxides (partitioning unknown), with Al>Fe>Mn during E1.

Controls on $^{26}Mg/^{24}Mg$, $^{44}Ca/^{40}Ca$ and $^{87}Sr/^{86}Sr$ isotope variability in two industrially polluted forested catchments in Central Europe: Insights into nutrient imbalances

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For the past 28 years, monthly hydrochemical monitoring has been performed in 14 headwater catchments of the GEOMON network located throughout the Czech Republic. Input–output mass balances show dramatic decreases in sulfur deposition and retention following the 1980s peak pollution, and decreasing net runoff export of basic cations. We used stable isotope ratios of Mg, Ca, and Sr at two high-elevation GEOMON sites as tracers of nutrient inputs into catchment reservoirs, mixing history between solutes, secondary mineral formation, plant–mineral interactions, and recycling of atmospheric and lithogenic inputs by vegetation. The Cervik catchment is situated on base-poor flysch sediments near the Czech–Polish border, while Jezeri, situated close to the Czech–German border, is underlain by base-poor orthogneiss. Spruce is the dominant vegetation at Cervik, beech covers the lower segments of Jezeri, while spruce stands mostly died back. These two sites belong to the steepest catchments of the network. Jezeri was limed during the acid deposition period. Because ecosystem processes are known to fractionate Mg and Ca isotopes, we expected different isotope ratios of these nutrients in runoff in comparison with isotope ratios of bedrock and atmosphere as the ultimate mixing endmembers. Previously described isotope fractionations include preferential assimilation of isotopically light Ca and isotopically heavy Mg by plants, and adsorption of isotopically heavy Mg by phyllosilicates. Surprisingly, in four out of six cases, we found nearly identical average isotope signature of atmospheric deposition (rainfall and throughfall) and runoff. These cases included Ca at both Cervik and Jezeri, Mg at Cervik, and Sr at Cervik. Strontium isotope ratios in Jezeri runoff were also relatively close to deposition. In all these cases, isotope signature of bedrock differed from atmospheric input and runoff. Magnesium at Jezeri represented the only opposite pattern: Mg isotope ratios in Jezeri bedrock and runoff were nearly identical while being different from local atmospheric input. Jezeri was characterized by hydrological export of mostly geogenic Mg. On the other hand, interpretation of the common deposition–runoff similarity (Mg/Ca/Sr at Cervik, and Ca/Sr at Jezeri) is not straightforward: Annual export of individual base cations is up to 15 times higher than their annual atmospheric input. Non-isotope data *per-se* would thus indicate geogenic rather than atmospheric origin of Mg, Ca and Sr in runoff. The interpretation is additionally complicated by contrasting isotope composition of Mg/Ca/Sr in individual bedrock minerals with contrasting dissolution rates. Funded by the Czech Science Foundation (21-27420S).

Calcium, magnesium and strontium isotope dynamics in Central European headwater catchments along lithological and pollution gradients: Atmospheric *vs.* geogenic sources for runoff

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During pedogenesis, the sources of nutrients change. As soils develop on freshly exposed bedrock, geogenic elements are gradually lost. When the rates of hydrological export of geogenic nutrients are higher than the rates of mineral dissolution, atmospheric inputs gradually replace rock-derived nutrient sources and help to sustain productivity of forests. This process was documented for highly weathered soils in humid warm regions, but also inland ecosystems in temperate climatic zones have been shown to store substantial amounts of atmospheric nutrients. Nutrient imbalances negatively affect the health status of forests exposed to multiple stress factors, including drought, and, in Central Europe currently also a bark beetle calamity. We present a combined Ca–Mg isotope and mass-balance study of 7 small forested catchments near the borders between the Czech Republic, Poland, Germany and Austria. Due to acid rain, part of this area suffered from massive spruce die-back 30-60 years ago. Atmospheric deposition of alkaline earth elements increased after 1950 as a result of dust emissions from Soviet-style thermal power plants. Due to technological upgrades, replenishment of base cations in ecosystems *via* deposition decreased after 1990. Our main objective was to constrain the provenance of Ca and Mg in surface runoff. Study sites included base-poor bedrock (granite, orthogneiss, paragneiss, and flysch turbidites; ~1 % of CaO and MgO, respectively) and base-rich rock types (amphibolite and serpentinite; over 10 % of at least one base cation). Throughfall Ca fluxes at individual sites were between 60 and 2.0 kg ha^{-1} yr^{-1}, those of Mg varied between 13 and 1.0 kg ha^{-1} yr^{-1}. Ca, Mg and Sr isotope signatures were determined for 10 ecosystem compartments, including whole rock, bulk soil, lysimeter solutions, rainfall, spruce throughfall, roots, needles, xylem, bark, and runoff. At some sites, up to 7 rock-forming and accessory minerals were separated from ground rock and analyzed for Ca, Mg and Sr isotopes. Strontium was used as a Ca analogue. Isotope ratios were compared with hydrochemical input–output mass balances constructed for the past 28 years. Intuitively, large net Ca/Mg/Sr export *via* runoff should be accompanied by geogenic isotope signatures. The data, however, revealed a much more complicated pattern. Even though bedrock minerals exhibited large isotope variability, one Ca/ Mg/Sr-rich, easily dissolvable mineral was usually responsible for the geogenic input to runoff. Calcium and Mg in runoff were also affected by isotope fractionations accompanying assimilation and adsorption/desorption. Funded by the Czech Science Foundation (Grant 21-27420S).

Chemical weathering of ultramafic rocks at the Rio Cupeyes NEON site in southwestern Puerto Rico

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The weathering of mafic and ultramafic rocks in tropical environments has been demonstrated to be a major consumer of atmospheric CO_2 (Dessert et al. 2003); however, determining weathering fluxes is complicated due to the time and expense of extensive sampling programs. For this reason, few studies of mafic rocks include calculated weathering fluxes over a range of yearly weather conditions. The Rio Cupeyes Core Aquatic NEON site is a 4.26 km^2 watershed in western Puerto Rico that has been continuously monitored since 2018. The entire Rio Cupeyes watershed is located on serpentinite bedrock, which is depleted in essential plant nutrients including K and P, has a low Ca to Mg ratio, and contains high concentrations of heavy metals. The watershed experiences wet and dry seasons as well as hurricanes leading to extreme high flow events; landslide activity is also common.

Watershed-integrated chemical weathering fluxes for the Rio Cupeyes watershed were calculated using discharge data from **continuous sensors** and stream and precipitation chemistry collected approximately twice monthly from 2018 to 2022, yielding nearly 100 distinct chemical weathering flux measurements. The average Ca to Mg ratio for stream samples is 0.1; average Mg concentrations are 1340 μmol/L and vary little with season or discharge. Average Ca concentrations are 130 μmol/L, and average K concentrations are 6 μmol/L. Because Mg is the dominant weathering-derived cation, seasonal changes in weathering fluxes are controlled by variations in discharge, which span three orders of magnitude. For the Rio Cupeyes watershed, this means that measuring chemical weathering yields infrequently and extrapolating those data over the calendar year could dramatically over- or underestimate weathering yields depending on sampling date.

Ecosystem $\delta^{15}N$ signature consistently integrates dissolved and gaseous N losses with microbial potential for nitrification and denitrification

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Global nitrogen deposition in forests can alleviate nitrogen limitations, impacting biodiversity, carbon storage, water quality, and greenhouse gas emissions. Predicting these effects relies on quantifying nitrogen fluxes, particularly nitrogen gas loss and soil retention. In central Europe, long-term catchment measurements and ^{15}N:^{14}N isotope data reveal key factors affecting dissolved and gaseous nitrogen fluxes in temperate forests, with stream nitrogen losses relating to forest floor nutrient ratios, increasing as ecosystems become more phosphorus-limited, and soil nitrogen storage increasing with iron and aluminium content. Gaseous nitrogen losses, estimated at 2.5 ± 2.2 kg N ha^{-1} yr^{-1}, comprise 20% ± 14% of total nitrogen deposition, and these losses rise with forest floor N:P ratio and dissolved nitrogen losses. We further integrated ecosystem $\delta^{15}N$ with soil microbiome gene data, finding that nitrogen losses correlated with soil $\delta^{15}N$, primarily driven by genes related to nitrite formation in nitrification and denitrification processes, which were more informative than those associated with nitrous oxide production. This suggests that nitrite formation is a critical step in nitrogen losses, and the genetic potential for ammonia oxidation and nitrate reduction serves as an indicator of ecosystem nitrogen losses.

Catchment scale nutrient balance as a tool in precision forestry

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Catchment scale management of forest nutrient cycles is an important part of modern forestry. A leap towards holistic management of ecosystem services through customised forest management strategies has become possible when high resolution forest, terrain, and soil data can be combined with detailed process-based ecosystem models. We have developed catchment level, spatially distributed nutrient balance and hydrology models, which calculate location-specific nutrient dynamics and the nutrient export from the terrestrial part of the catchment to water courses. Model applications have shown that the nutrient export is very unevenly distributed throughout catchments: 5 % of the catchment area can produce 25% of the nitrogen export. This identification of nutrient export hotspots facilitates knowledge-based planning and cost-efficient locating of water protection. We have found that catchments may contain a wide range of different nutrient balances. Simulations also reveal locations where the forest stand growth is nutrient-limited, and thus opens the possibility for precision fertilization. In precision fertilization the quality, dose and timing of the fertilization can be adjusted so that the site-specific nutrient supply meets the nutrient demand and thus the harmful environmental impacts, such as increased nutrient exports, can be diminished. Furthermore, these models can be used to compare different harvesting methods and forest management strategies with respect to multiple ecosystem services. Process-based ecosystem models including nutrient balance and geospatial high-resolution data are particularly useful in forecasting the effects of climate change allowing development of pro-active adaptation schemes in a specific catchment.

The effect of agricultural practices on stabilization of organic matter in various soil types.

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This contribution presents the preliminary results of the DivLand project – Centre for Landscape and Biodiversity. One of its branches deals with long-term changes in agricultural land cover and the effects of agricultural practices on soil properties. Over the last 70 years, the Czech landscape has undergone extreme changes, from the politically motivated massive consolidation of agricultural land and a change in the ownership structure through the intensification of agriculture to the limitation of livestock production and thus the use of organic fertilizers. All these changes can affect soil properties however, preliminary results show not unidirectional changes e.g., in soil pH and carbon content in arable land over this period in regions involving Cambisols, Luvisols and Chernozems. Therefore, it cannot be generalized that soil conditions have improved or worsened. Only the conversion of arable land to permanent grassland in the Cambisol areas resulted in an increase in carbon content.
A detail study (10 study sites; 20-year on-farm trial) focuses on the effect of manure application and crop residues incorporation (as measures often mentioned in connection with the carbon storage in the agricultural soils) on qualitative parameters of soil organic matter (SOM). The quality of SOM was assessed using diffuse reflectance infrared spectroscopy. The results show that the addition of certain forms of organic matter, such as manure, can increase the total organic matter content, but does not significantly determine the chemical composition of long-time retained organic matter. Rather, soil conditions determine which components are fixed in the soil on a long-term scale. A dominant effect of soil type was found in the distribution of all measured spectral parameters (potential wettability index, organic matter quality index, and decomposability index). The main differences between the soil types concern the aromatic and oxygen groups contained in the SOM. At the same carbon content, organic matter of Chernozems maintains high proportion of aromatics even with different treatment, and in contrast, proportion of aliphatic components remains high in all treatments on acid Cambisols. The stabilization of SOM in soils can thus be based on their specific affinity for minerals (clays, oxides) and on the formation of stable aggregates protected by the hydrophobic character of SOM components.

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Episodic carbonate cementation in Eger Graben claystone: insights into metal cycling and biogeochemical dynamics in Early Miocene lake systems

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The lacustrine sedimentary records of the Eger Graben in the Czech Republic serve as a window into the Miocene Climatic Optimum (MCO, 16.9-14.7 Ma)—a period that bears concerning similarities to our future projections of pCO_2 levels and climate. In that geological framework, we investigated the intricacies of metal respiration, biogeochemical cycles, and microbial lake paleoecosystem dynamics. These aspects are elucidated by studying stratigraphic abundances of primary ferroan dolomite. This mineral punctuates the Early Miocene sedimentary infill of the Eger Graben. Lacustrine carbonates are widely recognized as reliable carriers of paleoenvironmental and paleoclimate signals. In this context, we analyzed bulk-rock elemental concentrations, stable isotopes (C, O, N), and carbonate clumped isotope paleothermometry, complemented by detailed mineralogical data of the dolomite-bearing intervals. Our findings shed light on how fluctuations in pCO_2 during the MCO influenced aqueous dolomite equilibrium in brackish alkaline paleolakes. The interplay between redox and salinity fluctuations served as an additional driver for lacustrine dolomite precipitation, highlighting the impact of climate change on runoff rates and delivery of solutes and nutrients. Microbial activity left a distinct isotopic imprint on the sediments, with $\delta^{15}N$ values averaging +9.8±0.7‰ (N=18), indicative of substantial N_2 losses. The mean $\delta^{13}C$ values of dolomite, +5.3±0.3‰ (N=13), on the other hand, captured a mix of dissolved inorganic carbon sources, including methanogenesis and a prevalent mantle-derived flux with $\delta^{13}C$ of about −4.0‰. Our data show that periodic pCO_2 fluctuations and microbes facilitated primary dolomite formation. Enhanced weathering in the catchments led to leaching of alkaline bedrocks, studied in the Czech GEOMON network, which supplied Mg^{2+}, Na^+, K^+, and rare earths. These ions elevated paleolake alkalinity leading to notable europium anomalies in the dolomitic marls; without corresponding cerium anomalies. This latter feature points to a generally redox-stratified water column, overlying an anoxic ferruginous lakebed containing abundant ferric particles. Thus, a long-term cycle of iron (and manganese) was sustained, coupled with nitrogen respiration. Despite prominent Eu anomalies, dolomite locking temperatures are consistently below 30°C, as indicated by the Δ_{47} paleothermometer, while the mineral abundance has a chemostratigraphic association with terrigenous potassium and barium contents, contributing further to our understanding of past climate controls over the carbonate factory. There is also interesting evidence suggestive of recurrent early dolomite resuspension events. Overall, our exploration of metal cycling and biogeochemical dynamics within the Early Miocene Eger Graben provides valuable insight into the past and future of our changing environment.

Title: **Contributions of hydropower reservoirs to global carbon emissions: breaking down sources of uncertainties**

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Abstract:
Hydropower reservoirs provide renewable electricity generation and many other services, such as drinking water, irrigation, flood control, and recreation. As with most aquatic ecosystems, reservoirs play an important role in the global carbon cycle and emit biogenic greenhouse gases in the forms of carbon dioxide and methane that influence their net carbon footprints. However, these carbon emissions are poorly quantified in reservoirs, especially in temperate systems. As a result, there is high uncertainty as to the spatiotemporal variability in emissions from individual reservoirs as well as uncertainty in national to global reservoir contributions to carbon emissions. To assess the sources of uncertainty in reservoir carbon emissions, we compared two empirical field-based methods and one modelling method of estimating upscaled, whole-reservoir emissions. We sampled six hydropower reservoirs in the southeastern USA using two different spatial survey designs to quantify the emission rates of carbon dioxide and methane via different emissions pathways. We paired this with modelled emissions estimates from the same six reservoirs and emissions pathways using the GHG Reservoir (G-res) tool. Comparing carbon emissions from the different pathways and different methods showed high uncertainty across the six reservoirs. While both field-based methods indicated strong carbon dioxide influxes (sequestration) at all six reservoirs, the G-res model showed carbon dioxide emissions at all six reservoirs. Methane degassing emissions, a pathway unique to reservoirs, was estimated to be orders of magnitude higher in four of the six reservoirs based on the G-res model compared to field data, but similar in the other two reservoirs. Methane ebullitive emissions showed the greatest variability across reservoirs and methods across all six reservoirs, with no clear consistency. Some reservoirs had similar field-based ebullition estimates while modelling estimated two to five times greater emissions, and others had ebullition estimates from modelling similar to one field-based method but not the other. Given these inconsistent discrepancies, upscaling whole-reservoir carbon emissions is still highly uncertain and can influence our understanding of hydropower reservoirs' carbon footprints. Methane emissions are particularly important to understand, as they are ~34 time more potent than carbon dioxide emissions and have very high within-reservoir spatial variability in ebullition emissions in particular. Hence, additional research breaking down sources of uncertainty in methodology, pathways, and

spatiotemporal variability in reservoir carbon emissions will be vital to understanding the carbon footprint of these renewable energy sources and contextualize their current and projected future contributions to global carbon emissions.

The variable sensitivity of soil respiration to temperature is determined by the climatic gradient along the GEOMON catchments.

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Abstract

Soil respiration (Rs) is an important part of the global carbon cycle. The current focus centers around the rising levels of carbon dioxide in the atmosphere and the endeavour to discover additional capacity within existing carbon storage systems. Soil respiration emerges as a pivotal factor in the exchange of gases between the soil and the atmosphere, significantly impacting the global carbon equilibrium and exerting an influence on the dynamics of climate change.

Measurements are conducted within the GEOMON catchments located in the Czech Republic. These catchments consist of fourteen forested experimental basins situated at various altitudes throughout the region. To monitor changes in Rs, measurements are taken periodically using the LiCor LI-8100A device over a three-year period. The variable sensitivity of Rs to temperature is determined by the climatic gradient along the GEOMON catchments. Temperature is the main predictor of Rs rates under moist temperate forest conditions. The temperature sensitivity of Rs increases with increasing elevation, which is a consequence of the accumulation of soil labile dissolved organic matter under cooler conditions.

Thus, as average temperature increases, we cannot expect a rapid increase in Rs (as long as ecosystem productivity remains unchanged), only a short-term increase before the "stock" of labile organic matter is depleted and a new balance between litter production and decomposition is established.

SOLAR RADIATION AS THE LIKELY CAUSE OF ACID-SOLUBLE RARE-EARTH ELEMENTS IN SEDIMENTS OF FRESH WATER HUMIC LAKES

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We studied photochemically induced precipitation of Rare Earth Elements (REEs) in water from a tributary to Plešné Lake, and a tributary to Jiřická Pond, Czech Republic. Both tributaries had high concentrations of dissolved organic matter (DOM, ~1.8 mmol C L^{-1}). Filtered (0.2 µm) samples were exposed to artificial solar radiation of 350 W m^{-2} for 48 to 96 hr, corresponding to 3 to 6 days of natural solar radiation in summer at the sampling locations. Experiments were performed with altered and unaltered pH ranging from 3.8 to 6.0. The formation of particulate REEs occurred in all exposed samples with the fastest formation observed at the original pH. The formation of particulate metals continued in irradiated samples after the end of irradiation, suggesting that photochemically-induced reactions and/or continuing precipitation continue in darkness or in deeper water due to mixing. Results were compared with paleolimnological records in Plešné Lake sediment. At pH 5.0, the photochemically-induced sediment flux was 3509 nmol m^{-2} y^{-1} for Ce, corresponding to 42% of the REEs' annual sediment flux in recent sediment layers. Combining the formation rates obtained in the laboratory irradiation experiments and known one-day incident solar radiation enabled the estimation of a possible REE sediment flux. For Plešné Lake, the photochemically-induced formation of particulate REEs explained 10–44% of the REE concentrations in the upper sediment layers. Observed photochemically-induced sequestration of REEs into sediment can explain a significant part of the REEs' history in the Holocene sediment.

Mycorrhizal associations mediate rhizodeposition but not soil C storage in response to nitrogen availability

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Mycorrhizal fungi provide plants with nutrients in return for photosynthate, linking above and belowground processes. Forests dominated by arbuscular (AM) versus ectomycorrhizal (EcM) fungi have well-documented differences in their distributions of soil carbon (C) and nitrogen (N). However, the mechanisms driving these patterns are uncertain. Potential mechanisms include differences in leaf litter quality, rhizodeposition, fungal nutrient acquisition strategies, and fungal necromass quality. Here, we investigated the role of rhizodeposition using a greenhouse experiment wherein eight species of seedlings (four AM and four EcM) were grown in a ^{13}C-labeled atmosphere under three levels of ^{15}N-labeled fertilizer. Over one growing season, we compared how plant N uptake and rhizodeposition differed between mycorrhizal types and between the rhizosphere and hyphosphere (excluding roots). Overall rhizodeposition was greater from EcM seedlings than AM seedlings and increased with increasing N availability in EcM but not in AM seedlings, making the overall belowground C cost of N uptake greater for EcM seedlings. Despite these differences, the net effect of the seedlings on soil carbon storage was similar between mycorrhizal types. For both mycorrhizal types, over the course of the experiment, there was a net loss of soil C in the rhizosphere, while the hyphosphere experienced a net gain in soil C. These findings suggest that trees mediate belowground C investment in response to inorganic N availability differently between mycorrhizal types, and that different mechanisms account for SOM accumulation and loss in the rhizosphere and hyphosphere.

Nutrient acquisition strategies and fine root dynamics determine differences in soil carbon between intact and disturbed tropical peat swamp forests

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Background/Question/Methods
Southeast Asian tropical peat swamp forests are highly distinct habitats, holding large numbers of endemic species and carbon stores. However, much of these intact peat swamp forests have been logged or drained, leading to the drying out of peat that has resulted in an increase in fire events. A critical first step to identifying restoration strategies is to quantify the degree to which disruptions in tree nutrient acquisition strategies due to degradation drive shifts in carbon dynamics. In Brunei Darussalam, the peat swamp forests hold a key tree species, *Shorea* albida, which dominates the waterlogged forests, growing up to 70 m high and forming extensive root mats above the peat. A gap in our understanding is how these unique trees acquire nutrients in intact peat swamp forests, and how these functions belowground may change with degradation. To unlock the hidden half of these forests, we examined how nutrients and carbon are cycled belowground along a degradation gradient experiment ranging from disturbed peat swamp forest to interior pristine forest. We also quantified fine root biomass, ectomycorrhizal colonization, and root necromass to a depth of 1.5 meters. We hypothesized that pristine forests would contain lower fine roots than the disturbed forest but would have a stronger rhizosphere investment, as well as, greater mycorrhizal colonization rates for nutrient acquisition. In contrast, disturbed peat swamp forest would contain greater fine roots along with a greater reliance on bulk soil microbes to acquire nutrients due to a lowered water table allowing for an increase in decomposition to occur in the peat.

Results/Conclusions
In line with our hypotheses, we found that while intact peat swamp forests store a lower amount of carbon in fine roots, at depth more carbon is stored in dead roots that resist decomposition in waterlogged conditions. Opposingly, at the disturbed forest sites, the trees store more carbon in fine roots at the surface but have lower amounts of carbon stored at depth in dead roots, potentially driven by a decrease in water in the peat. Additionally, we found differences in root investment in mycorrhizae and rhizosphere extracellular enzymes, in which the intact forest had greater ectomycorrhizal colonization than the disturbed forest, with the types of nutrient-acquiring enzymes varying by forest type. These differences are important in understanding how intact peat swamp forest trees grow and implications for how these forests will store carbon belowground with human degradation.

Stem CH_4 and N_2O fluxes from Downy Birch during the spring sap-run period and dependence on dissolved gas concentrations in xylem sap

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Tree stems are known to emit greenhouse gases CH_4 and N_2O to the atmosphere but the processes and drivers behind these fluxes are still contested. Soil water is taken up by tree roots and moves up the xylem due to a negative pressure gradient caused by transpiration through the leaves. Consequently, dissolved gases in the soil water move up the stem and are potentially diffused to the atmosphere through the bark. Periods of soil freeze-thaw in the spring are crucial hot-moments of GHG release from the soil, as well as stems. As birch trees go through a sap running period between the thawing of the soil and bud break, they provide an opportunity to study GHG fluxes during the peak time of emissions, together with the concentrations of dissolved gases in the birch sap.

Accordingly, we quantified the fluxes of CH_4 and N_2O from Downy birch (*Betula pubescens*), as well as Norway spruce (*Picea abies*) for comparison, in a temperate nutrient-rich drained peatland forest in April and May 2023. In addition, we studied the relationship between birch stem CH_4 fluxes and dissolved CH_4 concentrations inside the xylem sap. Stem fluxes were determined using static chambers attached to the tree stems and automatic LI-COR gas analysers. In addition, we analysed dissolved gas concentrations in birch sap and soil water, and the chemical and microbiological composition of the soil.

Birch stems CH_4 and N_2O fluxes ranged from 1.48 to 7.24 µg CH_4 m^{-2} h^{-1} and −0.47 and 2.98 µg N_2O m^{-2} h^{-1}, respectively. Meanwhile, spruce stem fluxes ranged between −0.12 and 2.19 µg CH_4 m^{-2} h^{-1} and −2.76 and 0.77 µg N_2O m^{-2} h^{-1}. Stem fluxes followed the temporal trend of soil and air temperature, with higher fluxes during warmer days, likely related to increased microbial activity in the soil. Dissolved CH_4 concentrations in the birch sap increased during the study period, from 2893 ppb to 9158 ppb. Average CH_4 concentrations were higher in sap collected from higher parts of the tree. A more detailed analysis together with examination of the underlying soil chemistry and microbiology will be presented to further explain the processes behind soil and tree stem GHG flux dynamics.

Monitoring groundwater levels and simulating groundwater flow near the Ring of Cenotes, northeastern Yucatan, Mexico.

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Groundwater, the primary source of freshwater in Mexico's Yucatan Peninsula, is a critical resource that is threatened by emerging groundwater contamination issues. To better define the physical processes that control flow paths and chemical transport in groundwater, data logging pressure sensors were placed in cenotes and wells at nine locations in and around the Ring of Cenotes, a prominent geomorphic feature in the Yucatan. Twelve locations were surveyed using a Trimble Net R9 GPS system and an autolevel to provide topographic control for water level measurements. Manual water levels in wells and cenotes were measured with an electrical water level indicator from surveyed control points and converted to water levels relative to sea level. Water level data show expected flow patterns toward the coast. Strong ocean tide signals were observed in monitoring stations near the coast and decreased inland. These tidal signals were not observed in a shallow well near Progreso, suggesting a dense carbonate layer acts as a confining unit and separates shallow and deep aquifers in the coastal zone. A dramatic, one meter increase, in groundwater levels was measured near Progreso and Merida (Mexico) associated with precipitation from Hurricane Kay and Tropical Storm Lester. This localized change in hydraulic head dissipated over the following month and locally altered groundwater flow patterns. Groundwater flow and solute transport models are currently being developed using The U.S. Geological Survey's MODFLOW 6 groundwater flow software to aid in the interpretation of water level data and simulate salt water intrusion within the study area. While simulations currently reproduce measured groundwater levels, the simulated position of the saltwater interface is deeper than what has been observed.

Does climate or tree roots control C and nutrient sequestration in temperate forests? A soil translocation approach

Session: Soil carbon stabilization and C sequestration

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Climate is an important master variable for temperate forests and is set to alter their hydrology, biogeochemical cycling, and add ecological pressures from the changing climate. In particular, increases in mean annual temperature are set to enhance the rate of abiotic and biotic processes from fewer days below freezing, greater day time temperatures, and longer growing seasons with implications for faster C and nutrient cycling in soils. Trees can alter nutrient dynamics through rhizosphere processes but capturing these effects at scale is difficult due to parent material controls through varying mineralogy and clay content. Here, we have conducted a study using translocated homogenized parent material within soil columns at six upland secondary growth forest sites following a climate gradient (MAT 6°C to 14 °C) along the Appalachian mountain range from Virginia to New Hampshire. The soil columns were filled with the sterile, sandy loam mixture and half were deployed with lateral root access windows while the other half did not. After four years of deployment, litter traps collection, and throughfall monitoring, we examined the biogeochemical fluxes and pools for C, N, K, and P. The six sites received comparable throughfall inputs and litterfall C and N inputs were comparable among the six sites. However, there were some significant differences in litterfall P inputs. Mean annual temperature was a significant factor in C, N, K, and P storage within the organic horizons, with greater pools in the northern sites. However, C and N mineral soil storage was increased by mean annual temperature but not K and P. Root biomass was significantly greater between the root exlusion and root inclusion soil columns but there was no significant difference in the storage of C, N, K, or P by rhizosphere processes. Our results show that after 4 years, temperature was a strong driver in organic horizon and mineral soil C and N sequestration but inorganic nutrients were not affected. We hypothesize the inorganic nutrients are either operating on much longer time scales and soil processes were unaffected.

Importance of inherited Fe oxides on toxic (As, Cd, Pb) and potentially toxic metals (Cu, Ni, Zn) from grey shale-derived soils on geologic timescales

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Shale is an important sedimentary rock in the eastern United States and globally due to its spatial abundance and potentially elevated trace element concentrations under shallow, low energy coastal depositional environments. Shale-derived soils inherit organic matter and oxides (Fe and Mn) which can promote accumulation and retention of both geogenic and exogeneous trace metals. This is particularly important as many shale environments are exposed to elevated deposition of trace element pollution from combustion of fuels, local smelting and metal works, and, industrial activities for energy extraction and manufacturing. Shale-derived soils have developed on the geologic time scale of recent glaciation (10 to 20 kya) to earlier Pleistocene peri-glacial action (100 to 200 kya). Pedogenesis promotes the formation of neoformed clay and secondary oxides that can promote sorption of trace elements in shale-derived soils. Here, we utilized a chronosequence of grey-shale derived soils to determine if the trace elements present in these soils are inherited and if pedogenesis has enhanced the trace element sorption capacity of these soils. We focused in on trace elements associated with anthropogenic activities: arsenic (As), cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn) due to their potential impacts on water resources and aquatic ecosystems. Titanium-based tau values show that shale-derived soils are net accumulators of Cd, Cu, Ni, and Pb for most sites across the chronosequence, despite the variation in proximity to human pollution sources. Considering sorption of the metals, < 5% of the metals were in oxidizable forms (e.g. organic matter bound) but 20 to 60% of Cu and Cd and 5 to 20% of Ni and Pb were within Fe oxides in both soils and shale bedrock samples. This suggests that a combination of inherited and neoformed oxides are retaining an important fraction of toxic and potentially toxic metals. These results imply that soils derived from grey-shale are net accumulators of metals from exogeneous sources and retain their geogenic trace elements.

Nutrient and organic carbon dynamics of a boreal hydroelectric reservoir complex over the initial years after flooding

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Reservoir construction can fundamentally alter the transport and export of nutrients and organic matter by rivers to coastal areas. Here we present a 9-year study of the La Romaine Hydroelectric Reservoir Complex, composed of four cascading reservoirs that were sequentially commissioned over 7 years, in Boreal Québec that flows into the St. Lawrence Estuary. We followed the longitudinal and temporal patterns in concentrations of total nitrogen (TN), total phosphorous (TP), dissolved organic carbon (DOC), and particulate organic matter (POM) as well as stoichiometric ratios (C:N, N:P, C:P) within the La Romaine River above, the four reservoirs, and downriver into the estuary. TN varied greatly within the reservoirs, suggesting active transformation and processing, and slightly increased from upriver to the bottom most reservoir but declined downriver. TP in contrast, consistently increased longitudinally suggesting that these young boreal reservoirs remobilise terrestrial P and are net exporters of P in the early stages of reservoir flooding. DOC was relatively constant between the river and the complex, suggesting no net change despite evidence of intense C processing within the reservoirs. POM declined through the complex suggesting that the cascading reservoirs act as POM traps up to the bottom most reservoir that was a new source of POM but did not export POM to the river. Stoichiometric ratios of N:P and C:P tended to decline from upriver through the reservoirs and downriver, as this are heavily influence by the longitudinal increases in TP while C:N ratios remained almost constant throughout the complex likely due to the little changes observed in DOC. Although the reservoirs were influenced by their upstream conditions, each had their own distinct nutrient and C dynamics, likely influenced by morphometry, residence time, and pre-flood landscape. Additionally, the bottom most reservoir plays an important role as the modulator in exports to the La Romaine River and St Lawrence estuary. The cumulative effect of the complex as a whole shifted in time, becoming less of a source of nutrients and POM relative to the pre-flood river as it ages.

Title: Drivers of riverine organic matter diversity vary across catchments of the contiguous United States

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Abstract:

Quantifying the relative influence of factors and processes controlling riverine ecosystem function is essential to predicting future conditions under global change. Dissolved organic matter (DOM) is a fundamental component of riverine ecosystems as it fuels microbial food webs, influences nutrient and light availability, and represents a significant carbon flux globally. The heterogeneous nature of DOM molecular composition (i.e., chemical diversity) and its propensity for interaction (i.e., functional diversity) can indicate riverine ecosystem function across scales. To investigate fundamental drivers of DOM diversity across spatio-temporal scales, we collected seasonal water samples from 42 nested locations within 5 watersheds spanning multiple watershed sizes and stream orders (~5 to 30k km^2) across the United States. Patterns in chemical diversity and calculated putative biochemical transformations of organic matter derived from high-resolution mass spectrometry (FTICR-MS) were assessed across gradients of land use/land cover, hydro-climatology, and water sample physico-chemical properties. No single explanatory factor common to all samples (e.g., upstream watershed area, season) explained patterns of DOM diversity across all watersheds. The data indicate that catchment-specific factors can significantly influence DOM diversity. For example, the number of putative biochemical transformations decreased with increasing percent of coniferous land cover in the Pacific Northwest but increased with coniferous land cover in the Gunnison watershed in Colorado. Similarly, metrics of DOM diversity decreased with the percent of deciduous land cover in the Connecticut basin. Overall, the results highlight the importance of considering land cover when interpreting longitudinal patterns in DOM chemistry and the continued challenge of identifying generalizable drivers that are transferable across watershed and regional scales for application in earth system models. This work introduces a Findable Accessible Interoperable Reusable (FAIR) dataset (>300 samples) to the community for further in-depth exploration.

Attributing changes in streamflow response to transpiration and canopy interception changes after defoliation from 2017 Hurricane Maria in Puerto Rico

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Hurricane Maria, a nearly Class-5 hurricane that crossed Puerto Rico on 20 September, 2017, brought heavy rainfall and winds in excess of 250 km/hr. We posed the following hypotheses: (1) the near-total defoliation across Puerto Rico from Hurricane Maria cut off transpiration, resulting in higher base flow and shallower recession slopes for up to a year; (2) the magnitude of this change was proportional to percent forest cover. Across Puerto Rico, we identified 21 streamgages that had natural flow regimes (no impoundments, wastewater discharges, or water withdrawals) and that had mostly uninterrupted streamflow record for the year before and year after the hurricane. We tested for slowing of flow recession using a master recession curve (MRC) approach, where the master curve is constructed from the assemblage of monotonic storm flow recessions, and an asymptotic base flow value can be computed. In the absence of transpiration, recession slopes would be shallower as higher soil moisture content and higher water tables move more water to the stream and slow the recession. MRC recession slopes were not different in the pre- and post-Hurricane years, but tended (non-significantly) toward shallower slopes in the months immediately following the hurricane. Resulting differences among base flows were strongest in the first month, when base flows were greater than either the pre-Hurricane or ensuing post-hurricane periods ($p=0.0002$, Kruskal-Wallace non-parametric one-way ANOVA). We believe the restoration of pre-hurricane evapotranspiration was caused by rapid understory regeneration in the forest. The defoliation followed by recovery in understory growth and evapotranspiration were mirrored by an increase and gradual (~10 weeks) recovery in vapor pressure deficit across an elevation transect in the Luquillo Mountains of eastern Puerto Rico. Thus in the Puerto Rico forest, the effect of Hurricane Maria on streamflow diminished in importance after the first few months.

Title: Chemical Cocktails from Coast to Coast: Is there a Universal Water Quality Signature of Urbanization in Streams?

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In urban systems, a wide variety of processes, including increasing impervious surface cover, road salt application, sewage leaks, and weathering of the built environment, contribute to novel chemical cocktails that are made up of metals, salts, nutrients, and organic matter. Due to heterogeneous land use and a myriad of pollution sources, water quality is highly variable as streams flow through urban areas. National sensor data sets reveal that water quality in many U.S. streams in different metropolitan areas is influenced by the urban environment; however, these datasets lack concurrent measurements of multiple contaminants over local spatial scales. To investigate if urban streams in different U.S. cities have similar water quality characteristics, we conducted synoptic-style sampling campaigns for nine rivers in five major metropolitan areas (i.e., Baltimore, Maryland; Washington, DC; Cincinnati, Ohio; Denver, Colorado; and Portland, Oregon). We collected 10-65 samples along the flowpath of each stream as the water flows through progressively more urban areas and analyzed for base cation, trace element, carbon, and nitrogen concentrations and organic matter optical properties. Results demonstrate an urban water quality signal in many of the sampled streams where salts/weathering ions, such as Ca^{2+}, Mg^{2+}, Na^{+}, Sr, and K^{+}, increased along rural to urban flowpaths. These ions are often significantly correlated to one

another and drive much of the overall dataset variability. Some streams with wide riparian buffer zones and stream restorations did not demonstrate these systematic increases in salt ions, suggesting that green spaces may disrupt this urban signal.

Modeling temperature sensitivity of soil carbon loss from a lowland tropical forest

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Soils represent the largest terrestrial carbon (C) pool, and the flux of carbon dioxide (CO_2) from soils to the atmosphere is ~ 6-10 times more than anthropogenic emissions. Understanding responses of soil CO_2 emissions to warming is crucial for evaluating feedbacks to climate change. The relationship between microbial respiration and temperature is typically modeled using a Q_{10} function. Generally, observations of the apparent Q_{10} of soil respiration are higher for cool vs. warm-climate ecosystems, reflecting expected biophysical controls of Arrhenius kinetics. However, results from two field warming experiments in the tropics contradict this expectation, both observing extraordinarily high soil respiration responses to in situ warming.

Here we systematically represent the potentially confounding effects of temperature sensitivity of enzymatic reactions, changes in the microbial enzymatic capacity, and substrate supply as they affect microbial decomposition of soil C in tropical forests under warming. The DAMM (Dual Arrhenius Michaelis-Menten) model was optimized using data generated from the Soil Warming Experiment in Lowland Tropical Forest in Panama. By including simple representations of measured warming-induced changes in microbial biomass and changes in soil moisture that affect substrate diffusion, we show that the observed increased soil respiration with warming does not reflect a change in activation energy, which remained at reasonable values (Ea: ~62-65 kJ mol^{-1}) for both warmed and control plots in optimized model parameterization. In contrast, optimization of the model without representation of changing microbial biomass required a higher activation energy (Ea: ~84-85 kJ mol^{-1}) in the warmed plots, which is inconsistent with kinetic theory. Hence, the higher soil respiration observed under warming could be explained by the increased enzymatic capacity of the microbial biomass rather than an increased activation energy of the enzymatic reactions.

Our parsimonious modular approach allows us to attribute agreement or disagreement of model outputs with measured respiration rates and specific model functions, as well as identify model structures necessary for representing soil temperature responses in broader Earth System Models. This will enable us to increase both the sophistication and capability of models to represent these processes from individual to Earth-System scales.

Assessing Methane and Nitrous Oxide Fluxes in Soil and Stems of Malaysian Tropical Peat Swamp Forests

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Tropical peat swamp forests are crucial global carbon (C) reserves. Prevailing waterlogged conditions in peat soils prevent the complete decomposition of dead plant material. As a result, more organic matter is produced than decomposed, leading to the gradual accumulation of peat. However, the destabilisation of tropical peatlands through climate warming, droughts, and changes in land use threaten this C sink capacity. Anaerobic conditions in peat soils lead to methane (CH_4) production through decomposition and nitrous oxide (N_2O) production under moderate levels of soil oxygen content. Earlier evidence suggests that tree stems in tropical peat swamp forests are significant sources of CH_4; however, little information is available on their exchange of N_2O.

This study investigated CH_4 and N_2O exchange of soil and stems of *Combretocarpus rotunditus* and *Shorea albida* trees in a peat swamp forest in Sarawak, Malaysia, from September 2022 to September 2023. To describe the temporal dynamics of greenhouse gas (GHG) exchange, we measured gas fluxes from the soil and stems at different heights (10, 80 and 170 cm from the tree's base) using the manual static chamber method and spectroscopic gas analysis. The chemical composition of the soil was analysed and several environmental parameters, including groundwater level, soil moisture content, soil and air temperature, were simultaneously measured with the GHG fluxes to determine the relationships between the fluxes and environmental factors.

Soil CH_4 emissions varied between 52.3 and 807 µg C m^{-2} h^{-1}, with higher values observed during the wet season in conjunction with higher groundwater levels. On the other hand, the soil N_2O fluxes were relatively low and did not show a distinct seasonal pattern, ranging from -1.33 to 3.54 µg N m^{-2} h^{-1}. Annual average soil CH_4 and N_2O emissions were 392 µg C m^{-2} h^{-1} and 0.65 µg N m^{-2} h^{-1}, respectively. The highest average stem CH_4 emissions (1.48 µg C m^{-2} h^{-1}) were recorded at the lowest parts of trees, with a vertical decrease in emissions and an overall uptake observed at the highest measurement point. In contrast, stem N_2O emissions were small, with no clear trend with measurement height.

In summary, we observed moderate and variable soil CH_4 emissions with limited generalisable relation to measured environmental parameters. Soil and stem N_2O emissions were relatively small. These results indicate the need for further comprehensive soil and stem GHG analyses in tropical peat swamp systems to better understand the GHG dynamics of this critical ecosystem.

Contribution of rime to atmospheric sulfur and nitrogen deposition in Central Europe

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Rime is an underexploited pathway of atmospheric deposition of ecological and environmental relevance, in particular in montane regions. The industrial part of Central Europe, especially the so-called "Black Triangle" near the borders between Czech Republic, Poland and Germany, was affected by massive spruce die-back due to acid rain during the 1970-1995 period. Sulfur (S) emissions, originating mostly from soft-coal burning power plants, peaked in 1987, and decreased dramatically thereafter, while high reactive nitrogen (N_r, mostly nitrate, NO_3^-, and ammonium, NH_4^+) emissions exhibited less pronounced temporal changes. We quantified the contribution of rime (ice accretions) to total atmospheric deposition of acidifying compounds of these two elements at 10 mountain-top sites during three consecutive winters. All study sites were located at an altitude of about 1000 m a.s.l in the Czech Republic. We used replicated custom-made rime collectors with high surface roughness, placed 1.5 m above snow surface. Average intervals between rime and snow samplings were 7 to 8 days, respectively. Sulfur and nitrate-N concentrations in rime were up to 10 times higher, compared to those in snow. Between-site differences in SO_4^{2-}-S and NO_3^--N were larger for rime than for snow. At nine sites, winter-time deposition of S *via* rime corresponded to 5-13 % of annual wet S deposition. At the most polluted 10th site situated close to the Czech–Polish border (Tetrevec, Eagle Mts.), S rime deposition reached 25 % of annual wet S deposition. Winter-time deposition of NO_3^--N corresponded to 6-25 % of annual wet NO_3^--N deposition. Large inter-annual differences in rime deposition rates were recorded for both S and N. While total atmospheric deposition of S and N was dominated by vertical deposition (snow), the contribution of horizontal deposition (rime) to the budget was far from negligible even in the era of easing air pollution. Funding by the Czech Technological Agency, Grant no. SS 02030031 ARAMIS.

Evaluation of soil carbon dynamics and microbial proxies under different climate-smart agriculture practices

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Regenerative and climate-smart agriculture practices can play a pivotal role in transforming the global agricultural system in the face of climate change and food security challenges. The primary focus of regenerative agriculture is to improve soil health by promoting soil microbial activities and ultimately increasing the potential of soil carbon (C) sequestration. Understanding the mechanisms of soil C sequestration is essential for strengthening natural C sinks and mitigating climate change. While changes in long-term soil C storage occur over extended timescales, biologically-mediated movement of soil C between pools can be more readily measured to provide precursory evaluations of management strategies. We are evaluating soil C dynamics and associated microbial proxies under different climate-smart agriculture practices (e.g., cover crop, agroforestry/silvopasture, conservation/reduced tillage, and soil amendments such as biochar and compost) within the Southeast USA. Soil samples collected from our on-the ground field studies are being measured for total C and N, potential C mineralization, soil C fractions (particulate and mineral-associated organic C), microbial biomass C and N, microbial necromass, potential extracellular enzyme activities, and microbial community structure. Evaluation of these parameters will provide information about the function and identify of the biological components of soil organic matter (SOM), and the extent to which soil C is being stabilized. Our findings will provide insights into how the boost of organic material provided by cover crops, amendments, conservation tillage, and agroforestry impacts the ability of soil microbes to sequester C. Our study combining functional and structural biological parameters may permit early evaluations of soil response to climate-smart agricultural practices to be made within a holistic context of soil C breakdown. Early-on, informative, and consistent indicators of changes in soil C cycling will help in decision making and adoption of climate-smart agriculture practices.

UNDERSTANDING THE FUNCTION OF MACROPHYTES IN NITROGEN AND PHOSPHOROUS MANAGEMENT IN SMALL WATER BODIES

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Small water bodies like ponds and wetlands can absorb and retain nutrients efficiently. This can largely be attributed to macrophytes - aquatic plants that play a vital role in maintaining the ecological balance of these ecosystems.

Our study aimed to investigate the critical environmental factors influencing nitrogen (N), phosphorous (P), and nitrogen stable isotope (d15N) uptake by *Phragmites communis* (reed) and *Typha latifolia* (cattail) growing in midfield ponds in the Mazurian Lakeland, NE Poland. Both plants are generalist species, used in sewage treatment and co-occurring in areas with similar chemical properties. To investigate the nutrient management of each species, we collected 37 leaf biomass samples of reed, 47 samples of cattail, and 110 samples of sediments from 15 small ponds in different surroundings (cultivated fields, fallows, meadows, forest).

Detailed statistical analyses showed significant differences in leaf N, P, and carbon isotopic ratios between reed and cattail, while no differences were recorded for their nitrogen isotopic ratios. Under similar conditions, reed leaves accumulate more N and heavy carbon isotopes than cattail, while the latter accumulates more P. These differences seemed to be driven exclusively by species-specific strategies for nutrient accumulation, as no correlations were found with environmental factors studied. The mathematical model describing the N:P ratio in reed and cattail showed that Ca content in plant biomass is an important feature influencing this ratio ($r=-0.7$). This effect was more pronounced in cattail than in reed. The second model explained the N isotopic ratio in leaf biomass and, thus, gave some insights into plant d15N uptake. According to the results, sediment pH positively influenced leaf dN_p in both species ($r=0.55$), while the sediment C:N ratio had a negative influence ($r=-0.55$). Sediment chemistry, including C:N ratio, was shaped by the characteristics of the pond surroundings ($r=0.4$). Additionally, leaf dN_p was determined by interactions between N and C isotopic ratios of the sediments and some water features (e.g. pH and phosphorus content).

The results of our research indicate an evident disproportion in the accumulation of nitrogen and phosphorus between both studied macrophytes. However, it must be acknowledged that the extent of this accumulation depends on various biogeochemical interactions in the sediments and the exchange of nutrients between water and sediments. Moreover, these processes are significantly influenced by the surroundings of small water reservoirs.

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Carbon sink strength in an Artic rich fen is driven by primary production and leaf area.

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Arctic peatlands harbor enormous stocks of carbon (C) owing to the imbalance between photosynthesis and respiration rates. The carbon stock has been exposed to a warming climate during the last century. The Arctic has warmed by three-quarters of °C during the recent decades, which is almost double the rate of global average. Although there is a wide range of studies on Arctic peatland C cycle, the factors behind the hot and cool moments of peatland C fluxes under warming climate are still a large source of uncertainty. We applied an intermediate complexity terrestrial ecosystem model (TEM) calibrated by a Bayesian model-data fusion framework at a weekly timestep with publicly available eddy covariance, earth observation, and in-situ datasets between 2014 and 2020. We found that the increasing C sink is forced by a steep trend in leaf area index, leaf lifespan, and GPP accompanied by a modest rise of ecosystem respiration (Reco). Relative to 2014, GPP and net primary production (NPP) almost doubled by 2017, transforming the peatland from a C source to a sink.

Assessing the Impacts of Sargassum Brown Tide to Nearshore Water Quality and Seagrass Beds in Jobos Bay, Puerto Rico

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The accumulation of beached *Sargassum* spp. each summer in the Caribbean region has led to a variety of impacts to both human and ecological communities. Referred to as Sargassum Brown Tide (Sbt), the enormous mats of Sargassum that arrive to nearshore environments tint the waters a brown, tea-like color as they accumulate and decompose. Impacts from Sbt events on nearshore ecosystems and the tropical island economies that rely on them are only beginning to be understood. Sbt is associated with dramatic changes in water column properties such as decreases in light, dissolved oxygen, and pH, eutrophication, and increased suspended particulate matter. In addition, Sbt events can result in localized fish kills and seagrass die off events. In this study we use the offshore mangrove keys and seagrass beds of Jobos Bay, PR, to assess the impacts of Sbt.

We present the preliminary results of monthly water quality monitoring at control and Sbt impacted sites to evaluate the biochemical impacts of Sbt on nearshore water quality. Combining light measurements (PAR) with water quality data (TSS/VSS, Chlor. a, CDOM, TN, TP) we evaluate the drivers of decreased light following Sbt, and potential impacts to adjacent seagrass beds.

Mitigation and adaptation of carbon sequestration in multi objective forest management through co-creation with stakeholders (CARBONPATH)

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Forest management has important role in storing carbon in forest biomass and forest soil. To Increase the understanding of optimal forest management practices considering carbon sequestration as well as water and biodiversity protection is crucial for reaching e.g., the set carbon neutrality goals. However, reaching them requires practice-validated strategies for the implementation of best-suited methods in multi objective forest management.

In the CARBONPATH project (www.luke.fi/en/projects/hiilipolku) our aim is co-create practices in partnership with local forestry actors (e.g., landowners, forest service entrepreneurs, NGOs) that nudge carbon sequestration in forests and which simultaneously support water and biodiversity protection. Practices are based on state-of-the-art modelling while striving for socially just and rewarding implementation.

CARBONPATH is carried out in the Puruvesi catchment area, in South-East Finland. The size of the catchment area is about 1017 km^2, including lake and land areas, the 92% of catchment land area is boreal forest which grows either on mineral or organic soils (peatlands). Main land use is forestry with minor areas of agriculture and urban land use. We are focusing on three subcatchments of the area, which size varies from 11 km^2 to 55 km^2 (total c. 16% of land area). The project has four workpackages, where 1) we study perceptions of forest stakeholders regarding sustainable forest use and management (i.e. carbon sequestration, biodiversity, water protection), 2) we run three scenarios with and without water protection emphasis were built from various forest management regimes (including e.g., longer rotation periods, continuous cover forestry, fertilization, increase of deciduous tree percentage) per each stand in the target area. The scenarios are estimated with Motti (doi.org/10.1007/s10342-014-0860-0) and SUSI-models (doi.org/10.14214/ma.10575) with simulations in current and future climate conditions, 3) we have carbon, water protective and biodiversity related counselling of forest owners, and finally 4) the local, voluntary-based model of carbon sequestration, water protection and biodiversity by individual forest owners produced in the study is conceptualized and its applicability nationally in forest counseling will be evaluated.

Preliminary results show:

- Local stakeholder participatory process shows the importance of balancing different objectives of forest management and shares information and practical knowledge.

- The simulations results show how different management options support various objectives, e.g., carbon sequestration is supported with longer rotation period and biodiversity benefits of the increased share of broadleaves trees.
- Forest owners' survey show that beyond economic objectives they emphasize particularly water conservation objectives.

Wetland restoration for the future - ALFAwetlands

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The global goal to mitigate climate change (CC) is to achieve net zero greenhouse gas emissions (GHGE) by 2050; the European Union (EU) aim is to cut GHGE at least by 55% already by 2030. These ambition targets require new GHGE mitigation measures across all land use sectors (LULUCF), where wetlands, as carbon (C) rich ecosystem, can effectively contribute to climate targets, biodiversity, and water-related ecosystem services. Natural peatlands accumulate C effectively due to water-logged conditions. However, they can turn into high GHG sources if they are drained, therefore there is still need to enhance knowledge regarding how and/or how much C is sequestered or released by peatlands after their restoration, as well as the socioeconomic effects.

"ALFAwetlands - Restoration for the future" (www.alfawetlands.eu) is a Horizon Europe funded project (2022-2026), which is coordinated by Luke and carried out at local to EU levels with 15 partners across Europe. It's main goal, in short, is to mitigate CC while supporting biodiversity and ecosystem services (BES) and being socially just and rewarding. This includes, e.g., increasing the knowledge about C storage and release in peatlands, specifically after restoration. While, in terms of C fluxes, focussing on peatlands, the project scope is larger and includes additionally floodplains, coastal wetlands and few artificial wetlands. ALFAwetlands will develop and indicate management alternatives for wetlands including such that have been or will be restored during this project. Measures under this project are not restricted to ecological restoration but include rehabilitation and re-vegetation action to improve ecosystem conditions (e.g., peatland forest: continuous-cover-forestry, cultivated peatlands: paludiculture). Studies are conducted in 9 Living Labs (LL's) including 30 sites, which are located in wetlands in different parts of Europe (north-south gradient). 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., by models to gain and understanding the potential impacts of upscaled wetland restoration measures. To achieve ALFAwetlands goals, 5 research workpackages are being implemented, namely: 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 achieved from field experiments, 4)develop policy relevant scenarios for CC and BES, and 5)study societal impacts of wetland restoration. The project will also encourage stakeholders to utilise outputs and support their active participation in wetland management.

Understanding soil organic carbon abundance and persistence at continental to global scales

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It is important to understand not only how much C soils store, but also how long this C persists. Climate change is rapidly altering the C cycle, yet information on the drivers of soil organic carbon (SOC) abundance (C storage) and persistence (retention of stored C) across continental regions and at the global scale is still limited. Previous studies have shown that the amount and age of soil SOC are strongly influenced by the interaction of climate, vegetation, and mineralogy. However, these findings are based primarily on studies from temperate regions and on fine-scale studies. Here, we present insights into SOC cycling across scales, based on a new large-scale radiocarbon and mineral dataset for sub-Saharan Africa (AfSIS), and for the global scale (ISRaD). We show that controls on SOC abundance and persistence differ substantially between major pedo-climatic regions. For example, mineral controls on SOC abundance and persistence are more important in moderately weathered soils in seasonal climate zones than in highly weathered soils in humid climate zones. Soils in arid climate zones store organic C for periods comparable to those in seasonal climate zones, yet overall store less SOC; likely reflecting climatic constraints on weathering, carbon inputs and microbial decomposition. These findings have implications for our understanding of large-scale SOC dynamics in general and for modeling efforts. The unique controls on SOC abundance and persistence in the identified pedo-climatic regions limit the ability to extrapolate outside of these regions and should be used to constrain statistical models for global soil mapping products and for benchmarking global C models.

Title: Dissolved organic matter release at the soil-water interface in isolated wetlands

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Abstract:

Isolated wetland landscapes have dynamic terrestrial-aquatic interfaces as water levels rise and fall seasonally in response to evapotranspiration or precipitation events. During rain events, when the groundwater table rises and the extent of surface water inundation expands, previously unsaturated soils are rapidly reconnected to the wetland surface water-groundwater continuum and may release pulses of soil-derived dissolved organic matter (DOM). In addition to pulses of DOM released at the soil-water interface upon initial rewetting, there may be lagged groundwater inputs carrying soil-derived DOM from the surrounding landscape. The relative magnitude and timing of these soil-derived DOM sources remains largely unknown. To quantify changes in concentration and composition of DOM as water moves across the dynamic soil-water interface during rain events, we sampled surface water and porewater along shifting soil-water interfaces at two Delmarva Bay isolated wetlands located in the Mid-Atlantic United States. We collected surface water and porewater at four predetermined spots both before and during a rain event as the soil-water interface expanded outwards from the wetland center. Samples were analyzed for DOM concentration, DOM composition, and water isotope signatures. Preliminary results during pre-event conditions suggest that porewater DOM concentrations are higher than wetland surface water and that porewater isotopic signatures reflect a mixture of surface water and groundwater sources. As wetland-dominated landscapes are expected to be altered by climate change (e.g., more intense precipitation events, longer drought periods), it is increasingly important to understand how shifting terrestrial-aquatic interfaces influence wetland carbon cycling and downstream carbon export.

Temporal and Spatial Precipitation Chemistry of Puerto Rico and US Virgin Islands

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Abstract

Precipitation chemistry has been studied in northeastern Puerto Rico for decades (McClintock, 2019); however, few studies have addressed precipitation trends across the island. With the addition of the new precipitation monitoring programs at three NEON sites in central and southwestern Puerto Rico, it is now possible to examine trends in precipitation chemistry temporally and spatially across Puerto Rico. We examine trends in Ca, K, Na,Mg, Cl, NH_4^+, NO_3^-, SO_4^{2-}, and PO_4^{3-} six sites in Puerto Rico: the Guanica Forest, Rio Cupeyes, and Rio Yahuecas NEON sites, the National Atmospheric Deposition Program's (NADP) El Verde site, the Luquillo Long Term Ecological Research's at El Verde site, and a monitoring site adjacent to the urban Rio Piedras in the San Juan metro area. We also compare these to an additional NADP U.S. Virgin Islands monitoring site in Virgin Islands National Park. Samples from all the sites were collected using wet-only disposition collectors, which consist of an automated climate-controlled assembly that begins collecting once precipitation is detected and closes when precipitation ceases, thereby eliminating input due to dry deposition between precipitation events. Sampling dates range from 2018 to present.

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Title: Changes in Biogeochemical Cycling of N in a Wetland-Dominated Coastal Basin with River Reconnection

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Abstract

Coastal wetlands provide many ecosystem functions and services, such as carbon sequestration, aquifer recharge, flood protection, and wildlife habitat. One other ecologically important function is improving surface water quality through nutrient removal. Nutrient loads in the Mississippi River (MR) have increased historically, causing eutrophication and hypoxia in coastal LA. Also, Louisiana experienced ~4800 km^2 of coastal wetland loss between 1932 and 2016 due to high relative sea level rise and reduced sediment from MR due to levees. Thus, the 2023 LA Coastal Master Plan aims to restore Louisiana's degraded coastline through a series of restoration projects, including sediment diversions or river reconnection.

The Mid-Barataria Sediment Diversion Project is intended to reconnect MR sediment-laden water with the wetlands of Barataria Basin to nourish degrading marshes. However, the diversion will also deliver substantial nitrate (NO_3^-) to the basin, potentially negatively impacting water quality. We sought to quantify NO_3^- reduction rates for marsh and submerged sediments in Barataria Basin using intact soil cores receiving 2 mg N-NO_3 L^{-1}. In addition, 2 cm of mineral river sediment from a MR crevasse splay was placed over the organic marsh soil as an additional treatment to replicate sediment deposition on the marsh once the MR is reconnected. We hypothesized that NO_3^- reduction rates would decrease once mineral sediment is deposited on the organic marsh soil. For an aerobic water column, nitrate reduction rates for vegetated marsh, post-diversion marsh, submerged eroded marsh (fringe) and estuarine mud zones were 71.1 ± 2.7, 27.8 ± 4.5, 19.7 ± 1.2, and 13.0 ± 0.75 mg N m^{-2} d^{-1}, respectively. Thus, the post-diversion marsh NO_3^- reduction rate decreased by ~60% compared to current vegetated marsh. The marsh is only flooded 31-48% of the time, lessening the impact of the reduction. In fact, adjusting for flooding time, the submerged sediments will conduct a greater proportion of denitrification due to constant contact with surface waters. These findings can improve parameterization of water quality models used to project nutrient loading and fate more accurately across the basin under a scenario of an operating large river reconnection project. This research also highlight the need to consider overall hydrologic connectivity in predicting spatial rates of water quality improvement through denitrification.

Title: Microplastic distribution in Puerto Rico streams

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Abstract:
Plastics are a major pollutant due to their abundance, ubiquity, and persistence. Studies indicate a pervasive presence of microplastics, which result from the degradation of plastics in the environment. Many studies have focused on microplastic presence in the ocean and its impacts on fauna, such as zooplankton, coral, and fish. It is estimated that 80% of microplastic in the ocean comes from land-based sources, including inputs from rivers. Island communities often struggle to manage solid waste generated by locals and tourists, which can contribute to high concentrations of microplastics in marine environments. While scientists have started to examine contributions from fluvial systems, little research has examined microplastics in island stream and river ecosystems. Since plastic has the potential to adsorb contaminants, the risk to individual organisms and potentially food webs could be high. In this preliminary study, we surveyed eight streams in Puerto Rico across a land-use gradient to determine if microplastic concentration was related to land use. Water samples were collected at upstream and downstream locations in every stream. Nutrient samples were filtered in the field, transported on ice, and then frozen. Microplastic samples were first passed through a 300um sieve, then filtered onto a 25um filter, folded, and stored in aluminum until counted. Salinity across all streams ranged from 0.14 to 14.9 ppt and turbidity ranged from 0.7 to 53.2 FNU, indicating a range of stream conditions. Land use ranged from high urban to agriculture, to forested/protected. Factors that might contribute to the distribution pattern of microplastics will be examined including population density, distance to upstream wastewater treatment facilities, and water quality.

Title

Dissolved organic matter dynamics in the Upper Mississippi River Basin

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Abstract

Dissolved organic matter (DOM) in river networks has been rigorously studied for decades because of its importance to food webs, co-transport of metals and other pollutants, effects on light penetration, and role in the global carbon cycle. Despite this, uncertainties remain in DOM sources, transport, and processing in river networks. We conducted a two-year study in the Upper Mississippi River Basin (UMRB) to investigate DOM dynamics across a large river network. Specifically, we examined dissolved organic carbon (DOC) concentration, DOM chemical composition, and DOC biodegradability from headwater streams to large rivers in a basin that has distinct contrasts in land cover and land use. Sampling locations included ten streams and rivers within the Chippewa River (Wisconsin) watershed, a 23,336 km^2 subbasin in the UMRB. Sampling sites were co-located with USGS stream gaging stations on rivers spanning Strahler stream order 1 to 7. The drainage areas were dominated by forest and wetland land cover (>50% by area) or agricultural land cover (>40% by area). In addition to the Chippewa River watershed, we sampled six large river sites (St. Croix River, Wisconsin; Minnesota River, Minnesota; and three sites on the Mississippi River, Minnesota/Wisconsin) representing Strahler stream orders 6-8 and watersheds with contrasting land use (ranging from 23% to 80% agricultural land cover by area). Again, sampling locations were co-located with USGS stream gaging stations. Sampling occurred over two Water Years (1 Oct. – 30 Sept.), capturing various hydrological and climatic conditions. Most sites were sampled at least twenty times. All samples were analyzed for DOC concentration and specific ultraviolet absorbance ($SUVA_{254}$), a measure of DOM aromaticity. A subset of samples from each site were analyzed for DOM fluorescence to determine Fluorescence Index (FI), which approximates relative contribution of terrestrial versus microbial-derived DOM, and were incubated in the laboratory to determine DOC biodegradability (BDOC). We found that DOC concentrations and $SUVA_{254}$ values were consistently higher in sites draining predominantly forested land than those draining agricultural land, and that FI values were consistently higher (greater microbial-derived DOM) in streams draining agricultural land across stream order. Overall, DOC was more biodegradable in streams draining agricultural land, with the greatest difference between land covers occurring during spring. Results from this study suggest that accounting for both stream order and land cover/land use effects on DOM sources and processing are important for conceptual and predictive models of river network DOC and DOM.

Assessment of change in the Upper Ohio River Basin: impacts of river regulation and climate change on streamflow and nutrient cycling

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There is a long history of human modifications to streamflow regimes in the Upper Ohio River Basin resulting from the region's industrialization, particularly related to the use of the Allegheny, Monongahela, and Ohio Rivers for river transportation. Recent downscaled climate model projections predict a 5-15% and 15-25% increases in streamflow from 2011- 2040 and 2041-2071, respectively, in parts of the upper Ohio River basin (USACE, 2017). Importantly, the Allegheny River watershed was identified as one of several most at-risk watersheds due to the severity of projected changes and resulting impacts to human communities and sensitive aquatic organisms. Despite these projections and evidence of widespread change in neighboring basins, there has been no comprehensive evaluation of changes in streamflow and associated nutrient export across the Upper Ohio River Basin. Given the tight dissolved nutrient export and watershed runoff, increased streamflow may alter nutrient concentrations and fluxes, and exacerbate nutrient pollution.

In this study, we evaluated long-term trends in streamflow and nutrient export from 35 United States Geological Survey (USGS) gages located on rivers and streams within the Upper Ohio River Basin, ranging in size, river regulation, and land use properties. Streamflow statistics and change from these 35 sites represent 31 tributary inputs to the mainstem Allegheny, Monongahela, and Ohio Rivers and analyses include recent changes (1990-2022) and long-term changes (starting at gage initiation to 2022). Of these sites, 10 had Total Nitrogen (TN) data available and were analyzed using the Weighted Regressions on Time, Discharge, and Season model developed by the USGS. Our preliminary analyses indicate that flows below the 50th percentile are increasing across the region, where 28 of the 35 sites showed up to 5 percent per year increases within this range of streamflow. Interestingly, streamflow above the 50th percentile showed low rates of change and even decreasing streamflow. These increases in streamflow were accompanied by increases in total nitrogen concentrations and fluxes at 5 of 10 sites.

AUTHOR INDEX

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